Disease profile and outcomes of neonates admitted to the paediatric intensive care unit at the Red Cross War Memorial Children's Hospital in Cape Town, South Africa

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Background. Neonatal healthcare is a key area in reducing global child mortality. Unwell neonates are usually managed in the neonatal intensive care unit (NICU), but may also be admitted to paediatric intensive care unit (PICU).
Objectives. To describe the profile of neonates admitted to a South African PICU and to identify risk factors associated with mortality.
Methods. This was a prospective observational study of patients with a post-menstrual age of <44 weeks admitted to the PICU between November 2018 and October 2019. Associations with mortality were evaluated with univariate and multivariate logistic regression analyses.
Results. A cohort of 266 neonates were included, accounting for 18.4% of PICU admissions. Median birth weight was 2 210 g, with an interquartile range (IQR) of 1 397 - 2 995 g. Chronological and post-menstrual age (IQR) at admission was 11 (2 - 28) days and 38 (35 - 40) weeks, respectively. The largest referral source was tertiary NICUs. Surgical admissions accounted for most patients. Congenital abnormalities occurred in 50.4% of the cohort. Neonatal mortality at ICU discharge was 10.9% compared with 3.8% in older patients (odds ratio=3.08, 95% confidence interval 1.89 - 5.02; $p<0.001$). The most common condition associated with mortality was congenital abnormalities, followed by necrotising enterocolitis and infections. Logistic regression analysis showed that the only variables independently associated with death/palliation were oscillatory ventilation and feeds received.
Conclusion. Findings on the patient profile of this cohort may help policy-makers and unit managers improve neonatal care, with directions for further research.

Keywords: Neonate, paediatric ICU, preterm births, congenital abnormalities, health policy

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Deaths in the neonatal period account for 47% of deaths in children under the age of 5 years globally.[1] Neonatal and paediatric intensive care services are limited in South Africa (SA).[2] Neonatal intensive care units (NICU) typically admit premature, low birth weight or term newborns with complications such as birth asphyxia, meconium aspiration or pulmonary hypertension.[3] Neonates admitted to a paediatric intensive care unit (PICU) likely have a different disease profile.

In Cape Town, neonatal care (as part of provincial health services) is primarily provided at the district, regional or tertiary level. However, neonates who become sick after discharge from their initial facility or those needing specialised surgical services (abdominal, cardiac, neurosurgical, ophthalmological) are referred to the Red Cross War Memorial Children's Hospital (RCWMCH).

The hospital is a 300-bed paediatric centre with a 22-bed PICU that provides medical and surgical care. There is limited access to veno-arterial extracorporeal membrane oxygenation (VA-ECMO). The hospital does not have a dedicated NICU and any critically unwell neonates are therefore admitted to the PICU. Any pre- and post-operative cardiac patients are admitted to the PICU and not a specialised cardiac ICU.

The aim of the study was to describe the disease profile of neonates admitted into the PICU at RCWMCH and to identify risk factors for mortality.

Methods

Data were collected prospectively between 1 November 2018 and 31 October 2019. Patients were included if they had a postmenstrual age (PMA) of <44 weeks and had been admitted to the PICU. There were no exclusion criteria. De-identified data were recorded in a password-protected Microsoft Excel spreadsheet and exported to SPSS (version 27; IBM Corp., Armonk, NY) for statistical analysis.

Continuous variables are reported as means with standard deviation (SD) or medians with interquartile range (IQR) depending on the normality of distribution, as determined using the Shapiro–Wilk *W*-test. Categorical variables are reported as absolute numbers and percentages. Appropriate to the variable and distribution, chi-squared ($\chi 2$) tests, independent *t*-tests or Mann–Whitney *U*-tests were used for univariate comparisons. Data found to be significantly associated with mortality on univariate analysis were entered into a stepwise binary logistic regression model to determine independent risk factors. Two-tailed *p*-values at a significance level of 0.05 were used.

Ethical considerations

Ethical approval for the study was obtained from the University of Cape Town's Faculty of Health Sciences Research Ethics committee (HREC 695/2018).

Results

Between November 2018 and October 2019, a total of 1 444 patients were admitted to the PICU. Of these, 266 (18.4%) met the neonatal case definition (Table 1).

Median birth weight was 2 210 g (1 397 - 2 995g), with 42.5% of neonates (n=113) being ≥2 500 g. Median chronological age on admission was 11 days (2 - 28 days), with 26.3% (n=70) admissions occurring in the first 72 hours of life. Median PMA was 38 weeks (35 - 40 weeks).

Close to three quarters (n=195/266, 73.1%) of admissions were referred from outside RCWMCH. Tertiary hospitals referred the highest proportion of patients (n=100, 37.6%). The majority of these patients were from specialised NICUs.

About a third (n=86, 32.3%) of admissions were preterm (<37 weeks PMA), with most needing surgical services (n=82/86). Among these surgical preterm admissions, 29 (33.7%) had a congenital abnormality. An acquired surgical condition was noted in 52 cases (60.4%), of which 29 (55.7%) were for necrotising enterocolitis (NEC).

Among the 180 term patients (≥37 weeks PMA), surgical and medical patients were fairly evenly distributed (n=95, 52.8% and n=85, 47.2%, respectively).

Sixty-two (23.3%) of the total number of admissions were ex-premature neonates (born with a gestational age of <37 weeks, but admitted with a PMA of ≥37 weeks).

Of the 27 patients referred from emergency units, 17 (62.9%) were term babies in the third or fourth week of life. The remaining 10 (37.0%) were ex-premature infants with pneumonia or other infections. Congenital cardiac lesions were noted in 14.8% (n=4/27).

Most admissions (32.4%) occurred in the autumn months (March - May), whereas the fewest (21.0%) were recorded in either the winter or spring months (June - August and September - November, respectively). The most common bacterial pathogen identified was extended-spectrum beta lactamase (ESBL) *Klebsiella pneumonia* and the most common viral infection was respiratory syncitial virus (RSV).

Sixty-eight (14.3%) babies had been exposed to maternal HIV. Half of these mothers had a suppressed viral load within 3 months of delivery (n=38, 55.9%). Three (4.4%) neonates tested HIV positive.

Congenital abnormalities were present in 135 (50.4%) neonates, of which 130 were considered major abnormalities (requiring ICU support or surgical intervention in the neonatal period). The majority involved the cardiovascular system (Fig. 1, 39.2%). Babies requiring surgical intervention for a cardiac abnormality were admitted as cardiothoracic patients.

In total, 167 patients needed surgery, of which 104 (62.3%) cases involved a congenital abnormality. Viewed according to discipline, the distribution of surgeries was as follows:

- All patients admitted for otorhinolaryngological conditions presented with an airway obstruction that needed surgical intervention.
- Seven of the 12 neurosurgical procedures were for myelomeningocele repair.
- Surgery for congenital cardiac conditions was performed in 34 patients (this was the second highest number of surgeries). Of these, 16 were for cyanotic cardiac lesions and eight were for aortic arch procedures.
- General paediatric surgeries represented the largest proportion (n=44/104), with 38 involving a gastrointestinal tract obstruction. Of these, four included oesophageal atresias.

Chromosomal screening was performed in 34 patients (12.8%). Karyotypes revealed abnormalities in 12 (35.3%) cases, most commonly trisomy 21 (n=6/12).

During the study period, the overall unit mortality was 5.12%. Non-neonatal mortality was 45/1 178 (3.8%), significantly lower than neonatal mortality of 29/266 (10.9%) (odds ratio = 3.08, 95% confidence interval 1.89 - 5.02; p<0.001). The risk-adjusted PICU mortality (actual/mean predicted) based on the paediatric index of mortality-3 score (PIM-3) was 1.12. An additional 15 neonates with a life-limiting condition were transferred out for palliation, of whom all died before discharge. These patients were incorporated in a non-survivors group of 44 (Table 1), resulting in a neonatal mortality rate at hospital discharge of 16.5% (44/266). All but one of the babies who were palliated had life-limiting congenital abnormalities,; two cases involved confirmed chromosomal abnormalities (trisomy 13; a translocation between chromosomes 7 and 3). The patient without a congenital abnormality in this group presented with NEC.

The most common underlying cause of death or palliation (as defined by the World Health Organization[4]) was congenital abnormalities (n=22, 50.0%), followed by NEC (n=9, 20.5%) and sepsis (n=8, 18.2%, Fig. 1 supplementary material). Congenital abnormalities were prevalent in all age groups with respect to the underlying cause of death, while NEC and sepsis were more prevalent in the preterm groups. Deaths following cardiac surgery occurred only among patients between 40 and 43 weeks. (Fig. 2 supplementary material)

The PICU course, therapies and outcomes are presented in Table 2.

Comparison between survivor and non-survivor groups

On univariate analysis, non-survivors were younger than survivors (p=0.022, Table 1); however, no difference was seen in survival across different birth weight categories (Fig. 3 supplementary material, p=0.437). A comparison of chronological ages on admission showed that there were fewer survivors among patients admitted on day 4 - 7 (Fig. 4 supplementary material, p<0.05). Similarly, there were fewer survivors among neonates who had a PMA of 28 - 32 weeks' gestation (Fig. 5 supplementary material, p <0.05).

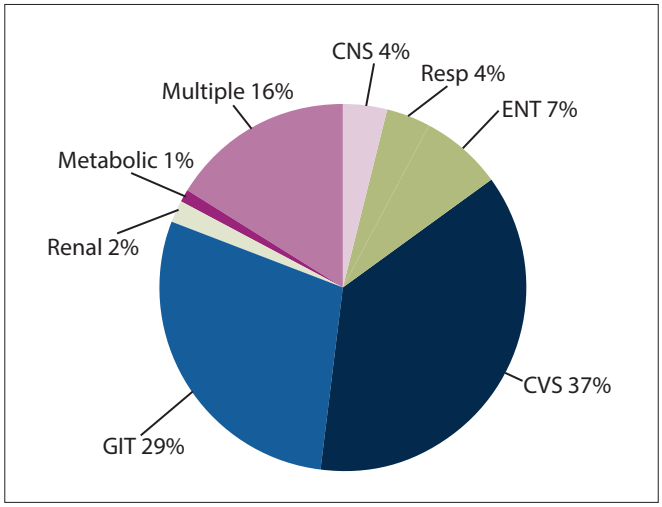

Fig. 1. Proportion of congenital abnormalities per system (CNS = central nervous system, RESP = respiratory system (includes congenital diaphragmatic hernia), ENT = ear nose and throat, CVS = cardiovascular system; GIT = gastrointestinal system)

Table 1. Demographic characteristics of cohort (*N*=266)

Characteristics		All (*N*=266), *n* (%)	Survivors (*N*=222), *n* (%)	Non-survivors (*N*=44), *n* (%)	*p*-value
Chronological age (days), median (IQR)		**11 (3 - 28)**	**12 (3.3 - 32)**	**5 (2.8 - 16)**	0.022
PMA (weeks), median (IQR)		38 (35 - 40)	38.3 (35.3 - 40.9)	37.6 (33.3 - 40.3)	0.193
Birth weight (g), median (IQR)		2 210 (1 397 - 2 995)	2 245 (1 410 - 2 980)	2 140 (1 396 - 3 000)	0.718
Admission weight (g). median (IQR)		2 400 (1 766 - 3 124)	2400 (1 785 - 3 150)	2 205 (1 600 - 2 933)	0.270
Referred from	Inpatient*	71 (26.7)	63 (28.4)	8 (18.1)	0.365
	Emergency unit	27 (10.2)	25 (11.2)	2 (4.5)	
	Tertiary	100 (37.6)	80 (36.0)	20 (45.5)	
	Regional	43 (16.2)	35 (15.8)	8 (18.1)	
	District	10 (3.8)	8 (3.6)	2 (2.3)	
	Clinic	10 (3.8)	7 (3.2)	3 (6.8)	
	Private	5 (1.9)	4 (1.8)	1 (2.3)	
Primary discipline	Ophthalmology	2 (0.8)	2 (0.9)	0	0.629
	Surgical	125 (47.0)	105 (47.3)	20 (45.5)	
	Cardiology	34 (12.8)	25 (11.3)	9 (20.5)	
	Cardiothoracic	22 (8.3)	18 (8.1)	4 (9.1)	
	Medical	55 (20.7)	48 (21.6)	7 (15.9)	
	Ear, nose and throat	14 (5.3)	13 (5.9)	1 (2.3)	
	Neurosurgical	14 (5.3)	11 (5.0)	3 (6.8)	
HIV exposed		68 (14.3)	52 (23.4)	16 (36.4)	0.088
Male		150 (56.4)	123 (55.4)	27 (61.4)	0.509
Congenital abnormality		135 (50.4)	107 (48.2)	27 (61.4)	0.137
Chromosomal abnormality†		12 (4.5)	9 (4.1)	3 (6.8)	1.000
SGA		20 (7.6)	17 (7.7)	3 (6.8)	1.00
Post-operative		44 (17.1)	38 (13)	6 (14)	0.378
Steroid mature‡		30 (32.3)	21 (26.9)	7 (46.7)	0.13
Surfactant		33 (12.4)	25 (11.2)	8 (18.6)	0.255
PIM 3, % (SD)		9.7 (13.5)	7.4 (9.7)	21.0 (21.9)	<0.001
SNAPPE-II, % (SD)		3.5 (6.7)	2.7 (5.4)	7.6 (10.6)	<0.001

PIM = Paediatric Index of Mortality; PMA = postmenstrual age; SGA = small for gestational age, SNAPPE = Score of Neonatal Acute Physiology with Perinatal Extension)
*Patients initially admitted to a lower acuity ward at Red Cross War Memorial Children's Hospital
†Of the 266 neonates, 34 were tested, of whom 25 were survivors and 9 were non-survivors.
‡Of the 266 neonates, 93 were eligible for steroid therapy, made up of 78 survivors and 15 non-survivors.

More confirmed sepsis episodes were recorded among non-survivors than survivors (p=0.025); however, there were fewer viral infections (p=0.039) and fewer cases of suspected sepsis in non-survivors (p=0.013).

Non-survivors had a higher risk of mortality as seen from scores on both the PIM-3 and the Neonatal Acute Physiology and Perinatal Extension (SNAPPE-II) index (p<0.001 for both, Table 1).

Proportionally, more non-survivors received high-frequency oscillatory ventilation (HFOV) (p<0.001), whereas more survivors received continuous positive airway pressure (p=0.026) (Table 2). Surfactant was administered to 25 (11.3%) of the survivors, of whom 76.0% were preterm. By comparison, all non-survivors (n=44) were preterm and eight (18.2%) received surfactant (Table 1).

Haemodynamic instability requiring inotropes was seen more often in non-survivors (p<0.001). In addition, these newborns had higher inotrope requirements than survivors (p=0.003). Total parenteral nutrition was used more often in survivors (p=0.009); non-survivors were more likely to receive no feeds (p<0.001). A higher proportion of non-survivors than survivors presented with acute kidney injury (p<0.001). The only two neonates who received renal replacement therapy both died (p=0.026).

Non-survivors presented with signs of coagulopathy more often, requiring fresh frozen plasma (p<0.001), platelets (p=0.003) or cryoprecipitate (p<0.001).

Binary logistic regression analysis based on variables with p<0.05 on univariate analysis showed that HFOV was independently associated with the outcome of death/palliation (β=7.4, p=0.003). Receiving total parenteral nutrition was associated with survival (β=-4.2, p=0.008). While receiving any kind of feed had a significant p value, the exponentiated Beta coefficient (which acts as an odds ratio) was 0 and is interpreted as not having any real world effect. (Table 1 supplementary material).

Discussion

We describe a population with a higher mortality rate than older PICU admissions and with a high burden of disease due to congenital abnormalities, NEC and sepsis, despite being more likely to have been born at term and with normal weight. The demand for neonatal care in our PICU was mostly driven by support for centralised surgical services.

Our study contributes to a small body of literature that profiles neonates admitted in a PICU. The cohort profiled by Vasudevan *et al.*[5] in northern India was treated in a smaller unit, which did not appear to offer specialist cardiac and surgical services. Half of their

Table 2. PICU interventions, complications, investigations and outcomes recorded in cohort (*N*=266)

Variable	All (*N*=266), *n* (%)	Survivors (*N*=222), *n*, (%)	Non-survivors (*N*=44), *n* (%)	*p*-value
Maximum ventilation support				0.001
HFOV	27 (10.2)	16 (7.2)	11 (25.0)	0.0004
IPPV	162 (60.9)	134 (59.9)	28 (63.6)	0.5
CPAP	33 (12.4)	31 (14.4)	2 (2.3)	0.03
High flow	7(2.6)	7 (3.2)	0 (0)	0.2
Inotropes	83 (32.3)	58 (26.1)	25 (58.1)	<0.001
Vasoactive infusion score*	10 (6 - 17.5)	8.5 (5.25-12.3)	17.3 (8 - 27.5)	0.003
Nitric oxide	5 (1.9)	3 (1.4)	2 (4.5)	0.184
Prostaglandin	25 (9.6)	18 (8.1)	7 (15.9)	0.146
TPN	75 (28.7)	70 (31.5)	5 (11.9)	0.009
Feeds received				<0.001
EBM	113 (44.5)	105 (47.3)	8 (18.2)	0.0002
Formula	60 (23.6)	55 (24.8)	5 (11.4)	0.046
Mixed	31 (12.2)	31 (14.0)	4 (9.1)	0.37
None	46 (18.1)	21 (9.5)	25 (56.8)	<0.001
AKI grade				<0.001
0	116 (45.3)	109 (49.1)	7 (15.9)	<0.001
1	49 (19.1)	31 (14.0)	18 (40.9)	<0.001
2	45 (17.6)	37 (16.7)	8 (18.2)	0.71
3	46 (18.0)	38 (17.1)	8 (18.2)	0.78
RRT	2 (0.8)	0	2 (4.5)	0.026
Sepsis episodes confirmed	71 (26.7)	53 (23.9)	18 (40.1)	0.025
Sepsis episodes suspected	144 (54.1)	128 (56.3)	16 (3.6)	0.013
Antibiotics received	189 (73.8)	159 (71.6)	30 (68.2)	0.716
Viral infection	42 (15.8)	40 (18.0)	2 (4.5)	0.02
Blood products received				
PRBC	78 (30.6)	60 (27.0)	18 (40.9)	0.063
FFP	35 (13.7)	19 (8.6)	16 (36.4)	<0.001
Platelets	48 (18.0	33 (14.9)	15 (34.1)	0.003
Cryoprecipitate	37 (13.9)	23 (10.4)	14 (31.8)	<0.001
Surgical procedures	167 (62.8)	145 (65.3)	22 (50.0)	0.403
Radiology procedures				
CT scans	38 (14.7)	30 (13.8)	8 (18.1)	0.474
Ultrasound	38 (14.6)	27 (12.2)	11 ((25.0)	0.03
Echocardiography	73 (28.1)	56 (25.2)	17 (38.6)	0.061
MRI	2 (0.8)	2 (0.9)	0	1.00
Contrast study	15 (5.8)	14 (6.3)	1 (2.3)	0.103
Length of stay (days)*	4 (2 - 8)	5 (2 - 8)	3 (1 - 7)	0.015

AKI = acute kidney injury; CPAP = continuous positive airway pressure; CT = computed tomography; EBM = expressed breast milk; FFP = fresh frozen plasma; HFOV = high-frequency oscillatory ventilation; IPPV = intermittent positive-pressure ventilation; MRI = magnetic resonance imaging; PRBC = packed red blood cells; RRT = renal replacement therapy; TPN = total parenteral nutrition
*Reported as median (IQR).

admissions were diagnosed with sepsis. The prevalence of being small for gestational age was 7.6% in our cohort, which is lower than the 12.7% reported by the associated tertiary neonatal unit.[6]

The percentage of HIV exposure in our study was lower than the 2019 local prevalence of 17%,[7] but the HIV transmission rate in our study was higher than the reported 3.5% for SA close to the time of the study.[8]

Congenital abnormalities are increasingly being identified as contributing to under-5 mortality.[9-11] In SA, policies that sought to deal with their care and prevention have historically been overshadowed by extensive HIV and tuberculosis epidemics, and possibly also the recent COVID-19 pandemic. Large epidemics such as these generally necessitate a redistribution of resources, which can leave patients with rare diseases vulnerable to missed diagnosis and access to treatment.[12-14]

Although congenital abnormalities were not associated with mortality in our study, they do contribute greatly to burden of disease. Genetic screening is not routinely performed at our centre owing to resource limitations. However, increasing evidence suggests that critically ill neonates may have genetic abnormalities;[15,16]

in future, it could be useful to consider further genetic studies, including whole-genome sequencing, in this group of patients. In addition, identifying congenital abnormalities during antenatal screening could also pre-empt the diagnosis and so allow for appropriate resources to be made available for affected babies. This can be achieved by offering all pregnant women a fetal anomaly scan during the second trimester, and not just those identified as having high-risk pregnancies. In well-resourced centres where appropriate care and services are available to manage congenital abnormalities, 30% of the deaths in the first year of life that are directly associated with a congenital abnormality cannot be prevented. However, 40% of the cases can be cured by a surgical procedure and 30% survive, with some disability.[9]

The proportion of neonates admitted in our study was 18.4%, which is in line with a range of 12 - 22% reported previously.[5,17-21] Although not specifically measured in our study, this may reflect a substantial percentage of bed days in our PICU. A large number of these are surgical admissions because of centralised paediatric surgical services. Most of the patients with a cardiac abnormality were admitted with a confirmed diagnosis, suggesting that the current screening programme is working well.

Ex-premature infants are a high risk group. The ex-premature surgical patients were mostly admitted from lower-acuity wards at RCWMCH with post-operative complications, whereas medical patients were admitted from emergency and outpatient units with infections. This phenomenon highlights the need for developing neonatal services within the tertiary hospital, and it is encouraging that a neonatal high-care area has recently been opened at the institution.

Neonatal mortality for babies admitted to a PICU varies widely among reports, possibly reflecting different resource environments and contexts.[5,17,18,20-23] The neonatal mortality seen in our study was lower than rates published by other PICUs from upper middle-income countries, such as Paraguay (24%)[22] and also elsewhere in SA (e.g. Johannesburg, 32.4%).[23] However, direct comparison is difficult: the latter unit focuses primarily on neonates but also offers ventilation to older children, whereas the PICU at RCWMCH is primarily a paediatric unit that also provides some neonatal services. Our study showed a higher neonatal mortality at discharge from the PICU compared with older children (10.9% v. 3.8%), similar to a finding by Mansour,[24] who described mortality rates in a mixed neonatal and paediatric ICU in Libya (24.4% v. 2.8%). The high mortality among babies of 28 - 32 weeks PMA may point to their being a group of immature babies with an added high-risk condition. The high mortality for babies admitted on day 4 - 7 of life possibly reflects organ pathology associated with major congenital abnormalities.

As mortality predictors, PIM-3 and SNAPPE-II scores underestimated the actual mortality seen in our study. Although PIM-3 has been validated in SA, it was in a population that excluded neonates.[25] Similarly, SNAPPE-II has not been validated in the PICU context. This highlights the need for prediction scores for this population to be developed for evaluation of care and subsequent comparison among units.

It is difficult to associate therapeutic interventions with outcomes, as decisions around management are complex and take into account many clinical, situational and resource-related factors that are not captured in our data. We have noted the outcomes that differed between survivors and non-survivors, but have chosen not to analyse them extensively. It is likely that multiple confounding factors exist.

Survivors primarily received non-invasive and some conventional ventilation compared with non-survivors, whose ventilation support was mostly conventional and of high-frequencey oscillatory nature. Proportionally more non-survivors received surfactant (although this was not statistically significant) and all such patients were premature. Given these findings, we postulate that non-survivors were more likely to be premature and have underdeveloped lungs or an element of bronchopulmonary dysplasia.

A large proportion of non-survivors received no feeds, possibly because they were too unstable to handle enteral nutrition. It is possible that the limited cases of parenteral nutrition in this group are due to many of these babies dying before such intervention could be considered in their management, as suggested by short stays.

We anticipated that infection would play a considerable role in this cohort, as neonates are vulnerable to pathogens.[26] Not surprisingly, there was more proven sepsis (i.e. where a bacterial or fungal pathogen was identified) among non-survivors, although it was not recorded whether the infections were hospital acquired or community acquired. ESBL *K. pneumonia* is more commonly identified as a hospital-acquired infection whereas RSV is usually a community-acquired infection. This could suggest that bacterial infections were more likely to be hospital acquired whereas viral infections may have been acquired in community settings.

Viral infections were more common among survivors and can probably be explained by more survivors being admitted from home. We did not consider seasonal variation in viral infections specifically, but we did notice that the highest number of admissions occurred between March and May, which coincides with the RSV season and probably accounts for an increased number of viral infections.[27] It also validates the reluctance of neonatal units to admit outpatients if isolation beds are not available. There may be less severe organ dysfunction with viral organisms, but survival may also just reflect older neonates with more physiological reserve.

AKI in the neonatal period may be challenging to diagnose.[28,29] It is likely that the severity of renal injury was under-represented in our study as a creatinine peak was probably not reached before some babies died and significant oliguria is often an absent feature of neonatal AKI.[30] Nearly half of the survivors had some measure of AKI and almost 20% had grade 3 AKI, yet no survivors received renal replacement therapy. Neonates tend to continue to produce urine even when their creatinine triples, so fluid overload is less of a concern. A large proportion of abdominal pathology in the cohort would have excluded the use of peritoneal dialysis. Providing haemodialysis in such small patients is limited by the availability of adequately sized dialysis catheters.

In general it appears that non-survivors use a considerable amount of resources (inotropes, blood products, HFOV, bed days) with disappointing results. Palliative care support is an important component of care for children with life-limiting congenital abnormalities and their families.

Neonatology is a highly specialised field and most paediatric intensivists are not trained neonatologists. One way of addressing the gap in expertise would be to create a space in critical care training that requires rotation through a specialised neonatal service. Ideally, critically ill neonates should be cared for in a dedicated neonatal unit outside of the NICUs attached to obstetric units, with specialist neonatal monitoring. These units should accommodate both neonates referred for centralised specialist services and isolation spaces for unwell neonates from home. Lastly, since many neonates are referred to centralised specialist services, resources could also be directed to specialised neonatal retrieval teams.

Study limitations

Our study is strengthened by its prospective design as well as its focus on a unique cohort not well described in the literature.

However, the single-centre observational study design does limit external validity and generalisability and the results cannot be extrapolated to other neonatal PICU populations. Our study did not include socioeconomic or transport delay data, which are major survival predictors in low- and middle-income countries. The lack of information on mode of death (i.e., haemodynamic, respiratory, neurological or multi-organ failure) limits the interpretation of mortality data.

Conclusion

Neonatal care may take place in critical-care spaces outside of the neonatal services. This population differs from neonates typically seen in a NICU. Congenital abnormalities as well as infection and NEC featured strongly in this cohort. Our study provides insight into risk factors and resources used in caring for this subgroup of the paediatric population. More research is needed to build on this data, including auditing of referral pathways and time-sensitive interventions, as well as developing a severity-of-illness score specifically for neonates and ex-premature babies.

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