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Paediatric Intensive Care Audit Network Annual Report 2021



Supplementary Chapters

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UNIVERSITY OF LEICESTER

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GIG CYMRU NHS WALES

HCA Hospitals
World-Class Healthcare

NOCA National Office of Clinical Audit

HSC Belfast Health and Social Care Trust

NHS National Services Scotland

Organisation key

A	Addenbrooke's Hospital, Cambridge
C	Noah's Ark Children's Hospital for Wales, Cardiff
D	Royal Manchester Children's Hospital
E1	Great Ormond Street Hospital, London (PICU/NICU)
E2	Great Ormond Street Hospital, London (CICU)
F	Evelina London Children's Hospital
H	King's College Hospital, London
I	Leeds General Infirmary
K2	Freeman Hospital, Newcastle upon Tyne
K3	Great North Children's Hospital, Newcastle upon Tyne
L	Royal Stoke University Hospital
M	Nottingham Children's Hospital, Queens Medical Centre, Nottingham
N	John Radcliffe Hospital, Oxford
O	Royal Brompton Hospital, London
P	Alder Hey Children's Hospital, Liverpool
Q	Sheffield Children's Hospital
R	Southampton Children's Hospital
S	James Cook University Hospital, Middlesbrough
T	St George's Hospital, London
U	St Mary's Hospital, London
V	Birmingham Children's Hospital
W	Bristol Royal Hospital for Children
X1	Glenfield Hospital, Leicester
X2	Leicester Royal Infirmary
Y	Royal Hospital for Sick Children, Edinburgh
Z	The Royal London Hospital
ZA	Royal Hospital for Children, Glasgow
ZB	Royal Belfast Hospital for Sick Children
ZC	Children's Health Ireland at Crumlin, Dublin (formerly Our Lady's Children's Hospital, Crumlin)
ZD	Children's Health Ireland at Temple Street, Dublin (formerly Temple Street Children's University Hospital)
ZE	Harley Street Clinic, London
ZF	The Portland Hospital, London
T001	Children's Acute Transport Service (CATS)
T002	Embrace: Yorkshire & Humber Infant & Children's Transport Service
T003	North West and North Wales Paediatric Transport Service (NWTS)
T004	South Thames Retrieval Service (STRS)
T005	KIDS Intensive Care and Decision Support
T008	Southampton Oxford Retrieval Team (SORT)
T010	Northern Ireland Specialist Transport and Retrieval (NISTAR) Paediatric
T020	Scotland Specialist Transport and Retrieval (ScotSTAR)
T022	Irish Paediatric Acute Transport Service (IPATS)
T024	Wales and West Acute Transport for Children (WATCh)
T026	North East Children's Transport and Retrieval Service (NECTAR)
T027	Children's Medical Emergency Transport Service (CoMET)
T028	Heartlink ECMO Children's Service

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Contents

For the Tables, Figures and Appendices relating to this report, please visit the PICANet website www.picanet.org.uk.

Special Chapter 1: COVID-19 and PIMS-TS in PICU

1. Introduction

This chapter presents data on children with a **confirmed coronavirus (COVID-19) diagnosis** treated in a paediatric intensive care unit (PICU) in the United Kingdom (UK) but excludes data from the Republic of Ireland. It should be noted that the reason for admission to PICU for these children **may not be due to COVID-19**. In this report, we use the term COVID-19 to describe all forms of presentations related to SARS-Co-V-2 infection as described below.

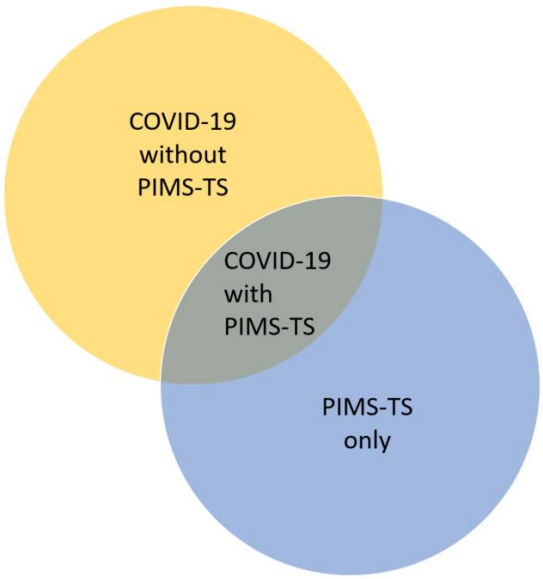
COVID-19 is an infectious disease caused by the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) virus. Children make up only a small proportion of COVID-19 cases compared to adults, and most show less severe symptoms [1-4]. Nevertheless, some children with a diagnosis of COVID-19 have required admission to PICUs in the United Kingdom with associated morbidity and mortality [5-9].

SARS-CoV-2 infection has also been linked with a multisystem inflammatory illness in children. This is commonly referred to as paediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2 (PIMS-TS). PIMS-TS is typically characterised by single or multi-organ dysfunction, although less serious symptoms include abdominal pain, vomiting and diarrhoea [10].

Children described in this chapter may have presented with 1) COVID-19 only (i.e., confirmed SARS-CoV-2 infection without PIMS-TS, which may or may not have been symptomatic or the reason for admission) 2) COVID-19 and PIMS-TS (PIMS-TS patients with a positive SARS-CoV-2 polymerase chain reaction (PCR) result)); or 3) PIMS-TS only (SARS-CoV-2 PCR negative regardless of antibody test results), as can be seen in Figure 1.

Owing to the established links between COVID-19 and PIMS-TS, we have also included a small section of this special chapter focusing on PIMS-TS (Table 3 and Section 3.2).

Figure 1: Relationship between the three cohorts featured in this chapter



2. Methods

2.1 Data collection and caveats

A PICANet customised audit was established at the start of the COVID-19 pandemic following a request by NHSE to facilitate the collection of additional information concerning:

1) All children who tested positive for COVID-19 either prior to or during their PICU admission, and;
2) Children who remained COVID-19 suspected or probable after repeated COVID-19 negative laboratory test results and in the presence of no other positive virology and bacteriology results. This included children admitted with PIMS-TS exclusive of other anti-microbial causes[1].

Additional data items included details about testing for COVID-19, symptoms, co-infection laboratory markers, echocardiogram findings and medication used. Details about testing for children was required to understand the use of different sampling for the identification of COVID-19. This included: COVID-19 status on admission, up to three rounds of testing including date and time of testing, reason for testing (suspected infection or routine testing), types of samples taken, results of each test, laboratory markers at admission, co-infections, symptoms, and medications. With regards to testing, multiple different types of tests can be undertaken in the same testing episode.

2.2 Data definitions and handling

2.2.1 Admission episode

An admission episode was defined as **any continuous period of intensive care,** including direct transfers between PICUs. For children readmitted to PICU more than 48 hours post PICU discharge the re-admission was considered separately as a new admission. Analyses based on PICU care episodes (Tables 1-3) used the first available patient characteristics and admission details and the last available discharge information. Details of treatment provided in a single care episode was an aggregate of all information available. Length of stay was calculated based on duration of PICU care as the difference in days between the admission date and discharge date; in cases where the child was re-admitted to PICU within 48 hours of PICU discharge or transferred, the calculation of length of stay included the period where the child was not being treated within a PICU.

2.2.2 Co-morbidities

Co-morbidities were reviewed for all children and grouped into major diagnostic categories:

- Inherited genetic / Chromosomal abnormalities
- Chronic Pulmonary Disease
- Congenital Heart / Cardiac Disease
- Malignancy including leukaemia, lymphoma, solid tumours
- Neurological/Developmental incl. autism, epilepsy, cerebral palsy
- Metabolic/Endocrine incl. diabetes
- Preterm

[1] PIMS-TS data was consistently collected from January 2021 and some units may have retrospectively provided data on children admitted with PIMS-TS prior to this.

2.2.3 Pandemic phases

In some instances, we present data according to two phases of the COVID-19 pandemic. Children in the COVID-19 only cohort (Section 3.1.1) were categorised as falling into one of two phases based on the date of the first positive confirmation of COVID-19 via PCR:

1. On or before 31 August 2020 (Phase 1)
2. On or after 1 September 2020 (Phase 2)

These dates were used to define phases for the whole of the UK for the analyses in Section 3.1 and Figure 2. This two-phase approach mirrors that used in other published reports on COVID-19 in critical care [11].

For instances where a child had multiple recorded admissions to PICU, they were categorised into a phase based on the date of the first positive confirmation of COVID-19 via PCR, during their first recorded admission to PICU.

Eleven children did not have a date of the first positive confirmation of COVID-19 via PCR recorded by the date of data cut-off (27 July 2021) and so were excluded from the analysis.

2.2.4 Townsend deprivation index

The Townsend deprivation index [12] is a census-based, area-level index which is widely used in healthcare research. Townsend scores were allocated to children by postcode of residence to provide a general measure of deprivation. Positive Townsend scores are indicative of high levels of deprivation, whereas negative scores indicate relative low levels of deprivation.

2.3 Data analysis

Descriptive data were reported as numbers and percentages for categorical variables and medians with interquartile ranges (IQR) and mean and standard deviations for continuous variables. Z-scores are a widely used measure to display and monitor growth measurements [13]. In childhood, weight-for-age z-scores can be used to assess growth and nutritional status. These are derived by comparing individual growth measurements against standardised growth data, or charts from a ‘normal’, or reference population. A z-score is the distance and direction of an observation away from the population mean. These were calculated using the UK-WHO Growth References [14], accounting for pre-term birth where required, to compare the weight of a child in PICU to the mean weight for a comparable child of the same sex and age. Estimates and 95% confidence intervals (CIs) for the difference between the COVID-19 and influenza cohorts (Table 2) were obtained using t-tests for continuous data, a type of inferential statistic which is commonly used to determine if there is a significant difference between the means of two groups. A two-sample test of proportions was used to compare discrete variables.

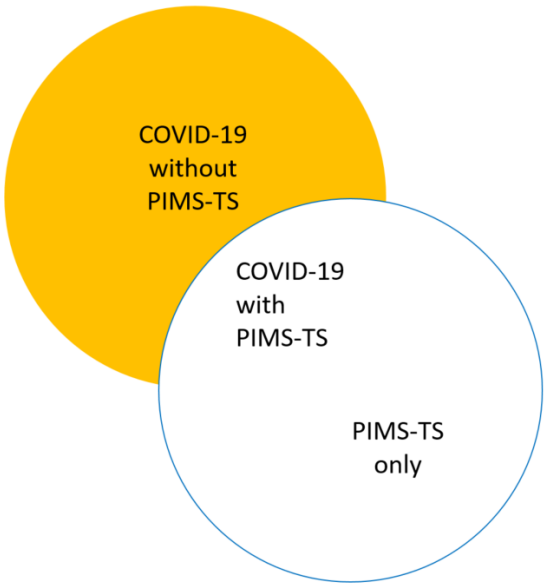
3. Results

3.1 COVID-19 only cohort

3.1.1 Analysis population

This section focuses on children who were positive for COVID-19 (as defined in Section 2.2) but did not present with PIMS-TS (Figure 2).

Figure 2: COVID-19-only cohort



Focusing on children with COVID-19-only allows for robust comparisons:

- Of patient characteristics across the two phases of the COVID-19 pandemic; and
- With a cohort of flu patients admitted in 2019

The influenza cohort included children admitted to a UK PICU between 1 January and 31 December 2019 with a primary diagnosis of influenza. This comparator group was chosen as it is known that influenza infections are associated with significant morbidity and mortality in children of all ages and that, as another respiratory infection, these cases may have several similarities with COVID-19 [3].

3.1.2 Overview of COVID-19 only cohort

There were **217** PICU care episodes for **209 COVID-19 positive children** who presented without PIMS-TS[2]. Eleven of these children did not have a date of first positive COVID PCR test recorded and therefore are excluded from analysis as they could not be assigned to a phase. This means that the COVID-19 only cohort comprises **198** children.

Figure 3 presents the number of PICU care episodes (UK PICUs) by week of first positive confirmation of COVID-19 via PCR, for all 209 children with confirmed COVID-19 (without PIMS-TS) between the 14 March 2020 and 19 July 2021.

Characteristics recorded in the first PICU care episode for each child in the COVID-19 cohort (n=198) are presented in Table 1a.

[2] With a recorded date of the first positive confirmation of COVID-19 via PCR.

- The **median age** of COVID-19 positive children when first admitted to PICU was **9 years** (interquartile range (IQR): 1–13 years). **60%** of children were aged **6 years and above**.
- Around **62%** of the children were **male**.
- **Just over two fifths** of children were **White (43%)**, just over **one quarter were Asian (27%)** and approximately **one-sixth** were **Black (17%)**. Data on ethnicity were **unavailable** for 4% of children.
- **64%** of children were admitted to PICU **for infections or respiratory conditions** with a further 12% for neurological problems and 6% for gastrointestinal problems.
- **91% (n=180)** of the initial admissions for these children were **unplanned admissions** to PICU (where the admission was not expected and therefore was an emergency admission).

Figure 3: Number of PICU care episodes (UK PICUs) by week of first positive confirmation of COVID-19 via PCR, for children with confirmed COVID-19 (without PIMS-TS)

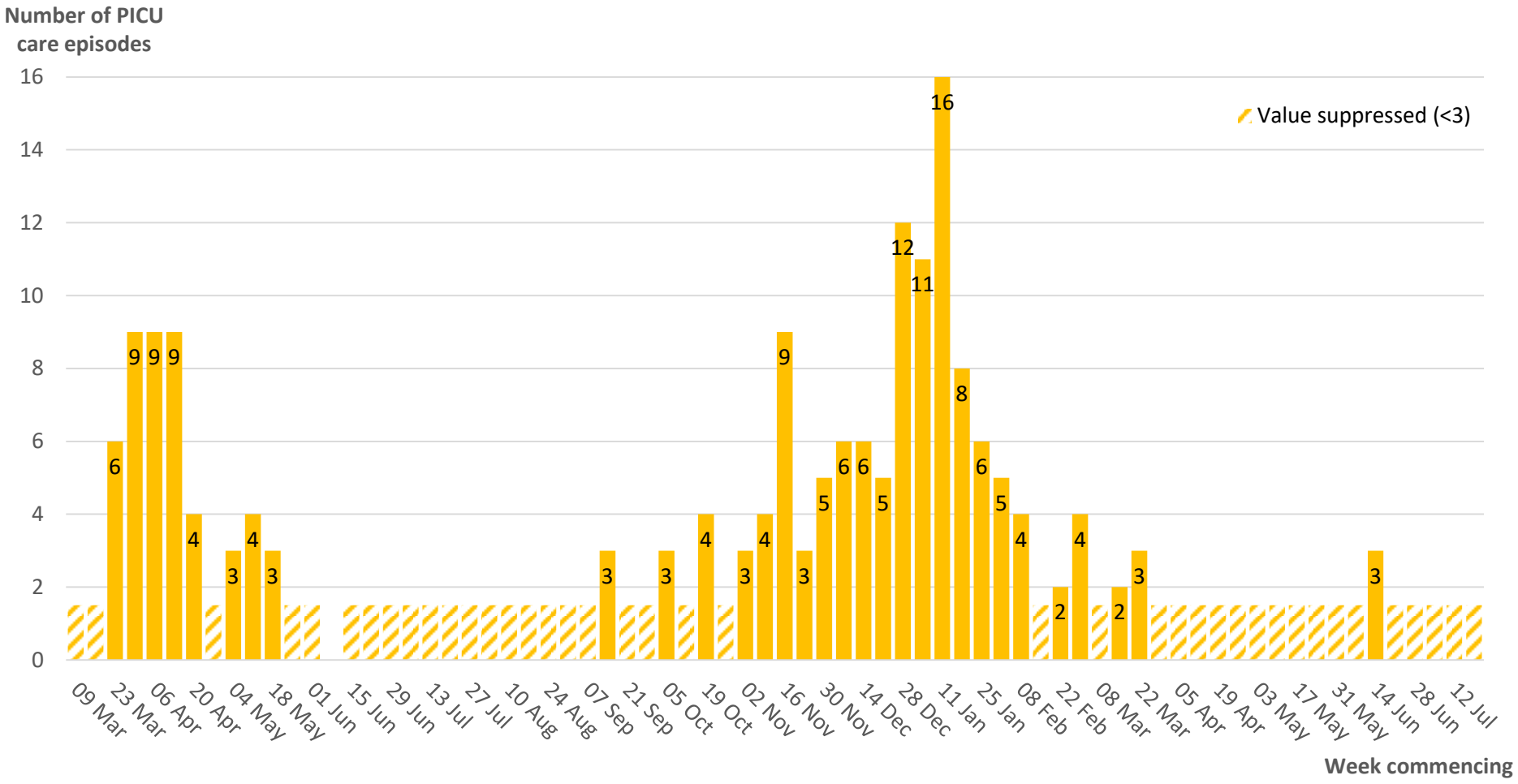


Table 1a: Characteristics and treatment details for all children (<18 years) with a confirmed COVID-19 (without PIMS-TS) diagnosis and treated in a paediatric intensive care unit (PICU) in the United Kingdom (UK), overall and for two phases of the COVID-19 pandemic alongside comparisons from previous years

	All COVID-19 positive children π n=198	COVID-19 positive children (Phase 1 Ω) n=55	COVID-19 positive children (Phase 2 Ω) n=143	Proportions from PICU admissions 2017–2019*
Age group at first PICU admission, n (%)				
Neonate <30 days	8 (4.0)	4 (7.3)	4 (2.8)	12.9%
Infant 31–365 days	29 (14.7)	9 (16.4)	20 (14.0)	29.3%
Young child 1y–5y	41 (20.7)	10 (18.2)	31 (21.7)	28.8%
Older child 6–12y	56 (28.3)	15 (27.3)	41 (28.7)	17.3%
Teenager 13–18y	64 (32.3)	17(30.9)	47 (32.9)	11.7%
Male, n (%)	122 (61.6)	33 (60.0)	89 (62.2)	56.7%
Ethnicity, n (%)				
White	87 (43.9)	21 (38.2)	66 (46.2)	60.7%
Asian	54 (27.3)	16 (29.1)	38 (26.6)	9.5%
Black	33 (16.7)	12 (21.8)	21 (14.7)	4.1%
Other	12 (6.1)	3 (5.5)	9 (6.3)	2.2%
Mixed	7 (3.5)	3 (5.5)	4 (2.8)	2.8%
Unknown	5 (2.5)	0 (-)	5 (3.5)	20.0%
Weight z-score				
n (%)	189 (95.5)	51 (92.7)	138 (96.5)	/ *
Mean (SD)	0.3 (2.0)	0.2 (2.0)	0.3 (2.1)	
Median (IQR)	0.2 (-0.7–1.6)	-0.1 (-1.1–1.4)	0.2 (-0.7–1.7)	
Townsend deprivation index score				
n (%)	191 (96.4)	55 (100.0)	136 (95.1)	/ *
Mean (SD)	2.8 (3.8)	3.1 (4.0)	2.8 (3.7)	
Median (IQR)	3.0 (-0.3–6.1)	3.9 (-0.6–6.7)	2.9 (0.1–5.7)	
Unplanned admission, n (%)	180 (90.9)	51 (92.7)	129 (90.2)	/ *
Comorbidity††, n (%)				
Neurological/Developmental‡	45 (22.7)	14 (25.5)	31 (21.7)	9.9%
Congenital Heart/Cardiac Disease	21 (10.6)	5 (9.1)	16 (11.2)	11.5
Inherited genetic/chromosomal abnormalities	17 (8.6)	9 (16.4)	8 (5.6)	3.8%
Pre-term	14 (7.1)	6 (10.9)	8 (5.6)	9.1%
Malignancy†	4 (2.0)	<3 (<5.5)	<3 (<2.1)	0.4%
Metabolic/Endocrine**	3 (1.5)	<3 (<5.5)	<3 (<2.1)	0.3%
Chronic Pulmonary Disease	6 (3.0)	<3 (<5.5)	4 (2.8)	3.3%
Otherβ	12 (6.0)	3 (5.5)	9 (6.3)	/ *
No recorded comorbidities	120 (60.6)	28 (50.9)	92 (64.3)	71.0%
PIM3 POD %				
Mean (SD)	3.7 (5.5)	5.0 (7.6)	3.1 (4.3)	3.3 (8.2)
Median (IQR)	1.6 (1.2–3.9)	3.2 (1.2–6.0)	1.5 (1.2–3.6)	1.2 (0.5–3.3)

Respiratory support				
Total length¶ of respiratory support in PICU (days)				
n (%)	140 (70.7)	39 (70.9)	101 (70.6)	/ *
Mean (SD)	9.1 (15.4)	12 (23.0)	8.0 (11.2)	
Median (IQR)	4.5 (2.5–9.5)	5.0 (3.0–11.0)	4.0 (2.0–9.0)	
Maximum respiratory support ¶, n (%)				
High frequency oscillatory or jet ventilation	11 (5.6)	4 (7.3)	7 (4.9)	0.1%
Invasive mechanical ventilation	104 (52.5)	33 (60.0)	71 (49.7)	55.6%
Non-invasive ventilation	20 (10.1)	<3 (<5.5)	18 (12.6)	12.2%
High flow nasal cannula therapy	18 (9.1)	<3 (<5.5)	16 (11.2)	7.1%
None	45 (22.7)	14 (25.5)	31 (21.7)	25.0%
Invasive ventilation				
Total length¶ of invasive ventilation in PICU (days)				
n (%)	115 (58.1)	37 (67.3)	78 (54.5)	61.0%
Mean (SD)	9.6 (16.1)	11.7 (22.5)	8.6 (12.0)	6.4 (15.7)
Median (IQR)	5.0 (2.0–10.0)	5.0 (3.0–11.0)	4.0 (2.0–9.0)	3 (2–6)
Vasoactive support				
Total length¶ of vasoactive support in PICU (days)				
n (%)	63 (31.8)	21 (38.2)	42 (29.4)	30.8%
Mean (SD)	5.6 (8.6)	6.9 (8.6)	5.0 (8.6)	
Median (IQR)	3.0 (2.0–5.0)	5.0 (3.0–6.0)	2.5 (2.0–3.0)	
Inhaled nitric oxide¶, n (%)	15 (7.6)	6 (10.9)	9 (6.3)	3.3%
Renal replacement therapy¶, n (%)	9 (4.6)	3 (5.5)	6 (4.2)	3.1%
Extracorporeal life support¶, n (%)	3 (1.5)	<3 (<5.5)	<3 (<2.1)	1.2%
Outcomeϕ, n (%)				
Discharged alive	185 (93.4)	49 (89.1)	136 (95.1)	96.6%
Died in PICU	11 (5.6)	6 (10.9)	5 (3.5)	3.5%
Unknown	2 (1.0)	0 (-)	2 (1.4)	-
Total length¶ of PICU care (days)				
n (%)	196 (99.0)	55 (100.0)	141 (98.6)	
Mean (SD)	9.0 (16.1)	11.0 (20.1)	8.2 (14.2)	6.0 (15.8)
Median (IQR)	4.4 (2.1–9.6)	5.0 (2.7–11.6)	4.1 (1.9–9.0)	2.4 (1.0–5.6)

Abbreviations: CI = confidence interval; SD = standard deviation; IQR = interquartile range; PIM3 POD = paediatric index of mortality 3 predicted probability of death;

π COVID-19 only cohort with a date of first positive PCR test between 14 March and 19 July.

Ω Phases of the COVID-19 pandemic are defined as follows:
Phase 1: 14 March–30 August 2020; Phase 2: 1 September 2020–19 July 2021.

*2017–2019 figures are based on 0-18 year olds. They are also based on admissions and not PICU care episodes, as is the case in this special chapter. For the COVID cohort, admissions are presented based on the first PICU care episode if there was more than one. In contrast, the 2017–2019 figures include multiple admissions for individuals. These proportions should therefore not be used for direct comparison.

†† comorbidities not mutually exclusive;

‡ Neurological/developmental including epilepsy, cerebral palsy;

**metabolic/endocrine including diabetes;

† malignancy including leukaemia, lymphoma, solid tumours;

β other including autism and attention deficit hyperactive disorder (ADHD)

¶ where a child had multiple admission events the number of days is summed across all events;

ϕ where a child had multiple admission events, the status from the last recorded admission is presented

3.1.3 Patient characteristics by phase

Characteristics of the **198 children** in the COVID-19-only cohort are presented by phase of the pandemic in Table 1a.

- **Over two-thirds** (72%) of this cohort were **admitted in Phase 2** (n=143 of 198).
- The age distribution was fairly constant across Phase 1 and 2. Admissions to PICU from young children (aged 1–5 years) **increased slightly** from Phase 1 to Phase 2. Admissions in this age group accounted for fewer than **18%** of all admissions in Phase 1, compared to **22%** of all admissions in Phase 2.
- The proportion of **males** in each phase was similar at around **60%**.
- A **higher proportion of White children** were first admitted to PICU in **Phase 2** (38% vs 46%) whereas the **proportion of Asian and Black children was lower** in the second phase (Asian: 29% vs 27%, Black: 22% vs 15%).
- Distribution of weight z-scores varied considerably across the two phases. Children first admitted in Phase 1 had the **lowest median z-score** (-0.1, IQR: -1.1 to 1.4). This contrasted with the **higher median weight z-score of children admitted during Phase 2** (0.2, IQR: -0.7 to 1.7), consistent with children first admitted during the Phase 2 being heavier.
- Townsend deprivation index scores decreased from a median of almost **4.0** in **Phase 1** to **2.9 in Phase 2**, indicative of a slightly **higher proportion** of children admitted to PICU in Phase 1 from **more deprived areas**.
- Neurological/developmental and congenital heart/cardiac disease **comorbidities were most common,** being recorded in 23% and 12% of cases respectively.
- Children were **sicker at presentation** (according to PIM3 score) when admitted to PICU **during Phase 1**, compared to children admitted during Phase 2. The estimated probability of death for children, taking into account their sickness levels at admission **more than halved** for children admitted during Phase 2 (1.5, IQR: 1.2 to 3.6) compared to Phase 1 (3.2, IQR: 1.2 to 6.0).

3.1.4 Management and outcomes

A range of interventions were reported in the COVID-19 only cohort. Table 1a displays information on interventions given during the child's first PICU care episode.

- **Respiratory support** was required in **most children (71%)** with similar proportions in both phases. Children required **on average one day less respiratory support** if admitted **in Phase 2** than **Phase 1** (median 4 days vs 5 days).
- **Over half (53%,** n=104) received the highest level of respiratory support (**invasive ventilation)**. During **Phase 2,** a **lower proportion** of the cohort **received invasive ventilation (55%) compared to** those diagnosed during **Phase 1 (67%).** In **Phase 2,** children **required on average one less day invasive ventilation** than in **Phase 1** (median of 4 days vs 5 days).
- Overall, just under one-third of children received vasoactive support during their first PICU care episode. The proportion of children requiring **vasoactive interventions** was **higher** for those diagnosed **during Phase 1 (38%) compared to Phase 2 (29%).** The **length of vasoactive support** provided was also **longer in Phase 1** with a **median of 5 days** (IQR: 3–6 days) **compared with 3 days in Phase 2** (IQR: 2–3 days).
- Very small numbers of children received inhaled nitric oxide, renal replacement therapy and extracorporeal membrane oxygenation (ECMO).

- **PICU length of stay** was **shorter** for those diagnosed **in Phase 2** (4 days, IQR: 2 to 11 days) **compared to Phase 1** (5 days, IQR: 3 to 12 days).
- **Eleven children** in the COVID-19 only cohort **died whilst on PICU**, although two of these deaths occurred more than 28 days after the first recorded positive COVID-19 test. 11% of children (n=6) first treated during Phase 1 in PICU died compared with 4% (n=5) of those first treated in Phase 2. It is possible that the cause of death in at least some children is unrelated to COVID-19 infection.

3.1.5. Testing and symptoms

Testing details presented in Table 1b relate to the first recorded positive PCR test for each child for the COVID-19 only cohort.

- A positive COVID-19 result was most commonly obtained **on the date of admission to PICU** (82 children, **41%**) or **more than 24 hours prior to PICU admission** (68 children, **34%**).
- **Most** of the cohort were **first tested** for COVID-19 **due to a suspected infection** (n=131, **72%**); the other **51 children had COVID-19 detected during routine screening (28%)**. As more tests became available and there was a shift clinically to conduct more asymptomatic screening, the proportion of children **identified when testing for suspected infections decreased** from **78%** in **Phase 1** to **70%** in **Phase 2**.
- Over 85% of children had no confirmed co-infections recorded, however, 27 children (**14%**) **had at least one other viral, bacterial or fungal infection** (Table 2). **Viral co-infections** were recorded in 18 children (**9%**), **bacterial infections** in eight children (**4%**) and **fungal infections** in three children (**2%**)[3]. Proportions were similar across both waves for all co-infection types.

[3] Infection types were not mutually exclusive so a child could have had both a bacterial co-infection and a viral co-infection hence the numbers total more than 27.

Table 1b: Symptoms and details of first positive microbiological testing for children in the COVID-19 only cohort (n=198) treated in a paediatric intensive care unit (PICU) in the United Kingdom (UK) across two phases of the COVID-19 pandemic

	All COVID-19 positive children π n=198	COVID-19 positive children (Phase 1 Ω) n=55	COVID-19 positive children (Phase 2 Ω) n=143
Timing of first laboratory confirmation of COVID-19 in relation to first PICU admission, n (%)			
Pre PICU admission	**83 (41.9)**	**27 (49.1)**	**56 (39.2)**
More than 24h prior to admission	68 (81.9)	12 (44.4)	56 (39.2)
Within 24h prior to admission	15 (18.1)	15 (55.6)	0 (-)
On date of admission	**82 (41.4)**	**17 (30.9)**	**65 (45.5)**
Post PICU admission	**33 (16.7)**	**11 (20.0)**	**22 (15.4)**
Less than two days after admission	19 (57.6)	6 (54.6)	13 (59.1)
2–7 days after admission	10 (30.3)	3 (27.3)	7 (31.8)
>7 days after admission	4 (12.1)	<3 (<27.3)	<3 (<13.6)
Reason for testing when first tested positive, n (%)			
Suspected infection	131 (72.0)	40 (78.4)	91 (69.5)
Routine screening	51 (28.0)	11 (21.6)	40 (30.5)
Other confirmed infection†, n (%)			
No other infection recorded	171 (86.4)	48 (87.3)	123 (86.0)
Number of children with bacterial infections†	8 (4.0)	<3 (<5.5)	6 (4.2)
Number of children with viral infections†	18 (9.1)	4 (7.3)	14 (9.8)
Number of children with fungal infections†	3 (1.5)	3 (5.5)	0 (-)
Symptoms‡, n (%)			
Fever >37.8°C	103 (52.0)	29 (52.7)	74 (51.8)
Cough	71 (35.9)	17 (30.9)	54 (37.8)
Abdominal pain	18 (9.1)	7 (12.7)	11 (7.7)
Diarrhoea	22 (11.1)	11 (20.0)	11 (7.7)
Rash	11 (5.6)	8 (14.6)	3 (2.1)
Shock	12 (6.1)	8 (14.6)	4 (2.8)
Sore throat	9 (4.5)	6 (10.9)	3 (2.1)
Conjunctivitis	3 (1.5)	<3 (<5.5)	<3 (<2.1)
Runny nose	9 (4.6)	<3 (<5.5)	7 (4.9)
Anosmia	3 (1.5)	0 (-)	3 (2.1)
Other symptoms	75 (37.9)	30 (54.6)	45 (31.5)
No symptoms	43 (21.7)	9 (16.4)	34 (23.8)

π COVID-19 only cohort with a date of first positive PCR test between 14 March and 19 July.
Ω Phases of the COVID-19 pandemic are defined as follows:
Phase 1: 14 March–30 August 2020; Phase2: 1 September 2020–19 July 2021.
† Co-infection types not mutually exclusive;
‡ Symptoms not mutually exclusive;

Details of the symptoms recorded in the COVID-19 only cohort are also summarised in Table 1b, a child may have had more than one symptom recorded.

- Of the common symptoms, **52%** (n=103) reported **fever** (>37·8°C) and **36%** (n=71) **cough**.
- Presentation of symptoms differed across the two phases of the pandemic: the **proportion** of the cohort presenting **with a fever was similar between Phase 1 (53%) and Phase 2 (52%)**. However, **a higher proportion** of children (**11%**) presented with a **sore throat in the first phase, compared to just 2% in Phase 2**.
- A **higher proportion** of the cohort who were diagnosed in **Phase 1** also presented with **shock (15%)** and a **rash (15%)**, compared to around **2% in Phase 2**.
- Overall, 43 (22%) children reported **no symptoms**; this increased from **16%** (n=9) in **Phase 1** to **24%** (n=34) in **Phase 2**.

3.1.6 Comparisons with 2017–2019 PICU admissions

In this section we present information based on the COVID-19 only cohort of 198 children alongside information relating to PICU admission between 2017 and 2019. Historic figures are based on 0–18 year olds; they are also based on admissions and not PICU care episodes, as is the case in this special chapter. For the COVID cohort, admissions are presented based on the first PICU care episode if there was more than one; in contrast, the 2017–2019 figures include multiple admissions for individuals. These proportions should therefore not be used for direct comparison.

- **62%** of children in the COVID-19 (without PIMS-TS) cohort were **male**, compared to around **57%** of male admissions for 2017–2019.
- **60%** of children with COVID-19 fell into the **6+ (years) age category**. This contrasts with usual age at admission to PICU (2017–2019), where 43% of admissions were in children aged less than one year and around a quarter of admissions were in children aged 1–4 years.
- The ethnic distribution of COVID-19 and 2017–2019 admissions varied considerably. There was a **much higher proportion of Black (17%) and Asian (27%) children in the COVID-19** (without PIMS-TS) **cohort**, compared to the admissions to PICU between 2017 and 2019 **(Black: 3%, Asian: 8%).**

3.1.7 Comparison with Influenza admissions from 2019

The characteristics of **193 children from the COVID-19 only cohort**[4] were compared with a 2019 cohort of **243 children admitted to PICU with influenza** in Table 2.

[4] n=5 children in the COVID cohort had a previous influenza admission to PICU in 2019 and so were excluded from the COVID-19 cohort prior to analysis.

Table 2: Characteristics and treatment details for n=193 children in the COVID-19 only cohort (with no influenza admission in 2019) and treated in a paediatric intensive care unit (PICU) in the United Kingdom (UK) and n=243 children with an influenza PICU admission in 2019

	COVID-19 positive children (n=193*)	Children admitted to PICU with influenza in 2019 (n=243)	Difference in mean/proportion (95% CI)
Age group at first PICU admission, n (%)			
Neonate <30 days	8 (4.2)	7 (2.9)	2.0% (-2.2% to 4.8%) α
Infant 31–365 days	29 (15.0)	47 (19.3)	-5.3% (-11.4% to 2.8%) α
Young child 1y–5y	39 (20.2)	99 (40.7)	-20.5% (-28.9% to -12.1%) α
Older child 6–12y	55 (28.5)	64 (26.4)	2.9% (-6.3% to 10.5%) α
Teenager 13–18y	62 (32.1)	26 (10.7)	21.6% (13.8% to 29.1%) α
Male, n (%)	120 (62.1)	142 (58.4)	3.7% (-5.5% to 13.0%) α
Ethnicity, n (%)			
White	86 (44.6)	137 (56.4)	
Asian	52 (26.9)	34 (14.0)	
Black	33 (17.1)	9 (3.7)	/ ϕ
Other	11 (5.7)	9 (3.7)	
Mixed	6 (3.1)	5 (2.0)	
Unknown	5 (2.6)	49 (20.2)	
Weight z-score			
n (%)	185 (95.9)	110 (45.3)	
Mean (SD)	0.3 (2.0)	-0.5 (2.0)	/ ϕ
Median (IQR)	0.2 (-0.7–1.6)	-0.4 (-1.4–0.6)	
Townsend deprivation index score			
n (%)	186 (96.4)	225 (92.6)	1.4 (0.7 to 2.1) τ
Mean (SD)	2.9 (3.8)	1.5 (3.8)	
Median (IQR)	3.2 (-0.1–6.1)	1.2 (-1.8–4.4)	
Unplanned admission, n (%)	175 (90.7)	235 (96.7)	-6.0% (-7.6% to 0.7%) α
Comorbidity††, n (%)			
Neurological/Developmental‡	43 (22.3)	59 (24.3)	/ λ
Congenital Heart/Cardiac Disease	21 (10.9)	17 (7.0)	
Inherited genetic/chromosomal abnormalities	16 (8.3)	9 (3.7)	
Pre-term	14 (7.3)	30 (12.3)	
Malignancy†	4 (2.1)	<3 (<1.2)	
Metabolic/Endocrine**	3 (1.6)	0 (-)	
Chronic Pulmonary Disease	6 (3.1)	18 (7.4)	
Otherβ	12 (6.2)	15 (6.2)	
No recorded comorbidities	117 (60.6)	169 (69.5)	
PIM3 POD %			
Mean (SD)	3.6 (5.5)	4.7 (6.87)	-1.1 (-2.3 to 0.5) τ
Median (IQR)	1.6 (1.2–3.8)	3.3 (1.2–5.1)	
Respiratory support			

Days[¶] of respiratory support in PICU			
n (%)	136 (70.5)	217 (89.3)	-19.1% (-26.5% to -11.7%)[α]
Mean (SD)	8.7 (15.0)	10.5 (29.8)	
Median (IQR)	4.5 (2.5–9.0)	5.0 (3–10)	
Maximum respiratory support [¶], n (%)			
High frequency oscillatory or jet ventilation	11 (5.7)	22 (9.1)	-3.4% (-5.4% to 12.6%) [α]
Invasive mechanical ventilation	101 (52.3)	161 (66.3)	-13.0% (-22.3% to 3.9%) [α]
Non-invasive ventilation	18 (9.3)	19 (7.8)	-1.5% (-4.2% to 6.4%) [α]
High flow nasal cannula therapy	18 (9.3)	26 (10.7)	-1.7% (-7.5% to 3.9%) [α]
None	45 (23.3)	15 (6.2)	17.1% (10.4% to 23.8%) [α]
Invasive ventilation			
Days[¶] of invasive ventilation in PICU			
n (%)	112 (58.0)	181 (74.5)	-1.7% (-25.3% to -7.6%)[α]
Mean (SD)	9.1 (15.7)	10.8 (31.9)	
Median (IQR)	5 (2.0–10.0)	5 (3.0–10.0)	
Vasoactive support			
Days[¶] of vasoactive support in PICU			
n (%)	61 (31.6)	83 (34.2)	0.2% (-11.4% to 6.3%)[α]
Mean (SD)	5.5 (8.7)	5.8 (7.8)	
Median (IQR)	3.0 (2.0–5.0)	4.0 (2.0–7.0)	
Inhaled nitric oxide[¶], n (%)	15 (7.8)	18 (7.4)	0.4% (-4.6% to 5.4%) [α]
Renal replacement therapy[¶], n (%)	9 (4.7)	16 (6.6)	1.9% (-6.2% to 2.4%) [α]
Extracorporeal life support[¶], n (%)	<3 (<1.6)	4 (1.6)	0.6% (-2.8% to 1.5%) [α]
Outcome, n (%)			-0.5% (-5.2% to 4.1%)[α δ]
Discharged alive	180 (93.3)	228 (93.8)	
Died in PICU	11 (5.7)	15 (6.2)	
Unknown	2 (1.0)	0 (-)	
Total length[¶] of PICU care (days) [Ω]			
n (%)	191 (99.0)	243 (99.6)	
Mean (SD)	8.0 (13.0)	10.7 (12.2)	-1.2 (-1.5 to 7.6) [γ]
Median (IQR)	4.3 (2.1–9.3)	4.8 (2.4–9.7)	

*n=5 children with a confirmed diagnosis of COVID-19 had a previous influenza admission to PICU in 2019 and so were excluded from the COVID-19 cohort prior to analysis.

Abbreviations: CI = confidence interval; SD= standard deviation; IQR = interquartile range; PIM3 POD %= paediatric index of mortality 3 predicted probability of death; PICU = paediatric intensive care unit;

γ: obtained from two sample independent t-test assuming unequal variances; α obtained from two sample test of proportions;

τ obtained from two sample independent t-test assuming equal variances;

ϕ no difference or confidence intervals presented due to the differential proportions of missing data;

λ no statistical testing conducted due to difference in completion styles of comorbidities between units.

†† comorbidities not mutually exclusive;

‡ Neurological/developmental including epilepsy, cerebral palsy;

**metabolic/endocrine including diabetes;

† malignancy including leukaemia, lymphoma, solid tumours;

β other including autism and attention deficit hyperactive disorder

¶ where a child had multiple admission events the number of days is summed across all events;

ϕ where a child had multiple admission events, the status from the last recorded admission is presented;

δ difference calculated based on proportion of children surviving PICU;

Ω for completed PICU admissions

- Compared with the influenza cohort, children in the COVID-19 only cohort were:
  - older at admission (median [IQR]: 9 [1–13] years vs 3 [1–8] years);

- similar in terms of sex and total duration of PICU care;
- less sick on presentation to PICU based on PIM3 predicted mortality risk at admission;
- less likely to be admitted to PICU as an unplanned admission (91% vs 97%);
- from more deprived areas.

- In addition, there were notably higher proportions of children of Black and Asian ethnicity (n=85, 44%) in the COVID-19 only cohort compared to the influenza cohort (n=43, 18%), although one-fifth of the influenza cohort had missing ethnicity data compared with only 3% of the COVID-19 only cohort.
- There was a considerable difference in the distribution of weight z-scores between the COVID-19 only and influenza cohorts; the COVID-19 only cohort had a median z-score of 0.2, compared to -0.4 for the influenza cohort. This is suggestive of the COVID-19 only children being heavier.

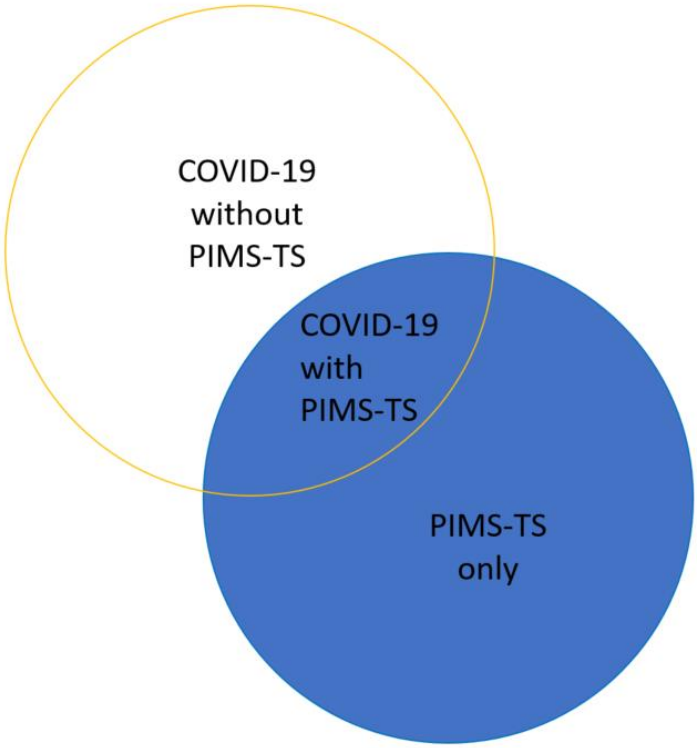
3.2 PIMS-TS cohort

3.2.1 Analysis population

This final section examines children who presented with PIMS-TS regardless of whether they had been confirmed COVID-19 positive or not (Figure 4).

A child was defined to have PIMS-TS based on clinical judgement.

Figure 4: PIMS-TS cohort



3.2.2 Overview of PIMS-TS cohort

- There were **459 PICU admissions for 444 children** (<18 years) where a child was admitted with PIMS-TS. As in Figure 4 above, this includes children presenting with and without COVID-19.
- Figure 5 presents the number of weekly admissions to UK PICUs for children with PIMS-TS where date of admission is between 14 March 2020 and 19 July 2021.
- 83 of the 444 children had confirmed COVID-19 (i.e. SARS-CoV-2 PCR positive) in addition to a PIMS-TS diagnosis (19%) whilst the remaining 361 children (81%) had PIMS-TS with no confirmation of COVID-19 recorded.
- Almost 60% of children (n=255, **57%**) presenting with **PIMS-TS** were admitted to PICUs in London, with a further **39%** (n=175) admitted to PICUs in the rest of England, whilst the remaining **3%** (n=14) of children were admitted to PICUs in the devolved UK nations.
- **26 of 30 PICUs** had at least one child admitted with PIMS-TS.

3.2.3 Patient characteristics

Table 3 compares the characteristics of the 444 children in the PIMS-TS cohort.

- The median age of children in the PIMS-TS cohort when first admitted to PICU was 9 years (IQR: 6 to 13 years). 75% of children were aged 6 years and above.
- Around **60%** of the children were **male**.
- **34% were White**, **one quarter were Asian (25%)** and just over one fifth were **Black (22%)**. Data on ethnicity were **unavailable** for 9% of children in the PIMS-TS cohort.
- **Just under 50%** of children were admitted to PICU **for endocrine or metabolic conditions** with a further 33% for neurological problems and 14% for infection or respiratory conditions.
- **Almost all** of the initial admissions for these children **(n=439, 99%)** were **unplanned admissions** to PICU (where the admission was not expected and therefore an emergency admission).
- **Comorbidities** in the PIMS-TS cohort were recorded **infrequently**; the most common types of comorbidities were neurological/developmental (5%) and congenital heart/cardiac disease (4%).

Figure 5: Number of admissions to UK PICUs by week of admission for children with Paediatric Multisystem Inflammatory Syndrome (PIMS-TS)

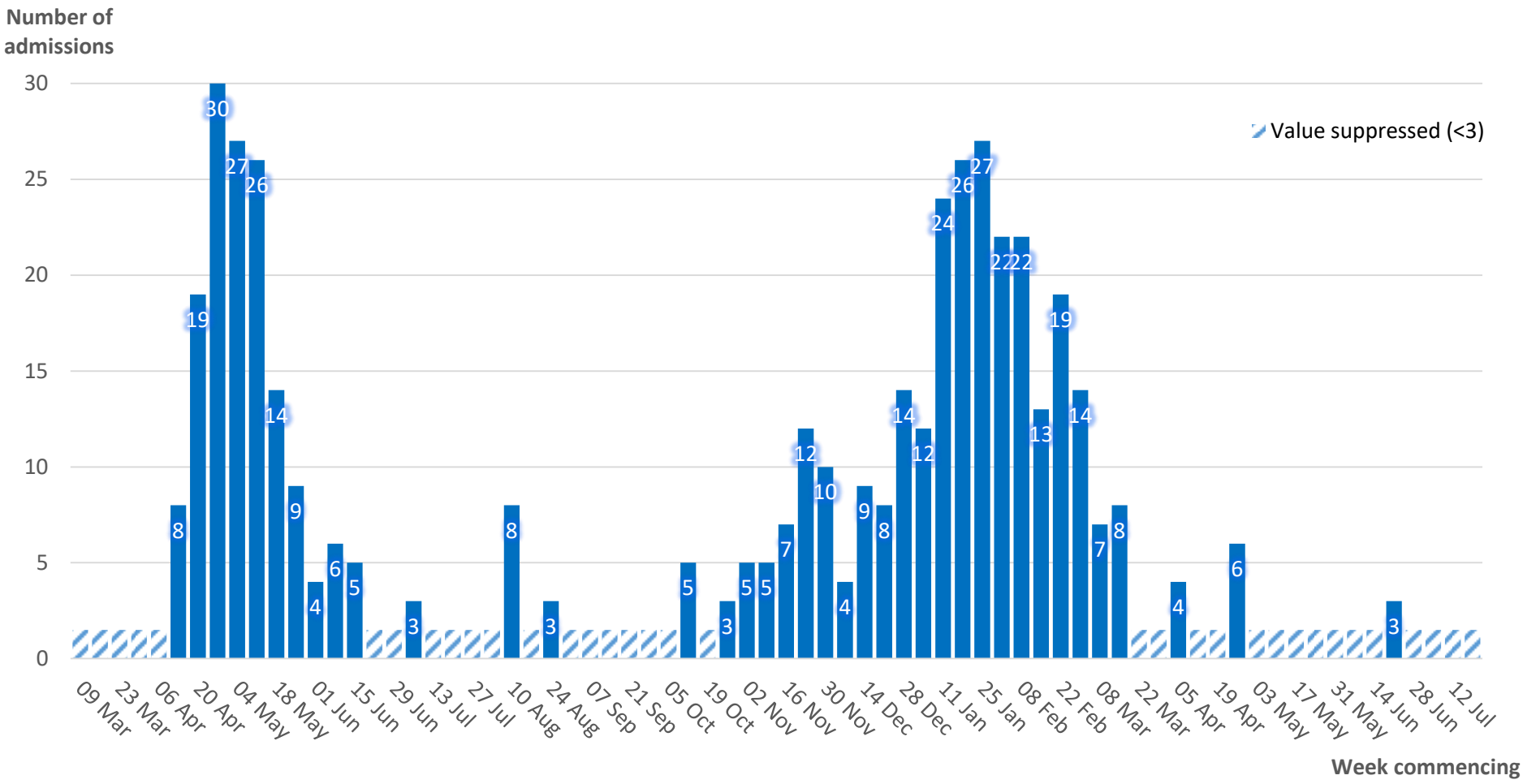


Table 3: Patient and clinical characteristics and treatments for all children (<18 years) treated in a paediatric intensive care unit (PICU) in the United Kingdom (UK) presenting with Paediatric Multisystem Inflammatory Syndrome (PIMS-TS) phenotype (n=444)

	PIMS-TS cohort n=444
Age group at first PICU admission, n (%)	
Neonate <30 days	0 (-)
Infant 31–365 days	10 (2.3)
Young child 1y–5y	100 (22.5)
Older child 6–12y	130 (51.8)
Teenager 13–18y	104 (23.4)
Male, n (%)	264 (59.5)
Ethnicity, n (%)	
White	149 (33.6)
Asian	113 (25.5)
Black	98 (22.1)
Other	19 (4.3)
Mixed	24 (5.4)
Unknown	41 (9.2)
Weight z-score	
n (%)	436 (98.2)
Mean (SD)	0.6 (2.6)
Median (IQR)	0.7 (-0.2–1.6)
Townsend deprivation index score	
n (%)	436 (98.2)
Mean (SD)	2.7 (3.8)
Median (IQR)	2.8 (-0.4–5.9)
Unplanned admission, n (%)	439 (98.9)
Admitted from, n (%)	
Same hospital	130 (29.3)
Other hospital	314 (70.7)
Comorbidity††, n (%)	
Neurological/Developmental≠	20 (4.5)
Congenital Heart/Cardiac Disease	15 (3.6)
Inherited genetic/chromosomal abnormalities	<3 (<0.5)
Pre-term	<3 (<0.5)
Malignancy†	<3 (<0.5)
Chronic Pulmonary Disease	0 (-)
Metabolic/Endocrine**	<3 (<0.5)
Otherβ	6 (1.4)
No recorded co-morbidities	405 (91.2)
PIM3 POD %	
Mean (SD)	3.0 (3.1)
Median (IQR)	1.8 (1.4–3.8)

Respiratory support		
Days‡ of respiratory support in PICU		
	n (%)	141 (31.8)
	Mean (SD)	5.5 (13.4)
	Median (IQR)	3.0 (2.0–5.0)
Maximum respiratory support ‡, n (%)		
	High frequency invasive ventilation	3 (0.7)
	Invasive ventilation	87 (19.6)
	Non-invasive ventilation	18 (4.1)
	HFNCT	41 (9.2)
	None	295 (66.2)
Invasive ventilation		
Days‡ of invasive ventilation in PICU		
	n (%)	87 19.6)
	Mean (SD)	7.0 (16.5)
	Median (IQR)	4.0 (3.0–6.0)
Vasoactive support		
Days‡ of vasoactive support in PICU		
	n (%)	325 (73.2)
	Mean (SD)	3.2 (2.5)
	Median (IQR)	3.0 (2.0–4.0)
Inhaled nitric oxide‡, n (%)		4 (0.9)
Renal replacement therapy‡, n (%)		7 (1.6)
Extracorporeal life support‡, n (%)		<3 (<0.5)
Outcome, n (%)		
	Discharged alive	440 (99.0)
	Died in PICU	<3 (<0.5)
	Unknown	2 (0.5)
Total length λ of PICU care (days)*		
	n (%)	442 (99.5)
	Mean (SD)	3.7 (8.2)
	Median (IQR)	2.5 (1.2–4.0)

Abbreviations: PIMS-TS = Paediatric multisystem inflammatory syndrome temporally associated with COVID-19; IQR = interquartile range; PIM3 POD = Paediatric Index of Mortality 3 predicted probability of death; HFNCT = high flow nasal cannula therapy.

†† not mutually exclusive;

≠ Neurological/developmental including epilepsy, cerebral palsy;

**Metabolic/endocrine including diabetes;

† malignancy including leukaemia, lymphoma, solid tumours;

β other including autism and attention deficit hyperactivity disorder

‡ where a child had multiple admission events the number of days is summed across all events for calculations;

λ where a child had multiple admission events the status from the last recorded admission is presented;

* for completed PICU admissions.

3.2.4 Management and outcomes

Table 3 displays information on interventions given during the child's first PICU care episode (n=444).

- **Respiratory support** was required in just under **one-third** of children (n=141, 32%).
- **One-fifth** required the highest level of invasive ventilation (n=90, 20%) for a median of 4 days (IQR: 3–6 days).
- Nearly three-quarters of children received vasoactive support (73%) for a median of 3 days (IQR: 2–4 days).
- Very small numbers of children received inhaled nitric oxide, renal replacement therapy and extracorporeal membrane oxygenation (ECMO).
- The median **length of PICU stay** was **2.5 days** (IQR: 1–4 days).
- **Less than three children died whilst on PICU (<1%)**.

3.2.5 Comparison with COVID-19 only cohort

Differences in terms of both patient characteristics, management and outcomes of the COVID-19 only cohort when compared with the PIMS-TS cohort are detailed in this section.

- In both cohorts, **children were of a similar average age** (median 9 years) but the **PIMS-TS** cohort had a much **smaller interquartile range** than the COVID-19 only cohort (IQR of 6–13 years compared with 1–13 years).
- Both groups were made up of a **similar proportion of males** (approximately 60%).
- COVID-19 and PIMS-TS cohorts had a **similar proportion of Asian children** (around one-quarter) whereas the **PIMS-TS cohort** had a **higher proportion of Black children** (22% vs 17%) and a **lower proportion of White children** (34% vs 43%) than the COVID-19 only cohort.
- In the **PIMS-TS** cohort, **99%** of first PICU admissions were **unplanned compared with 91%** in the COVID-19 only cohort.
- **Much higher proportions of neurological/developmental and congenital heart/cardiac disease comorbidities were observed in the COVID-19 only cohort** than the PIMS-TS cohort (23% vs 5%, and 12% vs 4% respectively).
- **Respiratory support** was required by just under **one-third** of the **PIMS-TS** cohort compared with **71%** of the **COVID-19 only cohort**. On average, respiratory support was **required for slightly longer in the COVID-19 group** compared with the PIMS-TS group (4.5 days vs 3.0 days).
- **Invasive ventilation** was also **required by fewer children in the PIMS-TS cohort** than the COVID-19 cohort (20% vs 53%) and these children had invasive ventilation for a median of 4 days compared with 5 days.
- **Vasoactive support** was provided in **nearly three-quarters of PIMS-TS cases** compared with **just under one-third of COVID-19 only** cases. Both cohorts received vasoactive support for a median of 3 days.
- **Median length of stay** in the **COVID-19 only cohort** was **longer** than in the PIMS-TS cohort at approximately 4.5 days compared with 2.5 days.
- The **proportion of deaths on PICU** in the **COVID-19 only cohort was higher** at around 6% than the proportion in the PIMS-TS cohort (<1%).

4. Discussion

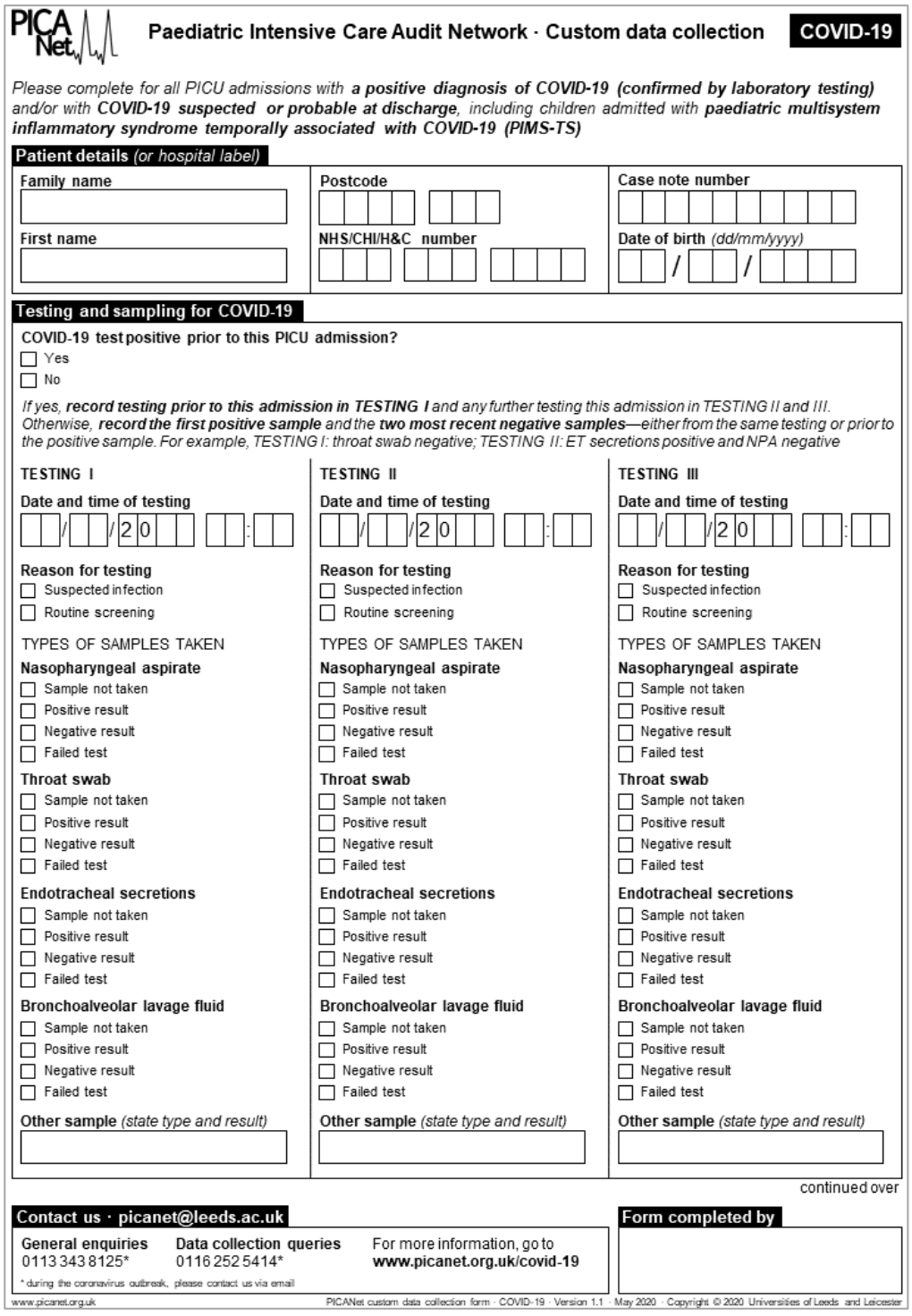
This report confirms that while the numbers and proportions of children affected with COVID-19 or related illness was small, its impact was significant. The impact of COVID-19 was disproportionately higher among children of Black and Asian ethnicities, children from deprived families and children of school age compared to overall PICU case-mix from previous years. The report highlights the importance of screening as an infection control measure as more than 20% of children were asymptomatic during PICU admission and were detected only on routine screening. Approximately 10% of children with COVID-19 had a viral co-infection reported in Phase-2 despite a reasonably 'quiet' season for viral illnesses. With seasonal and inter-seasonal resurgence of respiratory viruses forecast, clinicians must be vigilant to the possibility of children being affected by multiple pathogens.

Clear differences in characteristics between the COVID-19 and PIMS-TS patients are described. For instance, a large majority of children admitted with PIMS-TS had no recorded co-morbidities and were admitted predominantly for vasoactive support rather than respiratory support, in contrast with patients admitted with COVID-19. While the survival outcomes reported were good compared to reports from adult critical care units, sadly 10–15 children died during their PICU admission. Given we do not collect causes of death, we are unable to confirm whether, at least in some cases, children may have died of unrelated health conditions. Finally, this report is a testament to the commitment of all contributing PICUs who were able to report additional custom-audit data in a timely manner despite significant workforce and re-organisation related challenges.

5. Appendix

5.1 COVID-19 customised data collection form

A PICANet COVID-19 customised data collection form is completed for all admissions to PICU, for whom the diagnosis of COVID-19 was confirmed as positive by laboratory testing and; for those admissions who are COVID-19 suspected or probable after repeat negative testing, but clinicians agree that the clinical presentation is consistent with COVID-19 infection. This includes multi-system inflammatory syndrome exclusive of any other microbial cause (PIMS-TS).



PICA Net

Paediatric Intensive Care Audit Network · Custom data collection **COVID-19**

*Please complete for all PICU admissions with **a positive diagnosis of COVID-19 (confirmed by laboratory testing)** and/or with **COVID-19 suspected or probable at discharge**, including children admitted with **paediatric multisystem inflammatory syndrome temporally associated with COVID-19 (PIMS-TS)***

Patient details *(or hospital label)*

Family name | Postcode | Case note number

First name | NHS/CHI/H&C number | Date of birth *(dd/mm/yyyy)*

Testing and sampling for COVID-19

COVID-19 test positive prior to this PICU admission?

☐ Yes
☐ No

*If yes, **record testing prior to this admission in TESTING I** and any further testing this admission in TESTING II and III. Otherwise, **record the first positive sample** and the **two most recent negative samples**—either from the same testing or prior to the positive sample. For example, TESTING I: throat swab negative; TESTING II: ET secretions positive and NPA negative*

TESTING I	TESTING II	TESTING III
Date and time of testing / / 20 :	**Date and time of testing** / / 20 :	**Date and time of testing** / / 20 :
Reason for testing	**Reason for testing**	**Reason for testing**
☐ Suspected infection	☐ Suspected infection	☐ Suspected infection
☐ Routine screening	☐ Routine screening	☐ Routine screening
TYPES OF SAMPLES TAKEN	TYPES OF SAMPLES TAKEN	TYPES OF SAMPLES TAKEN
Nasopharyngeal aspirate	**Nasopharyngeal aspirate**	**Nasopharyngeal aspirate**
☐ Sample not taken	☐ Sample not taken	☐ Sample not taken
☐ Positive result	☐ Positive result	☐ Positive result
☐ Negative result	☐ Negative result	☐ Negative result
☐ Failed test	☐ Failed test	☐ Failed test
Throat swab	**Throat swab**	**Throat swab**
☐ Sample not taken	☐ Sample not taken	☐ Sample not taken
☐ Positive result	☐ Positive result	☐ Positive result
☐ Negative result	☐ Negative result	☐ Negative result
☐ Failed test	☐ Failed test	☐ Failed test
Endotracheal secretions	**Endotracheal secretions**	**Endotracheal secretions**
☐ Sample not taken	☐ Sample not taken	☐ Sample not taken
☐ Positive result	☐ Positive result	☐ Positive result
☐ Negative result	☐ Negative result	☐ Negative result
☐ Failed test	☐ Failed test	☐ Failed test
Bronchoalveolar lavage fluid	**Bronchoalveolar lavage fluid**	**Bronchoalveolar lavage fluid**
☐ Sample not taken	☐ Sample not taken	☐ Sample not taken
☐ Positive result	☐ Positive result	☐ Positive result
☐ Negative result	☐ Negative result	☐ Negative result
☐ Failed test	☐ Failed test	☐ Failed test
Other sample *(state type and result)*	**Other sample** *(state type and result)*	**Other sample** *(state type and result)*

continued over

Contact us · picanet@leeds.ac.uk

General enquiries 0113 343 8125*
Data collection queries 0116 252 5414*
For more information, go to **www.picanet.org.uk/covid-19**

* during the coronavirus outbreak, please contact us via email

Form completed by

www.picanet.org.uk PICANet custom data collection form · COVID-19 · Version 1.1 · May 2020 · Copyright © 2020 Universities of Leeds and Leicester

Laboratory markers at admission

☐ None of these laboratory markers were tested

C-reactive protein
☐☐☐ mg/L

Ferritin
☐☐☐☐ microg/L

Haemoglobin
☐☐☐ g/L

Lymphocyte count
☐☐.☐ x10^9/L

Neutrophil count
☐☐.☐ x10^9/L

Platelet count
☐☐☐☐ x10^9/L

Serum triglycerides
☐.☐ mmol/L

BNP
☐☐☐☐☐ pmol/L

NT-proBNP
☐☐☐☐☐ ng/L

Troponin I
☐☐☐☐ ng/L

D-dimer *(specify units, e.g. microg/mL FEU, microg/mL DDU)*
☐☐☐☐.☐☐ ☐☐☐☐☐☐☐☐☐☐

Symptoms

Identify all symptoms *(tick all that apply)*

☐ No symptoms
☐ Abdominal pain
☐ Anosmia
☐ Conjunctivitis
☐ Cough
☐ Diarrhoea
☐ Fever >37.8°C
☐ Rash
☐ Runny nose
☐ Shock
☐ Sore throat
☐ Other symptom *(specify)*

☐☐☐☐☐☐☐☐☐☐

Imaging this admission

Was an echocardiogram performed this admission?

☐ Yes
☐ No

If yes, complete this section; otherwise, go to the next section

Was there echocardiographic evidence of coronary artery aneurysm?

☐ Yes
☐ No

If yes, state date of first echocardiogram when aneurysms were detected

☐☐/☐☐/2☐☐

Was an echocardiogram performed that DID NOT detect evidence of coronary artery aneurysm?

☐ Yes
☐ No

If yes, state date of last echocardiogram when aneurysms were NOT detected

☐☐/☐☐/2☐☐

Coinfection

Other respiratory organisms identified by testing *(tick all that apply)*

☐ No other respiratory organisms
☐ Acinetobacter baumannii
☐ Adenovirus
☐ Citrobacter freundii
☐ Human metapneumovirus
☐ Influenza
☐ Klebsiella pneumoniae
☐ Mycoplasma pneumoniae
☐ Parainfluenza
☐ Pseudomonas aeruginosa
☐ Respiratory syncytial virus
☐ Rhinovirus
☐ Staphylococcus aureus
☐ Streptococcus pneumoniae
☐ Other respiratory organism *(specify)*

☐☐☐☐☐☐☐☐☐☐

Other infection *(specify organism and site)*

☐☐☐☐☐☐☐☐☐☐

Medication

Medication used *(tick all that apply)*

☐ No medication used

ANTIVIRALS
☐ Inhaled interferon beta-1a
☐ Lopinavir with ritonavir
☐ Oseltamivir
☐ Remdesivir

ANTIBIOTICS
☐ Azithromycin
☐ Ciprofloxacin
☐ Clarithromycin
☐ Co-amoxiclav
☐ Gentamicin
☐ Piperacillin with tazobactam

IMMUNE MODULATORS
☐ Anakinra
☐ Dexamethasone *(excluding for extubation)*
☐ Hydroxychloroquine
☐ Intravenous immunoglobulin
☐ Tocilizumab

OTHER
☐ Other medication *(specify)*

☐☐☐☐☐☐☐☐☐☐

Special Chapter 2: COVID-19 Staffing Survey

1 Introduction

Many articles have been written describing the effects of the coronavirus (COVID-19) on critical illness and specifically the relatively minimal impact on critical illness in children compared to adults, two examples pertaining to the UK are included [4, 15]. Data collected from the 31 PICUs covered by PICANet showed a reduction in all PICU admissions (18%), unplanned admissions (20%), planned admissions (15%), and bed days (25%). It is known that during the first wave of the COVID-19 pandemic there was a significant demand for adult intensive care beds. Remodelling of intensive care beds to meet the surge in adult critical care demand led to the utilisation of paediatric intensive care beds located within a paediatric intensive care unit (PICU) [16-19]. PICUs therefore as well as supporting this adult critical care expansion through loaning equipment and space, also repurposed themselves (staff included), to receive and care for adult patients. Sinha et al in 2021 [18], described the experiences of 7 PICUs who had repurposed to care for adult patients during the first wave of the COVID-19 pandemic. Through real time data collection PICANet were aware that there were more than seven PICUs providing this service, in a variety of ways, which also occurred during the latter half of 2020 and early 2021. In addition, children were being transported to other hospitals to free up adult critical care beds in PICUs. There was very little evidence of the skill mix of staff looking after adults in PICUs, and staff as well as child movement. This chapter considers the impact of the pandemic on paediatric intensive care units through a review of PICU activity including adult admissions, paediatric admissions, paediatric bed closures and the relocation of children. The impact on PICU staff in terms of staff relocation is also discussed.

1.1 Data collection

PICANet undertook an extra staffing survey in June 2021 and all 31 PICUs *responded* to the collection of data. They were asked to retrospectively relate PICU and staff activity over three time periods. These time periods were related to the timelines of the UK coronavirus lockdowns, March 2020 to March 2021 (Institute for Government Analysis, 2021)[19]. At the time of the survey there was some debate as to the evolvement of the actual number of COVID waves in the UK, and it is still unclear as to the start and end dates of the waves. The Office of National Statistics (ONS), in its publications refers to two waves, but dates of these vary according to publication, and indeed state that there is no clear definition when a wave starts and ends [20, 21]. Add in geographical variation in the transmission of the virus and the boundaries become even more blurred. It was decided to use the starting dates of the coronavirus lockdown as a reflection of a peak in the reproduction (R) number and positivity rate. The end of the time periods reflect the period of lockdown restrictions easing overall taking into account geographical differences that are less diverse than the pandemic waves. In addition PICUs that were affected in terms of adult admissions and staff relocation were asked to state the dates when this actually occurred in their unit. The time periods that were used were:

- First Period: 23 March to 30 June 2020
- Second Period : 5 November to 20 December 2020
- Third Period: 6 January to 30 April 2021

A series of questions were asked, repeated for each time period of the pandemic. These comprised:

- Bed occupancy on PICU, adult and paediatric, extra capacity, and bed closure
- Staffing, skill mix of staff looking after adult patients, and redeployment of staff by location, discipline, and grade
- Relocation of children

Data is presented from all 31 PICUs in England, Wales, Scotland, Northern Ireland and the Republic of Ireland, both NHS and private. Inclusion was based on the completion by a designated senior nurse or clinician of a Microsoft Forms survey sent and received electronically. All units that received the form responded (100% response rate).

2 Results

2.1 Bed occupancy in PICU

Table 4 shows the data illustrating the caseload for the different PICUs in respect of the number of the number of PICUs accepting adult and paediatric patients.

Table 4: Total number of beds open for adult and paediatric patients in PICU and as a percentage of the total of 31 PICUs

	1st period		2nd period		3rd period	
	Beds	PICUs	Beds	PICUs	Beds	PICUs
Open for adults	204	14 (45%)	40	6 (19%)	137	11 (35%)
Open for paediatrics	426	26 (84%)	472	31 (100%)	436	28 (90%)

A total of 16 different PICUs accepted adult patients and the data shows a variation over the three time periods in the number of adults admitted to those PICUs. The number of beds open to adult patients, and the number of PICUs accepting adults were at the highest in the first period (204) beds, and 14 (45%) PICUs, decreasing in the second period when 6 PICUs (19%) had 40 adult beds open, and an increase in the third period when 11 PICUs (35%), provided 137 adult beds.

Next, the survey looked at whether the PICUs accepted only adult patients, a mixture of adults and paediatrics or just continued to accept paediatric patients only. This is not a reflection of the individual PICUs but rather organisational decisions regarding geographical location, number of beds, and consideration of continuing non elective work [16, 17].

The case mix for the all the PICUs are shown in Table 5.

Table 5: Case mix for all PICUs over the three time periods

	1st period	2nd period	3rd period
Adults only	5	0	3
Adults and Paediatrics	10	6	10
Paediatrics only	16	25	18
Total	**31**	**31**	**31**

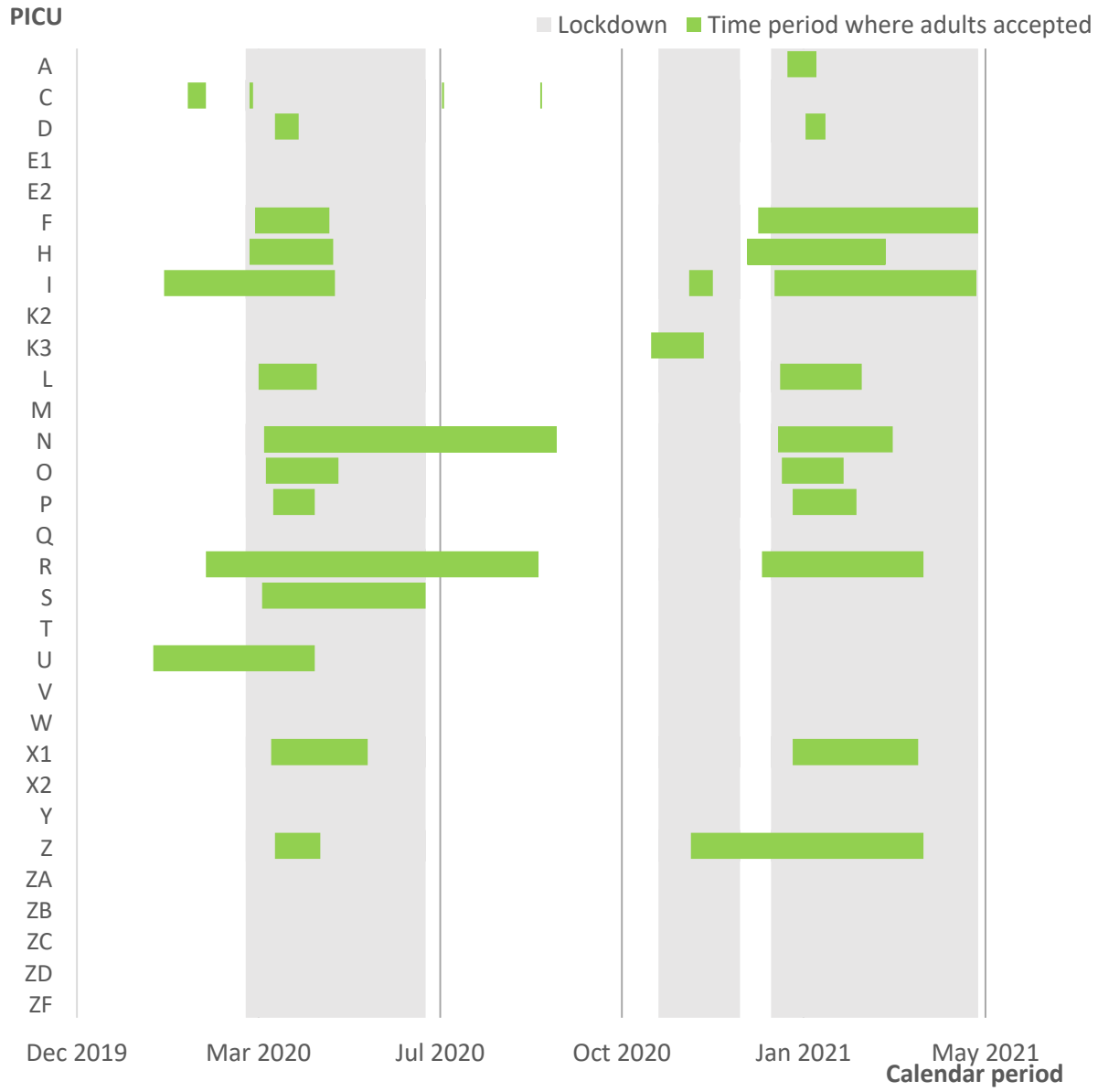
During the first time period five out of the 15 PICUs (33%) that accepted adult patients, were only open for adults. During the second period no PICUs were only open to adults. During

the third time period, 3 out of 12 (25%) PICUs that were accepting adult patients were adult only, compared to 33% in the first period.

2.1.1 Adult bed occupancy in PICU

Table 4 illustrated the variation in adult and paediatric activity in PICU over the three time periods. Figure 6 shows the time variation of admission to PICUs of adult from the times documented by PICUs in the survey as to the start and end dates of having adult patients. The earliest date recorded of receiving adult patients was the 7 February 2020 and the last date recorded was the 29 April 2021.

Figure 6: Time line of adult patients admitted to PICUs



Most of the activity featuring adult patients occurred in the first and third time periods with very few PICUs (three) accepting adults in the second lockdown time period. Four PICUs accepted adult patients before the first lockdown period, and three PICUs accepted adult patients beyond the first lockdown period. Similarly three PICUs accepted adult patients before the third lockdown period, and one PICU accepted adult patients extending through the second and third lockdown period without a break, reflecting the ongoing peak in adult activity from December 2020. Reviewing workforce models in December 2020, NHS England and NHS Improvement supported Trusts in maintaining both acute and elective paediatric

services with various staff and resource initiatives [22]. There was a focus on empowering acute adult wards with training and resources to care for severely unwell adult COVID-19 patients, proven therapeutics, and early detection and care in the community, thus reducing ICU and PICU burden. It is difficult to estimate how far these initiatives affected the numbers of PICUs accepting adults, but there was certainly less demand in the second wave, although there was an increase in the third wave.

The survey then considered the burden on paediatric activity with the demand for adult intensive care beds.

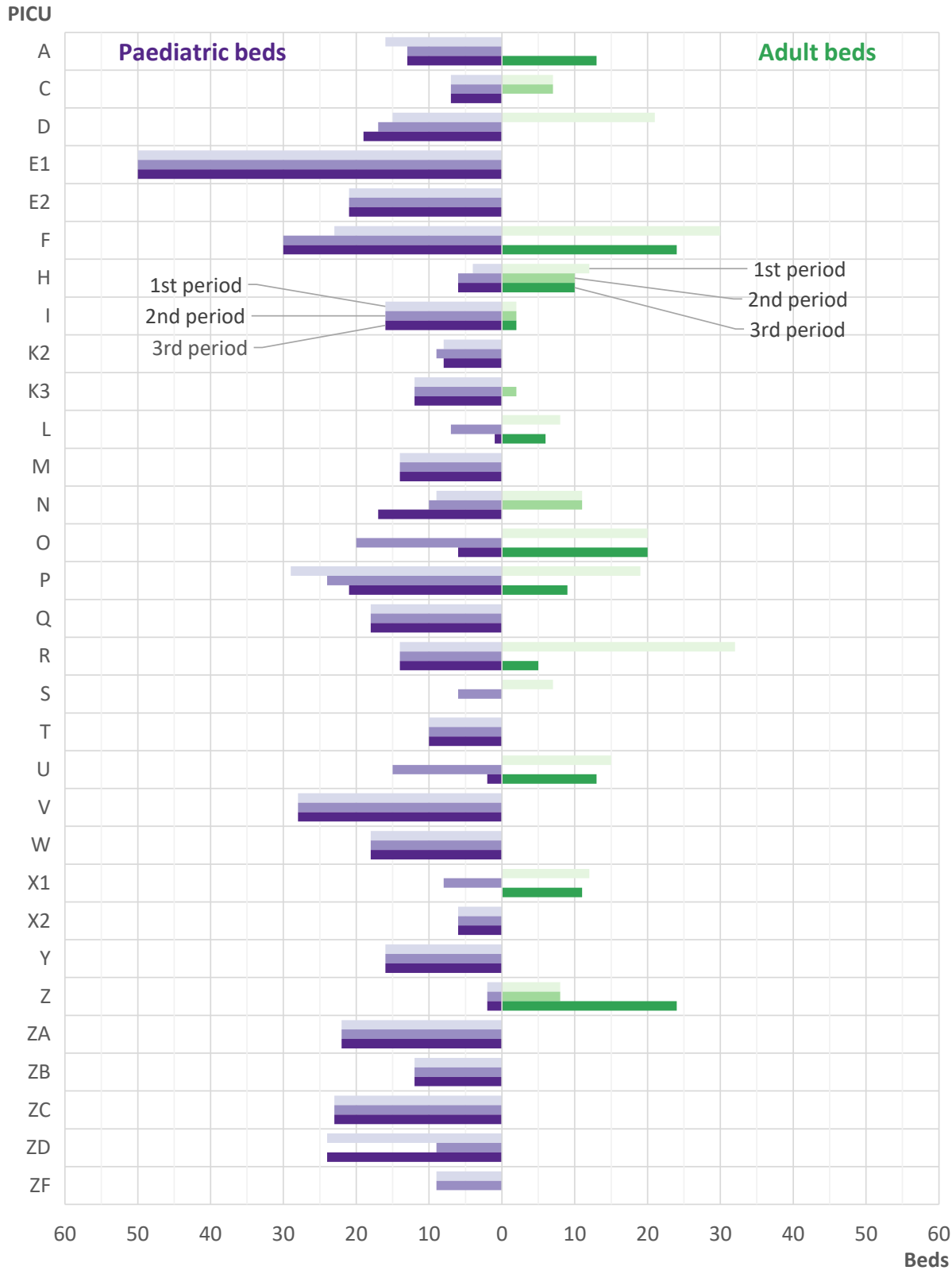
2.1.2 Paediatric activity in PICU

The number of paediatric beds open was then surveyed in response to admission of adult patients. Table 4 showed that out of 31 PICUs participating in the survey 17 had no change to paediatric bed occupancy over the three time periods (55%). Of the 45% remaining PICUs two had more paediatric beds occupied in the first period than in both the second and the third.

Three PICUs had an increasing number of beds open from the first to the third time period, and one PICU had less beds open in the second period although they were not open to adult patients. The number of PICUs open for paediatrics showed a decrease in the second period, with an increase in the third period and more PICUs open for paediatrics than both periods.

Figure 7 shows in more detail the variation of both paediatric bed activity over the three time periods by organisation matched against the number of adult beds open within the same unit (where relevant), to place context of paediatric bed activity during these periods.

Figure 7: The number of paediatric and adult beds open by period and PICU



For the first time period for 9 PICUs (D, F, H, L, N, O, S, U, and X), adult activity corresponds to a decrease in paediatric activity. The second period of adult activity on PICUs, of which there were only 5 PICUs, had little or no impact on paediatric bed activity. In the third time period, of the 11 PICUs reporting adult admissions, five PICUs had a corresponding decrease in PICU admissions. One PICU (R), showed no increase or decrease in PICU activity despite adult admissions.

The survey then looked at whether extra beds had been opened on units in order to meet increased demand (Table 6).

Table 6: The number of adult, paediatric, and extra beds open during the three time periods

	1st period		2nd period		3rd period	
	Beds	PICUs	Beds	PICUs	Beds	PICUs
Open for adults	204	14 (45%)	40	6 (19%)	137	11 (35%)
Open for Paediatrics	426	26 (84%)	472	31 (100%)	436	28 (90%)
Extra beds opened	172	13 (42%)	34	3 (9%)	146	7 (22%)
Total of open beds	**802**		**546**		**719**	

Regarding extra capacity beds this showed an overall downward trend from 172 in the first time period, a steep drop in the second time period by 66% to 34, but an increase in the third period to 146, which was also 22% less than those initially opened in the first period. Demand was still high in the third period although less than the first period, but considerably higher than the second period

The data obtained from the survey was then compared to the number of funded paediatric beds on each unit for each wave (Figure 8).

Figure 8: Paediatric and adult beds open as a proportion of funded beds by PICU and period.

In the first period 17 PICUs exceeded 100% of funded beds, with 4 PICUs reaching equal to or greater than 200% (F, P, R, and ZD). Of these four it is to be noted that three (75%) capacity comprised of a mixture of adult and paediatric patients, whereas ZD exceeded 200% capacity with only paediatric patients, and had created extra capacity only for paediatric patients. One PICU (R) exceeded 300% capacity. In the second period even though there was less adult bed activity nine PICUs were over 100% of their funded activity, most notably E1, where regional paediatrics patients were taken as part of remodelling of paediatric critical care in the region (this regional bed activity was also shown in the first and third period). In the third period 13 PICUs had exceeded the 100% capacity whilst 4 PICUs had reached or exceeded 200% capacity.

Creating extra capacity, and opening PICU beds to adults may have had an impact on the closure of paediatric beds. PICANet data for 2020 shows that there was an overall reduction

by 20% of PICU admissions of both elective and emergency admissions. Consideration then also needed to be given as to whether there were paediatric bed closures during the three time periods (Table 7).

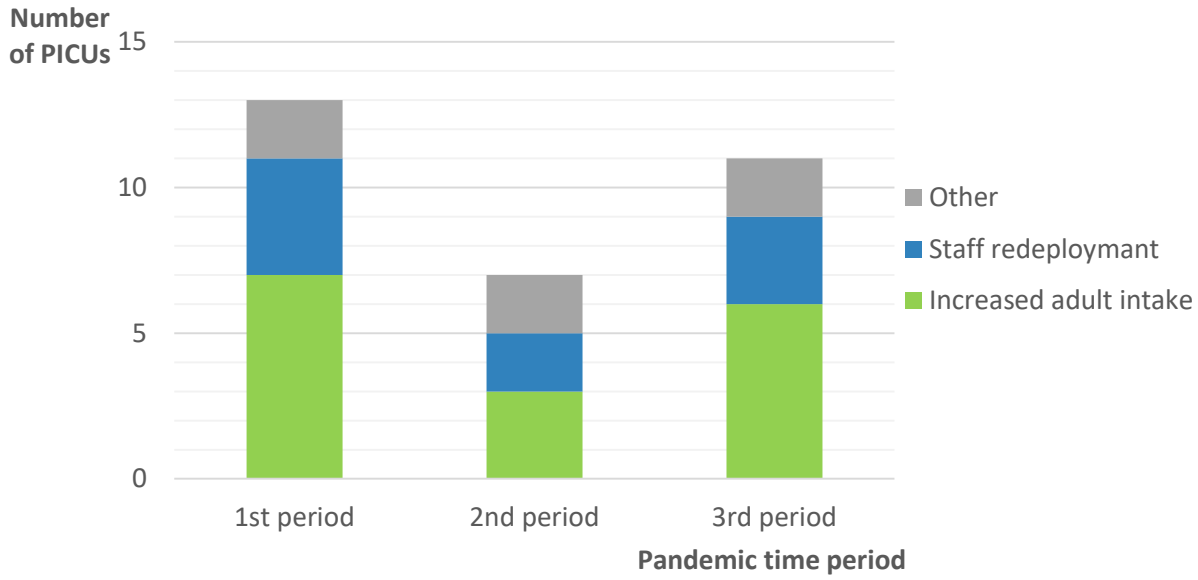
Table 7: The number of paediatric beds closed by the number of PICUs per period

	1st period		2nd period		3rd period	
	Beds	PICUs	Beds	PICUs	Beds	PICUs
Paediatric beds closed	82	9	30	5	57	7
Total number of open beds	802		546		713	

From this, it can be seen that the highest number of paediatric beds closed occurred in the first period, where 10% of the total beds open within PICU sites were closed to paediatric patients. During the second period this dropped to 5% of the total beds open and in the third period 8% of the total beds open were closed to paediatric admissions. As with all PICUs that were open to adults and paediatrics there are variations between units.

Of those units that had paediatric beds closed the rationale was increased adult intake (7 PICUs stated this over the different waves), staff redeployment (5 PICUs cited this), and 2 PICUs gave staffing issues as 'other' reason for paediatric bed closure. On further exploration this referred to staffing issues such as sickness, staff shielding, staff vacancies, and maternity leave.

Figure 9: Rationale for bed closure by number of PICUs and by periods



The survey then looked at issues surrounding staffing, firstly the nursing staff that cared for the adult patients, representing those that delivered the day-to-day care for adult patients, and secondly whether staff were relocated, and if so by discipline and grade, and thirdly the location where the staff were deployed.

2.2 Staffing

2.2.1 Staffing in the PICU

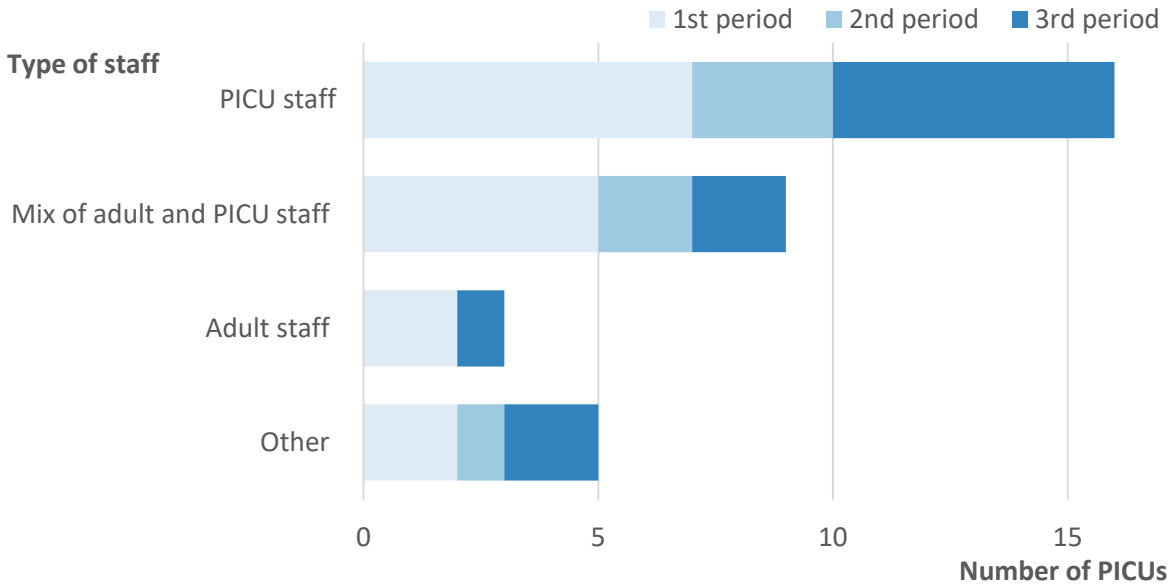
The question was asked as to who delivered the nursing care to these adult patients, whether it was adult trained staff, paediatric trained staff, or a mixture of both (Table 8 & Figure 8).

Table 8: Type of staff caring for adult patients in PICU by time period

	1st period	2nd period	3rd period
PICU staff only	7	3	6
Adult and paediatric staff	5	2	2
Adult staff only	2	0	1
Other	2	1	2

There was a predominance of PICU only staff during all three periods in relation to other combinations of staff. During the first time period there was also a larger mixture of adult and paediatric staff together than in the next two periods. Two PICUs only had adult staff caring for patients in the first period and one PICU in the second period. Recruitment of 'other' staff, occurred more in the first and third period. This group of staff were documented in the free text as, non PICU children's nurses, non-adult ICU nurses, theatre nursing staff, and staff from the Burns Unit.

Figure 10: Type of staff caring for adult patients in PICU by time period

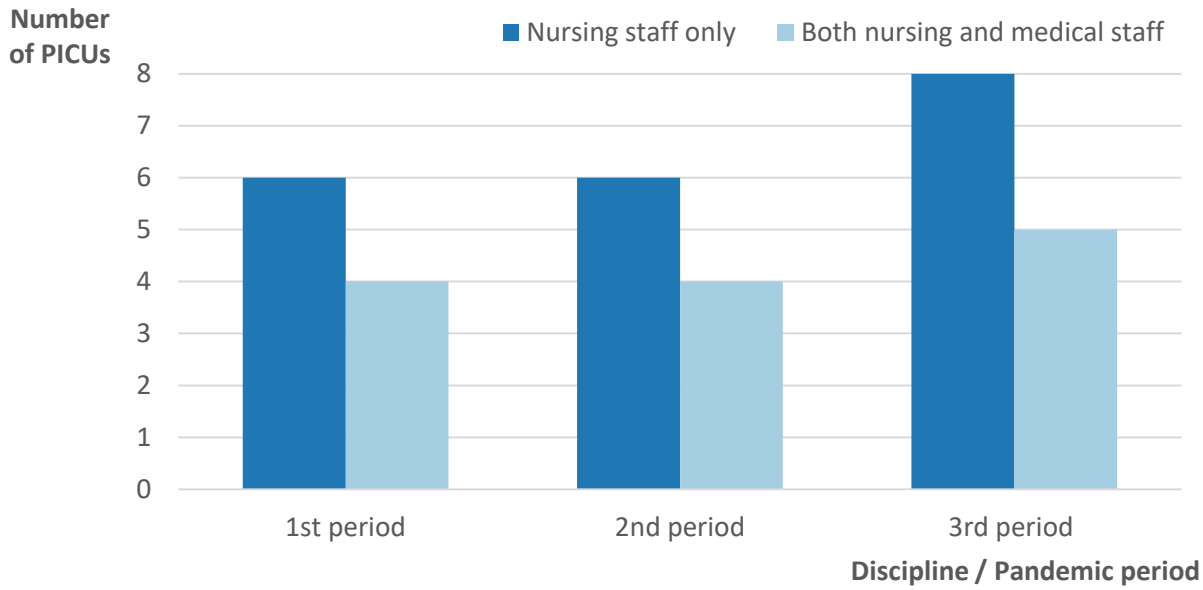


2.2.2 Relocation of staff

During the three lockdown periods of the pandemic both nursing and medical staff were redeployed to other areas. In the first period 17 PICUs (55%) had staff that were relocated or redeployed, this dropped to 10 PICUs (32%) in the second period and rose to 13 PICUs (42%) by the third period.

Overall through the three time periods both medical and nursing staff were relocated (Figure 11

Figure 11: Relocation by discipline



What was shown was the nursing staff were involved in redeployments more frequently than medical staff. In the first period 6 PICUs (20%), sent only nursing staff to other areas, whilst 4 PICUs (13%), sent a mixture of both nursing and medical staff. These figures were exactly the same for the second period, despite PICU bed capacity being reduced. In the third period 8 PICUs (26%), redeployed only nursing staff, whilst 5 PICUs (16%), sent nursing and medical staff. Overall more staff were redeployed during the third period than the first or second. No PICUs sent only medical staff.

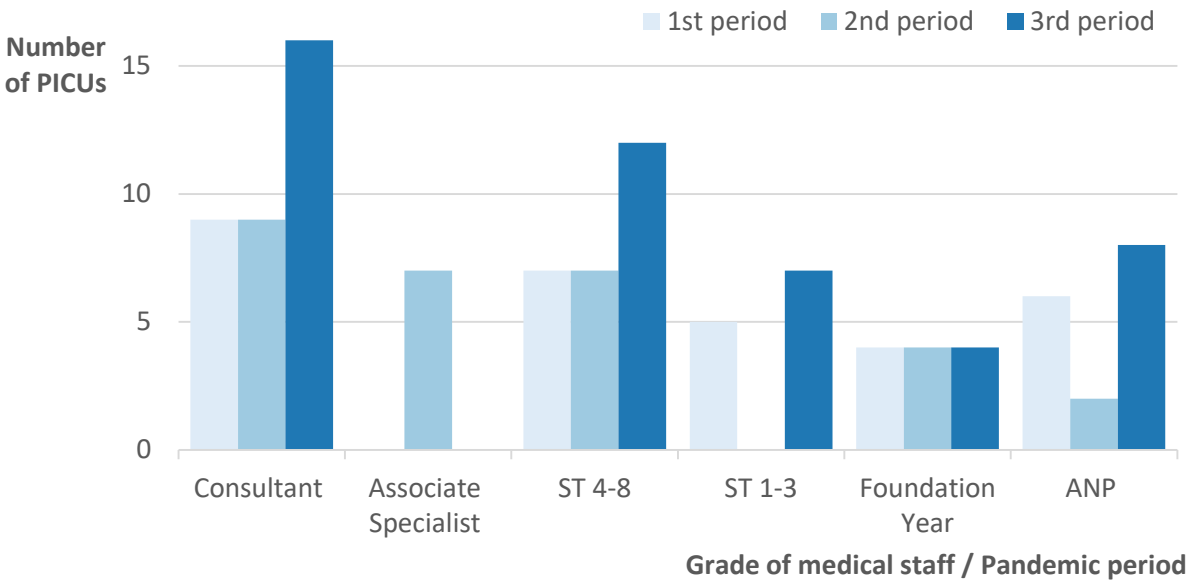
2.2.2.1 Relocation of medical staff

With regard to redeployment of staff, for those PICUs who did not accept adult patients the majority did redeploy their staff to adult ICUs, mainly within their own hospital but for two PICUs it was to adult ICUs external to their Trust. The grades of both medical and nursing staff redeployed were reviewed and Table 9 shows the grade of medical staff relocated. Advanced Nurse Practitioners (ANP), who were on the medical establishment were included in the staffing figures (Table 9 and Figure 12).

Table 9: Grade of medical staff redeployed over the three time periods

Medical grade	1st period	2nd period	3rd period
Consultant	9 (29%)	9 (32%)	16 (34%)
Associate Specialist	0	7 (24%)	0
ST 4–8	7 (23%)	7 (24%)	12 (26%)
ST 1–3	5 (16%)	0	7 (15%)
Foundation Year	4 (13%)	4 (13%)	4 (8%)
ANP	6 (19%)	2 (7%)	8 (17%)
Total	31	29	47

Figure 12: Grade of medical staff redeployed over the three time periods



As can be seen, the Consultant medical staff were redeployed the most frequently in all three periods, rising from 29% in the first period to 32%, and then 34% in the third period. ST 4–8 redeployment follows a similar pattern and were the next highest group to be redeployed, with 23% in the first period, followed by a slight increase to 24%, rising to 26% in the third period.

ANPs were also redeployed with the highest number of ANPs in the third period, a third less in the second period and just 7% (2) in the third.

ST 1–3 were redeployed in the first and third period only, whilst Foundation Year medical staff were redeployed in all three periods. Associate specialist medical staff were only redeployed in the third period.

2.2.2.2 Relocation of nursing staff

The nursing grades of staff relocated were then reviewed (Table 10), this included healthcare assistants who delivered clinical care.

Table 10: Grades of nursing staff and healthcare assistants redeployed over the three time periods

Grade of Nurse	1st period	2nd period	3rd period
Band 8	6 (3%)	2 (2%)	6 (4%)
Band 7	37 (21%)	19 (20%)	33 (22%)
Band 6	46 (26%)	28 (29%)	41 (28%)
Band 5	64 (37%)	42 (44%)	46 (31%)
Band 4	0	0	6 (4%)
Band 3	10 (6%)	0	6 (4%)
Band 2	11 (7%)	5 (5%)	11 (7%)
Total	174	96	149

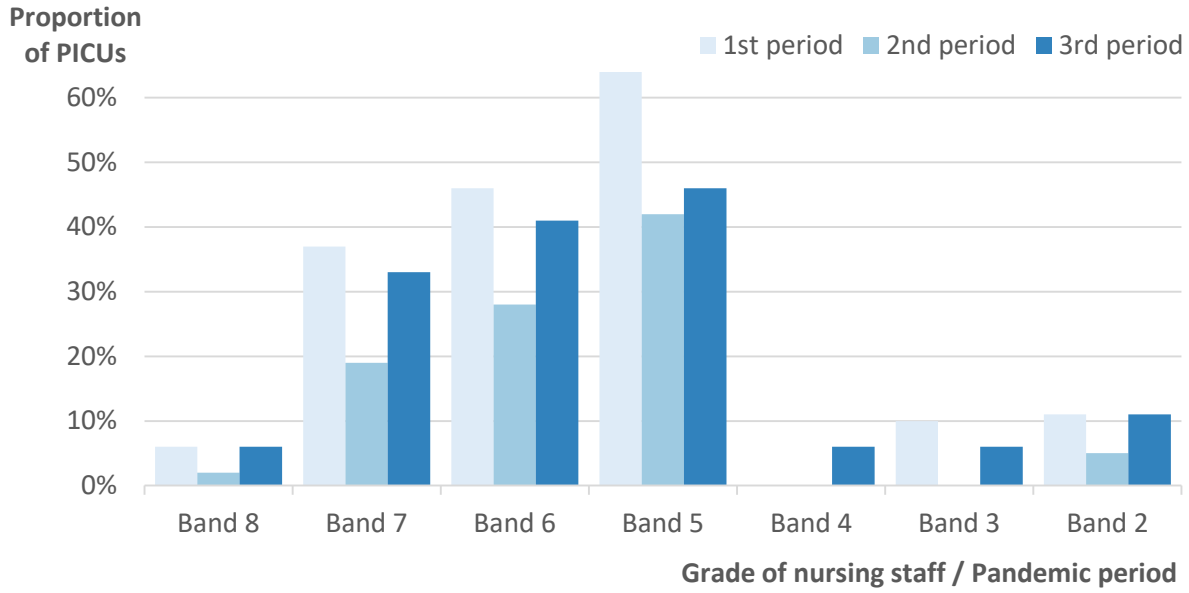
During the first period Band 5 nursing staff were the highest group of the total workforce to be redeployed at 37%, followed by Band 6 at 26%, then Band 7 at 21%. Bands 2 and 3 were next at 7% and 6%, with the lowest percentage being redeployed were those at Band 8 (3%).

In the second period again the highest proportion by Band of nursing grade were those of Band 5 at 44%, then Band 6 at 29%, followed by Band 7 at 20%. There was less redeployment in this period for Band 2, and Band 8, with no Band 3 being redeployed.

The third period follows the same pattern with the highest proportion of nursing being redeployed at Band 5 (31%), followed by Band 6 at 28%, Band 7 at 22%, Band 2 at 7% and Bands 8, 4, and 3 at 4% of the total workforce being deployed.

This emphasis on Band 5 redeployment is also shown in the percentage of PICUs that redeployed nursing staff by grade shown in Figure 13.

Figure 13: Grade of nursing staff and healthcare assistants redeployed over the three time periods



2.2.2.3 Location of staff redeployment

Where staff had been redeployed the units were asked to indicate where the staff had moved to for each time period (Table 11).

Table 11: Location of staff redeployed

Location	1st period	2nd period	3rd period
Adult ICU	16 (52%)	9 (29%)	12 (39%)
Children's Ward	4 (13%)	1 (3%)	2 (6%)
Other PICU within the same Trust	1 (3%)	0	1 (3%)

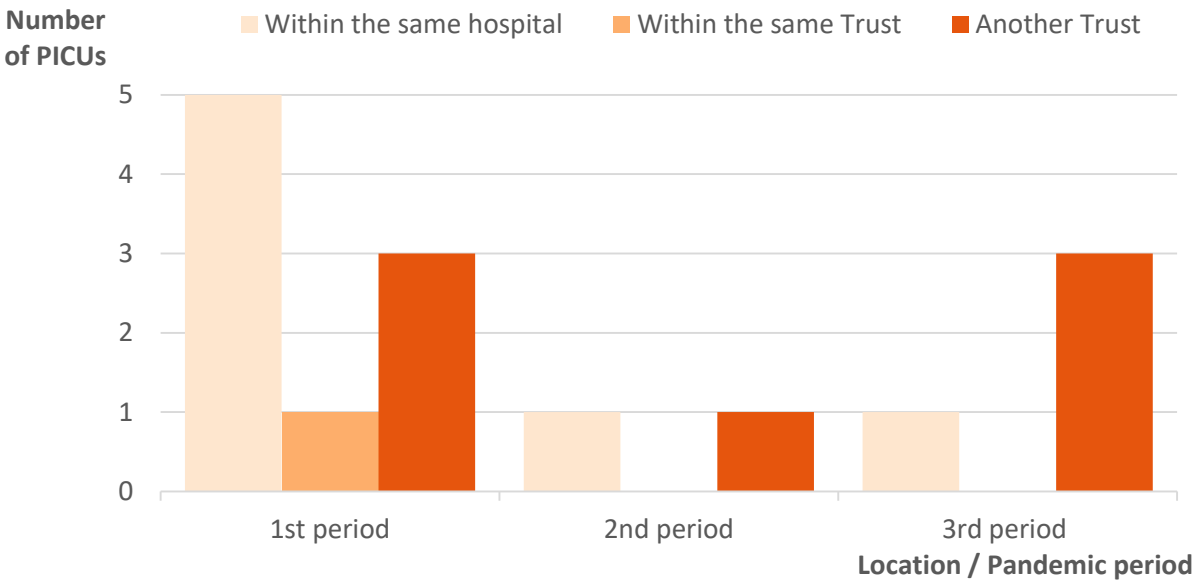
For all three time periods the majority of staff were sent to Adult Intensive Care. The number of PICUs relocating staff was at its highest in the first period, decreasing in the second period and rising again in the third period, although not at the same levels as the first period. A small number of PICUs sent staff to the Children's wards during the three time periods, only one PICU sent staff to another PICU located within the same Trust.

The survey then looked at the relocation of children from PICU.

2.3 Relocation of children

The PICUs were asked whether their children were relocated, and if pertinent whether this was within their own hospital, within the same Trust, or moved to a location within another Trust, over the three time periods (Figure 14).

Figure 14: Location of child moved during the three time periods



Overall, there appears to be less movement of children during the second and third periods. Five PICUs in the first period relocated their children within the same hospital, to their HDU where possible, or to reconfigured children's wards. Those relocated within the same Trust utilised children's wards within the organisation, whilst the few PICUs that transferred children outside the Trust were documented as going to Birmingham Children's Hospital and Great Ormond Street Hospital.

3. Summary of findings and discussion

3.1 Bed occupancy in PICU

Between 7 February 2020 and 29 April 2021, 16 out of 31 PICUs accepted adult patients with variation over the three time periods. The highest number occurred in the first period (45%), the next highest in the third period (35%), and the lowest in the second time period. This pattern of lower demand during the second time period also featured in the PICUs who had only adult patients (16%, 0, 10%), although those units receiving both adult and paediatric patients showed the same demand for both the first and the third period (32%). The number of PICUs receiving only paediatric patients for the three time periods (52%, 80% and 58%), reflects not only the demand for adult bed occupancy (48%, 20%, and 42%), but also the fluctuations in demand for adult beds over the three time periods. Extra bed capacity was created during this period, again reflecting demand with 102 beds in the first period, 34 in the second and 146 in the third time period, and this was also demonstrated in the percentage of PICUs exceeding 100% funded capacity.

In March 2020, the Paediatric Intensive Care Society (PICS) and PICANet proposed a modelling of minimum paediatric intensive care capacity required for predicted demand for adult critical care during the COVID-19 pandemic [16]. This included PICUs being prepared to reduce their bed base to accept adult critical care patients. Figure 6 showed the distribution over time of PICUs accepting adult patients over the three time periods. Inherent

in this modelling though was also the caveat that some PICU beds remained open for elective and paediatric surgical cases where a delay may impact on the child's potential outcome and ultimately become an emergency admission. Therefore there is variation inherent in the number of PICUs able to offer adult critical care capacity, with some able to offer adult beds only, other PICUs accepting adults but maintaining some PIC activity, and those stand-alone children's hospitals who scaled up PICU capacity to relieve other PICUs, such as Birmingham Childrens and Great Ormond Street, shown in Figure 14.

3.2 Staffing

Predominantly over the three time periods paediatric intensive care nurses and healthcare assistants delivered care to adult patients, aided by adult intensive care staff, and some nursing staff from 'other' areas such as theatres. Overall, as there were less adult intake there was less demand on intensive care and other staff as shown in the second and third period (Table 8). This was also in line with government initiatives and proposals. NHS England and NHS Improvement recognised in December 2020 [22], that previous strategies to provide extra workforce to critical care areas looking after adult critically ill patients needed to be reviewed. In the first pandemic wave the response had been to utilise theatre staff for example by cancelling surgical procedures, outpatient staff had also been redeployed with the closure of clinics, and in particular both medical and nursing students had also been part of the workforce. Consideration needed to then be given to ensure that attention was not diverted from elective and screening services whilst also dealing with emergency admissions. The focus was then on expanding critical care services to be able to provide COVID-19 and non COVID-19 services and major surgery. This may reflect the decrease in number of adult patients in PICU in the second and third wave, although what is common throughout all the tables is the marked decrease in adult activity in PICUs during the second wave.

It is to be noted that for the medical staff there was a higher proportion redeployed during the third time period, although the highest numbers of nurses being redeployed was in the first time period.

In addition the review, along with recommendations from the PICS, also endorsed allocating resources for additional staff training, to deliver additional workforce supply outside of the individual hospital staff base (return to work schemes), and a focus on the health and wellbeing of the workforce [22, 23]. It is beyond the scope of this report to comment on the latter recommendations. What it can show is the organisation and strategies undertaken to achieve the extra capacity demand either within an individual PICU or moving staff to care for the extra capacity. The comments made indicated that on the whole where there was a paediatric HDU, the PICU patients were transitioned to this and the adult patients occupied the designated PICU beds. This strategy however did change over time and demand, where demand for adult capacity was less some PICUs remained as paediatric and the adults went to PHDU (usually less PHDU beds than PICU beds). One PICU adopted an ad hoc approach where admission of adults to PICU was dependent on daily bed availability at the time it was requested. In these cases the PICU supported the adult cardiac surgery speciality and therefore only cared for elective adult admissions. One PICU commented that although their PICU was closed to paediatric patients they relied on the paediatric critical care outreach team that supported deteriorating paediatric patients on the wards.

The proposals from NHS England and NHS Improvement [22] also promoted moving staff (in teams), the use of rostering to ensure time for rest, and recommended staff/patient ratios. Whilst staff to patient ratios were not considered in this survey, it was clear from survey responses that over time units responded to redeploying staff in a more organised way, through rotas, assessment of availability, and a combination of scheduled and voluntary shifts.

Criticism of the survey may be that lockdown periods were used as timelines versus actual peaks or waves of the pandemic. However the waves and timing were not as clear cut as the lockdown periods and were in response to a rise in the R number as an indication of the acute mortality and morbidity being experienced. Also the survey was limited in not asking all PICUs whether staff were not working due to shielding, although this was documented in the free text by three PICUs.

4 Conclusion

What is clear from this survey is that the disruption to PICUs was twofold. Those who accepted adult patients experienced disruption in their environment through experiencing technology geared for adults, learning how to care for adult critically ill patients, and transferring their intensive care skills from paediatric to the demands of adult critical care. In addition they had to support a range of staff sent to support them. Secondly, even if a PICU did not accept adult patients then COVID-19 still impacted on the PICU through redeployment of paediatric staff for adult critical care or children's ward areas, also experiencing a rapid transition to learning new skills outside of their particular skill set, and in addition to the burden of working shifts in full PPE, and staff shortages through shielding, sickness and vacancies.

This survey set out to demonstrate the impact of COVID-19 through a deeper exploration of issues in PICUs during these three time periods in terms of bed occupancy, staffing of adult beds, staff and child relocation. Although these issues varied in the different PICUs and over the three time periods it does give an indication of the burden placed upon PICUs during a time of unprecedented adult intensive critical care activity, and the strategies undertaken by PICUs and their responses to meet these demands.

Special Chapter 3: Diabetic ketoacidosis in English PICUs: the impact of COVID-19

Why this chapter now?

During the 2020 COVID-19 pandemic there were international reports of an increase in the number of general paediatric patients and adults presenting with ketoacidosis [24, 25]. However, there are currently no UK reports of the impact of COVID-19 on children presenting to paediatric intensive care (PIC) with diabetic ketoacidosis (DKA).

In addition, there is a lack of recent detailed information regarding the demographics, complications and outcomes of children with diabetic ketoacidosis admitted to paediatric intensive care units (PICUs) in England. In fact, it has been more than a decade since this group of patients was reviewed using data extracted from the PICANet database covering the period from 2003–2007 [26].

The aim of this special chapter was to review trends in DKA admissions to PICUs in England during the last eleven years (2010–2020), focusing on the impact of the COVID-19 pandemic on these admissions comparing 2020 PICU activity to 2010–2019.

Methods

PICANet collects prospective data on all admissions to PICUs in the UK and Republic of Ireland. For this report, data were extracted retrospectively on admissions to NHS PICUs in England occurring between January 2010 and December 2020 for children aged 0–15 years where the primary or secondary diagnoses were either: diabetes; Type 1 diabetes; diabetic ketoacidosis (DKA); or diabetes mellitus (recorded via Read Codes CTV3). Any admissions to PICUs which were re-designated as a Level 2 paediatric critical care episode during the study period were excluded from analysis.

Pseudonymised data available included: primary and secondary diagnostic codes, date of admission, sex, age, blood pressure and ethnic group. Interventions included in the analysis were fluid bolus (any episodes of > 80ml/kg in a 24-hour period) during the admission, use of invasive ventilation, intravenous vasoactive therapy and renal replacement therapy including continuous veno-venous haemofiltration (CVVH) and peritoneal dialysis (PD). Expected probability of mortality was calculated using the Paediatric Index of Mortality (PIM3) [27]. Outcomes included in the analysis were length of stay, acute renal failure, cerebral oedema and mortality. Blood pressure centile data were computed from the blood pressure, age and sex of the child as height and weight data were often missing [28].

A descriptive analysis was carried out with summary statistics presented as medians and interquartile ranges for continuous data, and frequency and percentages for categorical data. Differences between 2020 and 2010–2019 are presented as difference in medians or proportions as appropriate with associated 95% confidence intervals.

Where comparisons are made to the general PICU population, information was extracted from last year's 2020 PICANet Annual Report which covered the period 2017–2019 [29]. This general population includes children admitted to PICU with DKA.

Results

Analysis population

Of the 23 NHS PICUs in England included in this analysis, 19 (83%) had patients admitted with a diagnosis of DKA during the study period; the remaining four PICUs were all cardiac centres. Of the 150,426 total admissions to these 19 non-cardiac PICUs within the 11 year study period, there were 959 DKA admissions (0.7%).

Trends in admissions

Between 2010 and 2019 the proportion of DKA admissions per year varied between 0.45% in 2017 and 0.73% in 2011 (Figure 15). In 2020 the proportion of children admitted with DKA more than doubled compared to the preceding ten years; the mean percentage of DKA admissions averaged 0.58% per year between 2010 and 2019 (95% confidence interval: 0.54–0.62%) compared with 1.3% of admissions in 2020.

Figure 15: Total number of annual paediatric intensive care admissions to non-cardiac paediatric intensive care units alongside annual diabetic ketoacidosis (DKA) admissions

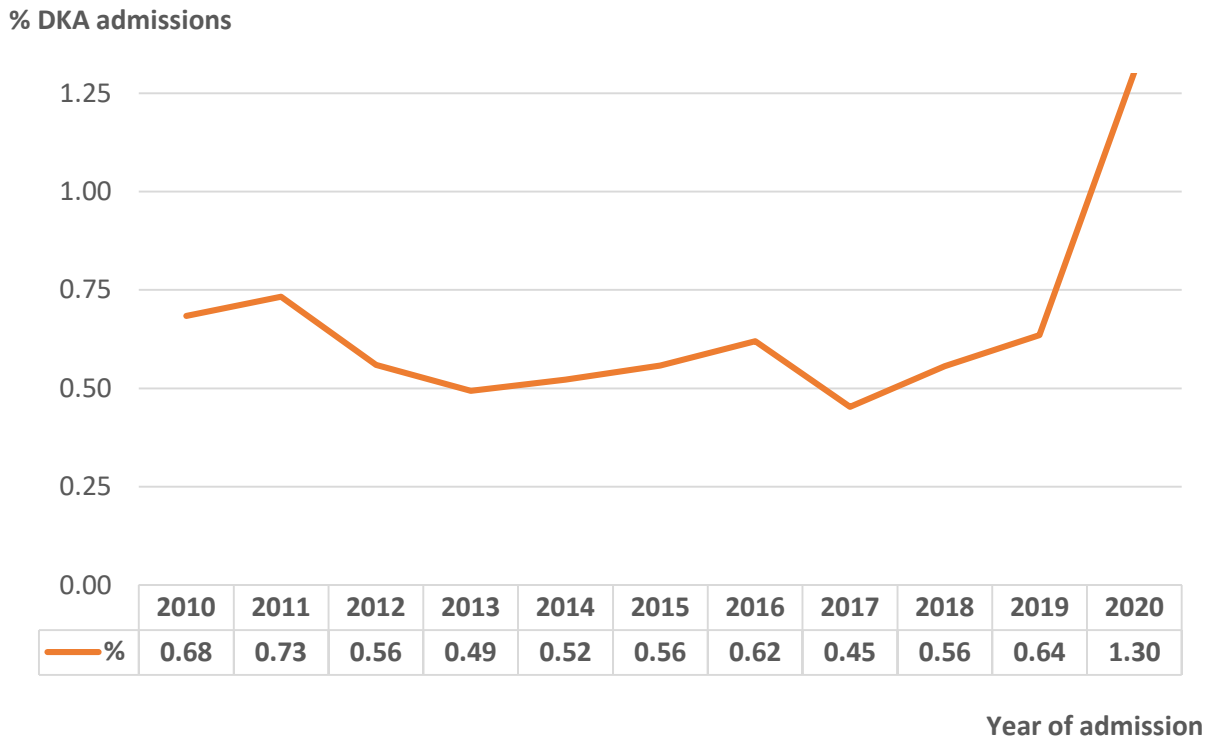
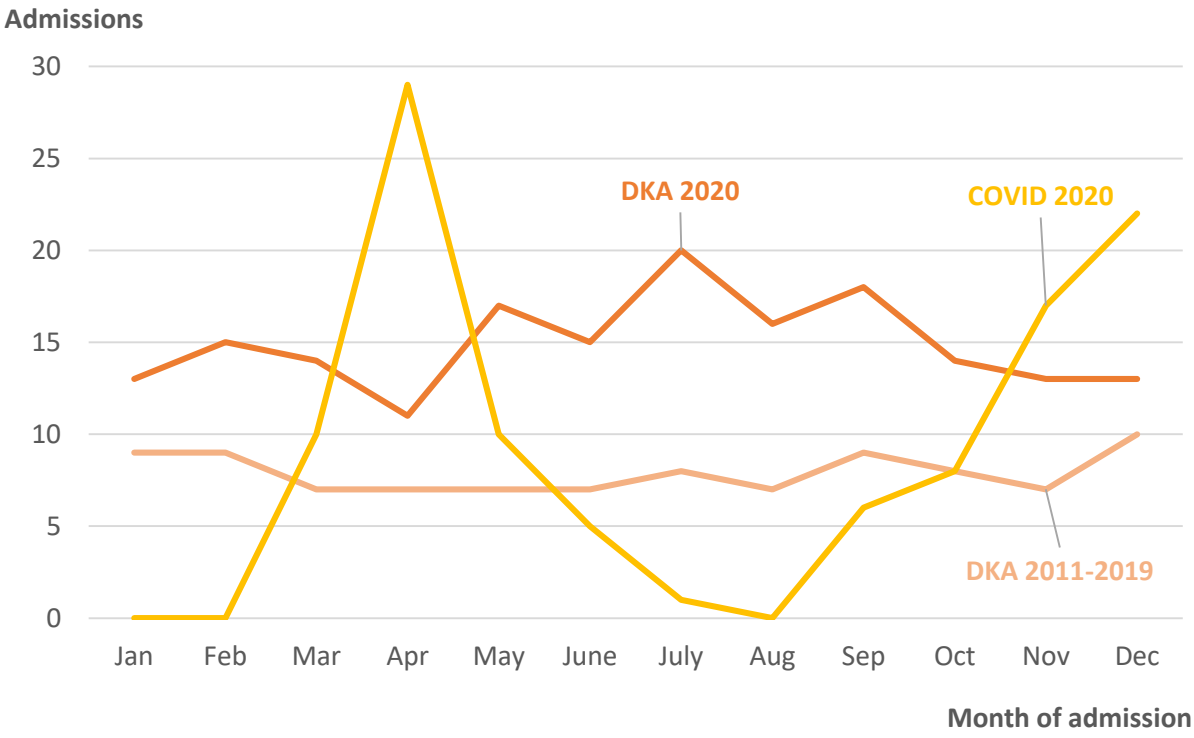


Figure 16 shows the number of DKA admissions per month in 2020 compared with the number in preceding years and the number of children admitted to PICU with COVID in 2020. In 2020, there were a higher number of DKA admissions from May to September (more than 15 per month) with a peak of 20 admissions in July, which was twice as many as admitted during the highest months of the previous ten years (December and January). The peak DKA admissions did not occur at the same time as the peak COVID admissions which occurred in April 2020 (n=29 admissions).

Figure 16: Diabetic ketoacidosis (DKA) admissions per month in 2020 compared to median admissions per month during 2010–2019 and to COVID-19 admissions in 2020



Patient characteristics

Table 12 shows the characteristics of the 959 children admitted to PICU with DKA within the study period. Just over half were female (55%) and the median age was 10 years (interquartile range (IQR): 5–14 years). By contrast, in general PICU admissions, males accounted for a higher proportion than females (57%) and the median age was approximately one year old. During the study period, 10 DKA admissions required cardiopulmonary resuscitation (CPR) prior to PICU admission; there was a higher proportion recorded in 2020 than in the preceding years (2.5% vs 0.8%).

Table 12: Characteristics of children admitted to PICU with DKA

	DKA admissions 2010–2020 n=959	2010–2019 n=805	2020 n=154	Difference * (95% CI)
Male, n(%)	436 (45%)	45%	47%	1.8% (-6.6 to 10.2%)
Age (years)				
n†(%)	959 (100)	805 (100)	154 (100)	0.2
Median (IQR)	10 (4–13)	10 (4–13)	10 (5-13)	(-0.7 to 1.0)
Weight (kg)				
n†(%)	439 (46)	340 (42)	99 (64)	1.0
Median (IQR)	32 (14–47)	32 (14–48)	33 (17–42)	(-3.5 to 5.5)
Blood pressure centile				
n†(%)	805 (84)	670 (83)	135 (88)	6.6
Median (IQR)	92nd (58–99)	91st (55–99)	93rd (72–99)	(-0.8 to 12.4)
Lactate				
n†(%)	597 (63)	469 (58)	128 (83)	1.7
Median (IQR)	1.7 (1.1–2.5)	1.7 (1.1–2.6)	1.6 (1.3–2.3)	(-0.2 to 3.6)
PIM3 POD (%)				
n†(%)	959 (100)	805 (100)	154(100)	0.7
Median (IQR)	0.6 (0.2–1.0)	0.6 (0.2–1.0)	0.5 (0.2–0.8)	(-0.2 to 1.7)
CPR prior to admission				
n†(%)	884 (92)	730 (90)	154 (100)	1.7
CRP recorded, n(%)	10 (1.1)	6 (0.8)	4 (2.5)	(-0.8 to 4.3)

Abbreviations: IQR=interquartile range; PIM3 POD=paediatric index of mortality predicted probability of death; †n=data available.

*Difference relates to 2020 compared with all previous years combined which acted as the control value

Looking at the age distribution in more detail (Figure 17a), only 7% of the DKA admissions occurred among those less than one year of age compared to the 45% of the overall PICU admissions. 45% of the DKA cohort were aged between 11–15 years whilst this age group only represented 13% of the general PICU population [29].

Figure 17a: Age distribution of all admissions compared to DKA (in age categories)

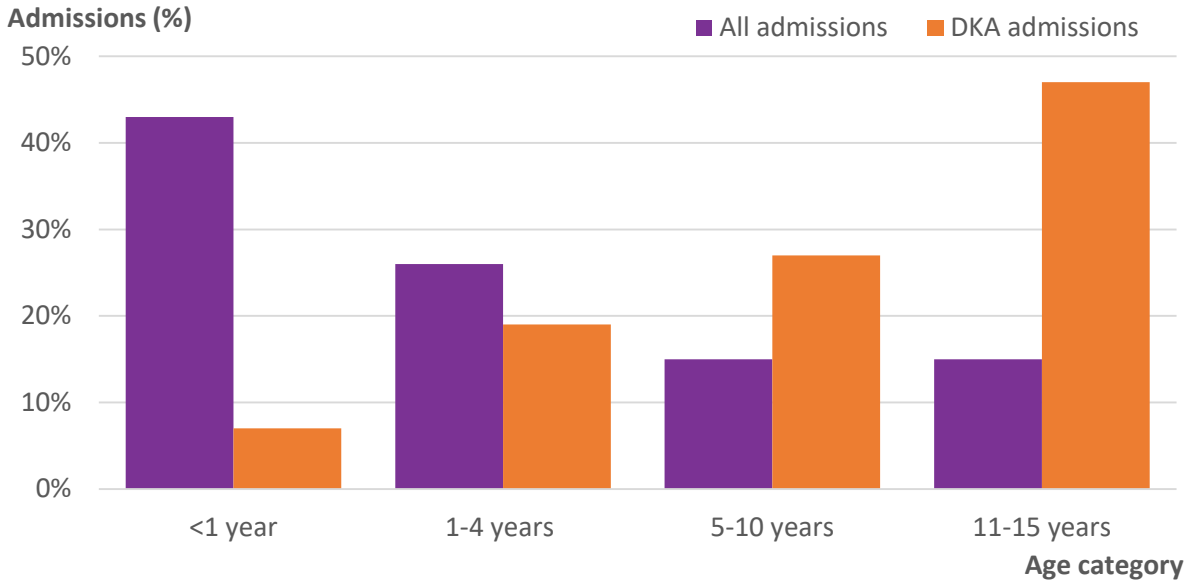


Figure 17b provides a more detailed breakdown of the DKA admissions demonstrating a bi-modal peak with children under two years of age accounting for 17% of PICU admissions and then a larger peak with the admissions between 12–14 years of age accounting for 32%.

Figure 17b: Age distribution of DKA admissions

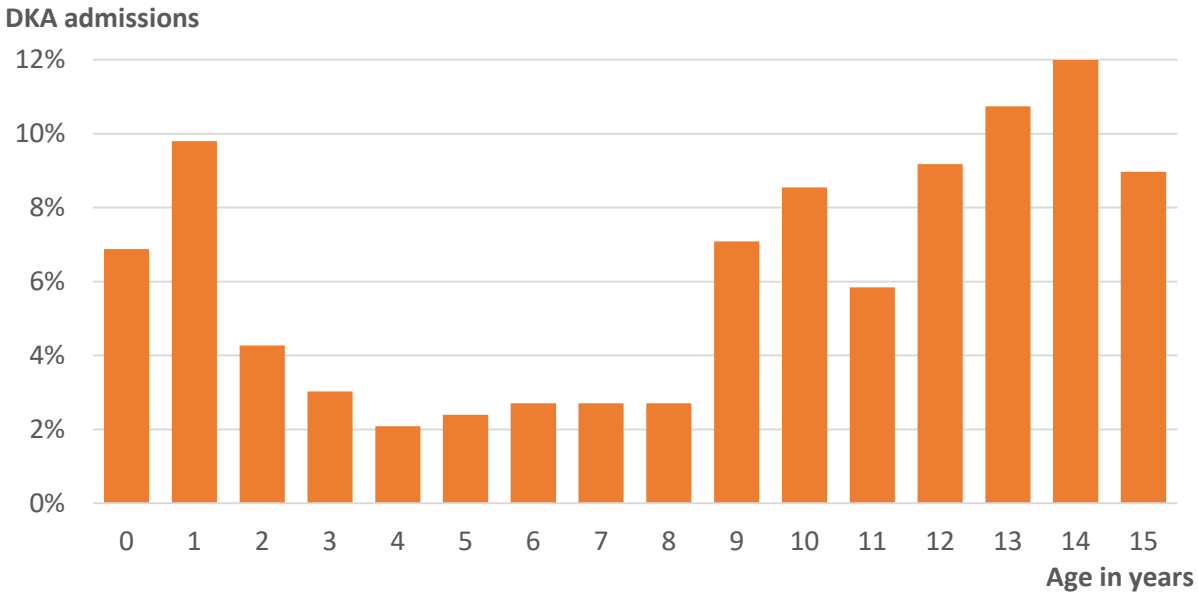
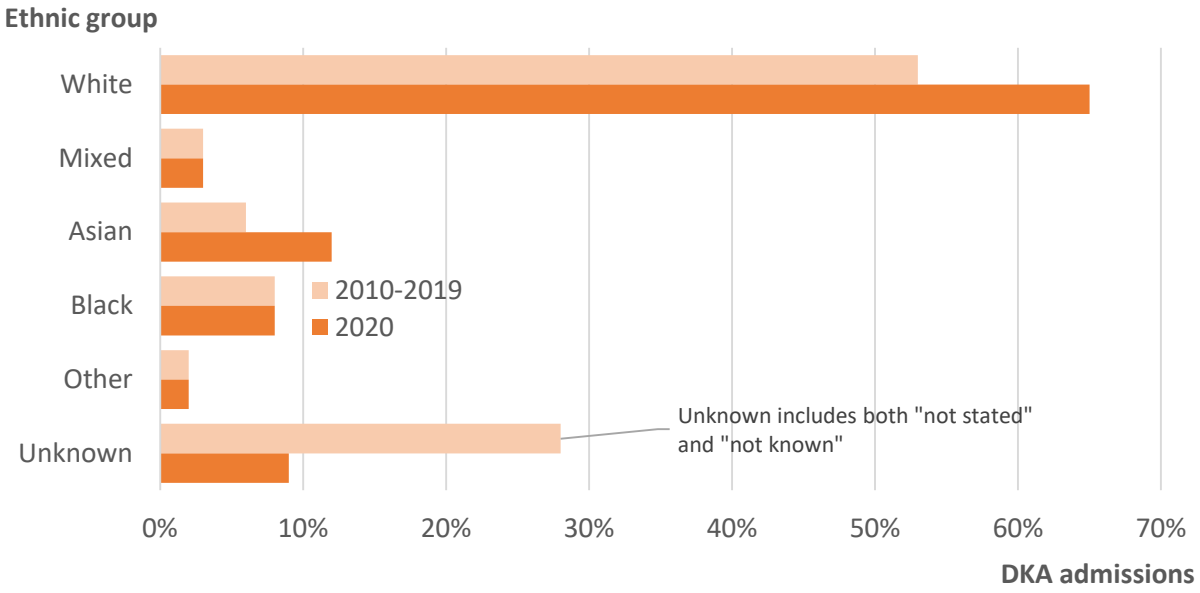


Figure 18 shows the ethnic breakdown of children admitted with DKA in the study period. Although the distribution of ethnic groups may appear different in the two time periods this could be due to better coding with only 9% of admissions in the “not stated/not known” category in 2020 compared to 28% between 2010 and 2019.

Figure 18: Percentage of diabetic ketoacidosis (DKA) admissions reported in each ethnic group



Interventions and complications

Table 13 shows a breakdown of interventions delivered during DKA PICU admissions as well as complications.

Table 13: Interventions delivered during diabetic ketoacidosis paediatric intensive care unit admissions and complications

	Overall n=959	2010–2019 n=805	2020 n=154	% difference* (95% CI)
Invasive ventilation, n(%)	185 (19)	157 (20)	28 (18)	-1.3 (-8.0 to 5.3)
IV vasoactive therapy, n(%)	109 (12)	95 (12)	14 (9)	-3.0 (-8.1 to 2.0)
Fluid bolus >80ml/kg, n(%)	38 (4)	31 (4)	7 (5)	0.6 (-2.9 to 4.2)
Low GCS, n(%)	82 (9)	47 (6)	35 (23)	16.7 (9.9 to 23.5)
Cerebral oedema, n(%)	44 (5)	39 (5)	5 (3)	-1.6 (-4.7 to 1.5)
Acute Renal Failure, n(%)	49 (5)	42 (5)	7 (5)	0.7 (-4.3 to 2.9)
Renal replacement, n(%)	39 (4)	32 (4)	7 (5)	0.5 (-3.1% to 4.0)

Abbreviations: IV=intravenous; GCS=Glasgow Coma Scale; CPR=cardiopulmonary resuscitation; CI = confidence interval

*Difference relates to 2020 compared with all previous years combined which acts as the control value. Percentages were compared using the equality of proportions test for large-sample statistics, and continuous data via the two sample t test.

The percentage of admissions receiving invasive ventilation for the DKA cohort (19%) was much lower than the general PICU population (63%, [29]). Likewise, the proportion receiving intravenous (IV) vasoactive drugs was lower at 12% compared to 32% among general PIC admissions [29]. However, the proportions receiving invasive ventilation and IV vasoactive therapy were similar in 2020 to those in 2010–2019 (19% vs 17% and 12% vs 9% respectively). Approximately 4% of DKA admissions in both time periods received >80ml/kg in a 24-hour period.

Cerebral oedema or diabetic encephalopathy were included in the primary or secondary diagnostic codes in 44 admissions (5%) out of all DKA admissions; in 2010–2019 these diagnoses were recorded in 5% of DKA admissions compared with 3% in 2020. However, there was a higher proportion of children with a low Glasgow Coma Score (GCS) recorded during their admission in 2020 at 22% compared to 6% in all the preceding years, an increase of 16% (95% CI: 10 to 23%).

Acute renal failure was included in the primary or secondary diagnostic code in 49 (5%) of DKA admissions with 39 (4%) requiring renal replacement therapy. This was higher than among the general PIC admissions in which renal replacement therapy was only recorded in 2.9% of admissions [29].

Outcomes

The median length of stay for the DKA PICU population was 1 day (IQR: 1–3 days). This was slightly shorter when compared to the median length of stay for all PICU admissions combined, at around 2.5 days [29].

Overall, there were 15 deaths reported among the DKA admissions during the study period, equivalent to a crude mortality rate of 1.6%. The majority (n=14) of these deaths occurred prior to 2020 with no evidence of a change in mortality throughout the study period. In the general PICU population, the proportion of children dying on PICU in England was generally higher at around 3.5% [29].

Discussion

The total number of DKA PICU admissions from 2010–2020 ranged from 62 to 154 per year which is slightly higher than the 57 to 94 admissions seen between 2003 and 2006 in the previous review of the PICANet cohort [26]. However, the proportion of DKA admissions out of all admissions to English PICUs in the study period was 0.59% in comparison to 0.61% in the 2010 report.

The age distribution of children admitted to PICU with DKA was similar to a report of children admitted to UK hospitals with DKA, both series having a median age of 10 years [30]. Although the bi-modal distribution of this cohort has not been described elsewhere, it is reported that children < 2 years are at increased risk of presenting with DKA compared to older children: Lokulo-Sodipe et al [30], reported that children < 2 years accounted for 80% of the DKA presentations. A systematic review by Usher-Smith et al [31], published in 2011, identified that children < 2 years of age had three times the risk of presenting in ketoacidosis as older children (odds ratio 3.41, 95% confidence interval 2.54 – 4.59).

From 2010 to 2019, the proportion of DKA admissions to PICU ranged between 0.48% and 0.73% with a median of 0.60%; in 2020, at the start of the COVID-19 pandemic, this proportion was double, totalling 1.3% of admissions. The increased number of PICU DKA admissions in 2020 is in keeping with international reports of an association with an increased number of DKA presentations in children and adults at the time of the COVID-19 pandemic [24, 25, 32, 33]. Our data identifies no clear differences between the cohorts admitted before and during the COVID pandemic apart from a higher proportion of patients with documented low GCS and more children requiring CPR in the latter group. However, this could be explained by improved reporting of GCS and CPR in the PICANet database over the same time period.

There are three potential reasons for the increase in PICU DKA admissions in 2020:

1. delayed presentation to hospital of children with DKA who therefore require PIC;
2. increased incidence of DKA due to direct pancreatic islet cell damage caused by Severe acute respiratory syndrome coronavirus 2 (SARS-COV-2, the virus which causes COVID-19) [33]; or
3. changes in British Society for Paediatric Endocrinology and Diabetes (BSPED) guidelines on the management of DKA in January 2020.

During 2020, 32% of 4,075 paediatricians surveyed by the British Paediatric Surveillance Unit (BPSU) reported children presenting late to emergency departments and paediatric assessment units during the COVID-19 pandemic [34]; a new diagnosis of DKA was one of the most common conditions reported in this publication. This finding would be consistent with a higher proportion of children having a low GCS recorded in PICU and requiring CPR in the 2020 PICU DKA cohort.

However, there are also several reports of a higher incidence of diabetes and DKA associated with COVID-19 [24, 25, 32, 33] and this would be consistent with our findings that despite an increased number of DKA admissions in 2020 the requirement for ventilation, IV vasoactive treatment and renal replacement therapy was comparable to the preceding ten years. Specifically, the data does not support theories that patients required more support in 2020 or that the threshold for admissions to PICU was lower during this time as the acuity of the cohorts was similar to previous years.

In the last ten years national guidelines published by National Institute for Clinical Excellence (NICE 2021) and British Society for Paediatric Endocrinology and Diabetes (BSPED 2020) have been revised twice (2015 and 2020). It is not known if the revised guidance has had an impact on the admissions to PIC and some PIC clinicians have raised a concern about the impact of a more liberal fluid regimen on DKA outcomes, specifically the incidence of cerebral oedema [35]. However, this study did not demonstrate significant differences in the 2020 admissions compared to the previous decade nor temporal changes related to the introduction of the 2015 guidance. This suggests that national guideline changes may have had minimal impact on mortality, incidence of cerebral oedema or acute renal failure in children presenting to PICU with a diagnosis of DKA. Alternatively, a database study such as this and the descriptive analysis undertaken may not be able to identify subtle changes in these outcomes.

Despite being the largest data set studied of paediatric critical care patients with DKA, some complications such as acute kidney injury (AKI) are likely to be under-reported. Only 5% of the patients admitted had a diagnostic code of AKI which was far lower than other studies looking at AKI and DKA [36, 37]. This is likely to reflect the different levels and standard of reporting of diagnoses across PICUs which is reliant on clinical coding.

There was evidence of improved reporting and clinical coding in 2020 PICU admissions compared to the previous decade. The number of children with ‘not stated /not known’ ethnic category reduced from an average of 28% to 9% in 2020. This trend was also noted in the recording of weight: an average of 42% admissions with documented weight prior to 2019 improved to 64% in 2020 and lactate recording increased from 58% (2010–2019 average) to 83% of admissions in 2020.

There does not appear to have been a significant change in mortality since the previous PICANet cohort was analysed in 2003–2007, in which there were five deaths reported with a crude mortality of 1.5%. The latest cohort showed a very similar number of deaths (n=15) equivalent to a crude mortality rate of 1.5% between 2010 and 2020. In addition, the analysis did not reveal any change in mortality over time during the period studied.

As mortality is low, median length of stay is one day and the majority of patients did not require inotropes nor ventilation, this group could be appropriately managed in a level 2 critical care setting.

A key strength of this review is that it included all admissions to PICUs in England for more than a decade. The data were collected and presented in a standardised format which facilitated comparison across the whole country and different time periods, providing a broad and longitudinal perspective of children admitted to PICU with a primary diagnosis of DKA. Limitations are primarily that historical data relied on coding and there was no access to granular data such as specific GCS or creatinine values to explore complications of DKA such as cerebral oedema or AKI more thoroughly. The improvement in the submission of data over time (e.g. ethnic coding) may have contributed to some of the findings (e.g. low GCS).

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