



# Using ICD-10 diagnostic codes to identify ‘missing’ paediatric patients during nationwide COVID-19 lockdown in Oxfordshire, UK

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## Abstract

The study aims to identify ‘missing’ diagnoses amongst paediatric admissions during the UK’s first national lockdown, compared with the previous 5 years. A retrospective observational cohort study of all children (0–15 years) attending for urgent care across Oxfordshire, during the first UK lockdown in 2020, compared to matched dates in 2015–2019, across two paediatric hospitals providing secondary care, including one with tertiary services. Our outcome measures were changes in numbers of patients attending and inpatient diagnoses (using ICD-10 classification) during the first 2020 lockdown, compared with the previous 5 years, were used. We found that total Emergency Department (ED) attendances ( $n = 4030$ ) and hospital admissions ( $n = 1416$ ) during the first UK lockdown were reduced by 56.8% and 59.4%, respectively, compared to 2015–2019 (5-year means  $n = 7446.8$  and  $n = 2491.6$ , respectively). Proportions of patients admitted from ED and length of stay were similar across 2015–2020. ICD-10 diagnoses in lockdown of 2020 ( $n = 2843$ ) versus matched 2015–2019 dates ( $n = 19,946$ ) demonstrated significantly greater neoplasm diagnoses ( $p = 0.0123$ ). Of diagnoses ‘missing’ in lockdown, 80% were categorised as infectious diseases or their sequelae and 20% were non-specific pains/aches/malaise and accidental injury/poisonings.

**Conclusions:** Pandemic public health measures significantly altered paediatric presentations. Oxfordshire hospitals had a 58% reduction in ED attendances/inpatient admissions, with ‘missing’ diagnoses predominantly infection-related illnesses. These are likely driven by a combination of the following: (1) public health infection control measures successfully reducing disease transmission, (2) parents/carers keeping mild/self-limiting disease at home, and (3) pandemic-related healthcare anxieties. Prospective studies are needed to ensure referral pathways identify vulnerable children, those with social concerns, and avoid delayed presentation.

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**What is Known:**

- Significant reductions of paediatric ED attendances and inpatient admissions are reported globally, throughout national and regional lockdowns for COVID-19.
- Previous studies (supplemental table 5) examined only ED diagnoses or specific inpatient diagnoses during lockdown periods, demonstrating reductions of infectious diseases, accidents/injuries, and safeguarding referrals.

**What is New:**

- Using ICD-10 coding, robustly controlling for five historical years and adopting a hypothesis-independent analysis, demonstrating 80% of ‘missing’ inpatient diagnoses during national COVID-19 lockdown were infectious diseases or its sequelae, the remainder being non-specific aches/pains/malaise and accidental injuries/poisonings.
  - Greater numbers of neoplasms and other specific diagnoses were detected during lockdown, including greater documentation of co-morbidities and incidental findings.
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## Introduction

The impact of the COVID-19 pandemic on global health issues requires constant review of public health measures. In 2020, the United Kingdom implemented the first set of national restrictions for asymptomatic individuals after the recognition of COVID-19 transmissibility, mortality risk, and excess burden on the healthcare system. On 16 March, these included advice against non-essential travel, reducing contact between households, ban on visiting social venues, and ‘work from home’ initiative [1]. On 20 March, the hospitality sector was closed to dining-in and schools closed except to key workers’ children. Lastly, on 23 March, a ‘stay at home’ order was implemented and is recognised as the start of the first national lockdown, continuing until 12 May. From 13 May, significant restrictions remained in place with limited interaction permitted between households, despite a cautious return to work.

Internationally, varying levels of lockdown restriction has led to reductions in paediatric emergency department (ED) attendances of around 50% (24.9–88%) [2–14]. Many authors expressed concern about children who may be ‘lost’ to secondary services during lockdowns, particularly those with concerning or significant disease [4, 5, 10, 14–16]. Although children are deemed to be relatively unaffected by primary SARS-CoV-2 infection [17], pandemic measures/messaging are altering patterns of paediatric disease presentation. Recent studies during the 2020 winter months show significant declines in admissions for bronchiolitis, respiratory infections, and gastroenteritis compared to previous years [18, 19].

Few studies suggest an internationally comparable way to continuously report on patients not attending for hospital care. Our study sought to clarify the effects of the first UK lockdown on paediatric ED attendances and hospital admissions in Oxfordshire, UK, using ICD-10 (International Statistical Classification of Diseases and related health problems 10) codes from electronic patient records. We aim to identify

diagnoses that were ‘missing’ during lockdown in 2020, compared to the previous 5 years (2015–2019).

## Methods

Data was extracted from electronic healthcare records for all patients aged 0–15 years attending ED and any urgent admission under specialist services across Oxfordshire University Hospitals NHS Foundation Trust’s two sites (Horton General Hospital, Banbury, and John Radcliffe Hospital, Oxford). Data collection occurred 3 weeks prior to, inclusive of, and 2 weeks after the first national UK lockdown period (02/03/2020–26/05/2020), and matched periods in 2015–2019 (02/03/2015–26/05/2015, 07/03/2016–24/05/2016, 06/03/2017–23/05/2017, 05/03/2018–29/05/2018, and 04/03/2019–28/05/2019). Dates used for lockdown data were 23/03/2020–12/05/2020. The matched 49 days for 2015–2019 begin on 23/03/2015, 28/03/2016, 27/03/2017, 26/03/2018, and 25/03/2019. Matched dates included the same number of weekdays/weekends, beginning on the nearest Monday to the 2020 date.

Diagnoses using ICD-10 classification are assigned by clinical coders. ICD-10 codes were matched with chapter headings and specific diagnoses using <https://icd.codes/icd10cm>. To our knowledge, there was no substantial change to clinical coding during the 6-year study period. Due to software limitations, the first ten diagnoses for each patient were extracted. Patients are assigned a primary diagnosis, whereas concomitant diagnoses (e.g. viral illness, wheeze) and historical diagnoses add relevant context to the complexity of patients. Therefore, all diagnostic codes were included for most of our analyses. Two patients without a discharge date (from 2019) had length of stay censored at extraction; patients without discharge diagnoses are documented (0–9 patients/year; Supplemental Table 1).

A diagnosis of ‘COVID-19, virus identified’ (ICD-10 code U071) was made only five times during the 2020 lockdown period (never for dates outside of lockdown). COVID-19 was grouped under ICD-10 chapter 1 (infectious and parasitic diseases), and the sub-heading ‘other viral diseases’.

Additional data included date of birth, postcode, length of stay (LOS), and source of admission. Postcode was used for assessing Index of Multiple Deprivation Rank, calculated using the UK government online tool (<http://imd-by-postcode.opendatacommunities.org/imd/2019>).

Information used for clinical audit in May 2020 followed Trust procedures to access anonymised patient data. NHS Health Research Authority for ethics committee review and approval were not required.

Data were handled in Microsoft Excel (Office 365). Graphical presentation of data was prepared in GraphPad Prism (Version 9.0.0 for Windows, San Diego, California, USA). Statistical analyses were performed in GraphPad Prism and SPSS (Version 27.0. for Windows, IBM, NY, USA). Multiple testing corrections were performed where necessary. Non-parametric testing was used throughout; significance was taken as  $p < 0.05$ .

## Results

### ED attendances and inpatient admissions reduced during lockdown, without increased severity of admissions

We observed significant reductions in paediatric ED attendances and inpatient admissions across both Oxfordshire hospitals, compared with 2015–2019 (Fig. 1A–B). Pre-lockdown admissions reduced by 22.6% ( $p = 0.05$ ) were lowest during the first week of lockdown (62.1% fewer,  $p < 0.0001$ ) and maintained throughout (supplemental figure 1). These reductions were consistent across Oxfordshire (supplemental figure 2A–F) and were reduced in all age groups (age <1 year—48.4%, 1–5 years—67.2.4%, 6–10 years—53.3%, and 11–15 years—48.9%; supplemental figure 2G–J). The socioeconomic background of ED attendees was similar across all years 2015–2020, as assessed by postcode-derived index of multiple deprivation rank (supplemental figure 3).

We examined for surrogates of disease severity. Reductions in admissions from all sources were matched by reductions in admissions from ED alone (Fig. 1C); the proportion of ED attendees requiring admission was similar for each year (approximately 20%, Fig. 1D), and consistent between hospitals (supplemental figure 2K–L). Mean subsequent LOS, based on day of admission, was similar for patients admitted during lockdown ( $1.95 \pm 0.338$  days) compared with previous years ( $1.94 \pm 0.120$  days) (Fig. 1E). A surrogate of severity of illness was the number of diagnoses per patient: a mean of

71.6% received >2 ICD-10 diagnoses (mean 4.81 diagnoses/patient) in lockdown versus 44.5% (2.97 diagnoses/patient) in 2015–2019 (Fig. 1F–G). Greater proportions in 2020 were given  $\geq 10$  diagnoses (13.1% versus 1.3–4.1% in 2015–2019) (Fig. 1G; supplemental figure 4).

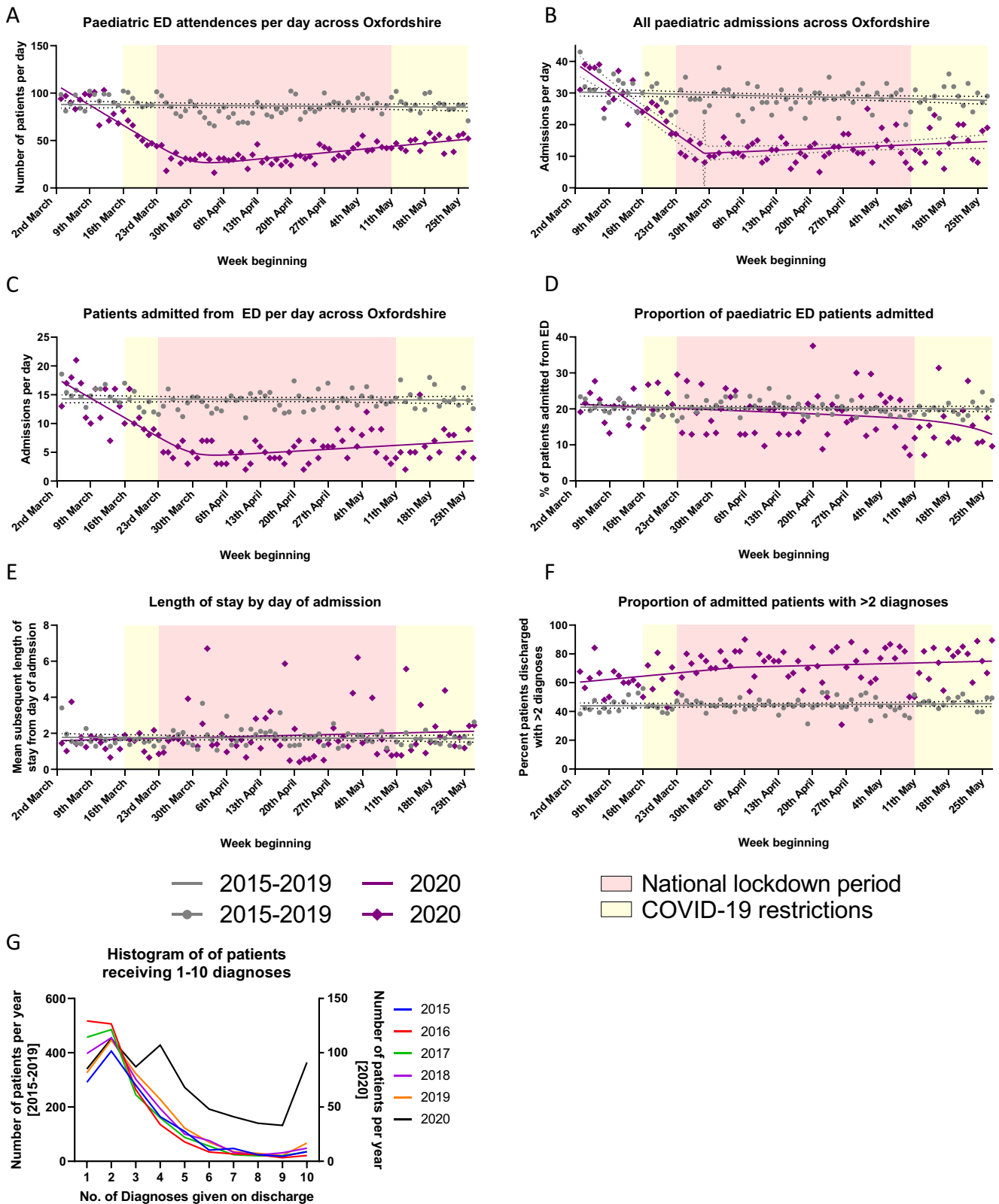
### Diagnoses amongst inpatients were decreased in 8 of 20 ICD-10 chapters during lockdown

ICD-10 chapter headings provide diagnostic groups for children admitted in 2020 (Fig. 2; supplemental table 2). Significant reductions were observed for five of six of the most commonly diagnosed groups and eight of 20 chapter headings, compared with 2015–2019. Notable reductions in diagnoses were observed amongst respiratory diseases (62.4%,  $p < 0.0001$ ), infectious diseases (58.9%,  $p < 0.0001$ ) and injury/poisoning (52.7%,  $p < 0.0001$ ). Only ‘neoplasms’ and ‘factors influencing health status and contact with health services’ increased in 2020 compared with previous years, by 75.9% ( $p = 0.0123$ ) and 64% ( $p = 0.0004$ ), respectively. When primary diagnosis is considered alone (supplemental figure 5), admissions within 11 of 20 chapters were significantly reduced in 2020. Neoplasms remained significantly increased throughout the lockdown period, whereas ‘factors influencing health status’ significantly decreased. Changes amongst these chapter headings were consistent week-to-week throughout the lockdown period (supplemental figure 6).

We explored relative changes in patient diagnostic groups admitted during lockdown (by chapter heading; Fig. 3). All diagnoses, and primary diagnoses, demonstrated reductions in the proportions of infectious and respiratory diseases. Similar proportions of non-specific diagnostic groups such as ‘factors influencing health status and contact with health services’ and ‘abnormal clinical or laboratory findings’ were observed amongst primary diagnoses in 2020 compared to previous years (Fig. 3, right panels).

### Diagnoses ‘missing’ throughout the 2020 lockdown were predominantly infective illness or sequelae of infectious illness

To identify specific diagnoses that significantly differed in the seven weeks of lockdown, compared to the same period over the previous 5 years, we assessed differences in weekly admissions for each diagnosis (supplemental table 3). All diagnoses in 2015–2019 with a mean  $\geq 1$  or any diagnosis made in 2020 were included. There were 726.8 (20.4%) fewer diagnoses during lockdown versus 2015–2019 ( $n = 2853$  in 2020 versus mean  $n = 3569.8$  across 2015–2019). This included significantly more patients with neoplasms admitted in 2020 (Fig. 2), with notable increases for both benign and malignant neoplasms. Sub-group analyses showed a skew toward greater



proportions of central nervous system (CNS) tumours, and secondary tumours diagnosed in 2020 (supplemental figure 7). Small but significant increases were observed in diagnoses

of gram-negative sepsis, ‘unspecified’ appendicitis, and ‘other unspecified’ diabetes mellitus in 2020 (supplemental table 3). Sub-group classification was used to identify whether these

◀ **Fig. 1** Paediatric ED attendances and admissions during the first national lockdown period in 2020, compared to 2015–2019. The numbers of paediatric ED attendances (A), inpatient admissions (B), and paediatric inpatient admissions referred from ED (C) are shown by day for 2020 (purple) and compared to matched period (mean) 2015–2019 (grey). The proportion admitted from ED (with total ED attendances for the day as a denominator) is shown across the same period (D). For each day of admission, the resulting length of stay is calculated for each patient, and averaged across all patients admitted on the same day (E). Proportions of patients with more than 2 diagnoses on discharge from paediatric wards are shown, based on day of admission (F), with the histogram of the numbers of diagnoses received by year (G). National restrictions on asymptomatic individuals are shown (yellow) with the first national lockdown period (red). Lines of 2015–2019 represent simple linear regression with dotted line demonstrating 95% confidence. Lines for 2020 are non-linear segmental regression lines, using least squares fit and continuous hinge function

may result from minor changes in diagnostic assignment for similar diseases (supplemental table 4). This showed no significant increase in any infectious disease subgroup, diseases of the appendix, or diabetes mellitus in 2020 compared to previous years. Amongst mental health diagnoses, significant reductions were observed for anorexia and the intentional self-harm subgroup, without any increased mental health diagnosis in 2020.

To identify the ‘missing’ diagnoses during lockdown, significant changes compared with 2015–2019 were categorised (Table 1). Net changes in numbers of diagnoses in 2020, compared with median numbers observed in 2015–2019, were used to demonstrate the degree of change. Diagnoses grouped as ‘likely related to pandemic screening’, ‘likely incidental finding or co-morbidity’, and ‘other diagnoses’ represented 24% of lockdown diagnoses and increased compared with 2015–2019 (Fig. 4A, right panel). ‘Infective illnesses’, ‘likely sequelae of infective illness’, ‘non-specific pains, aches and malaise’, and ‘accidental injury/poisoning’ had a net decrease in 2020. Net differences amongst ‘missing’ diagnoses totalled  $n = 761$ , more than accounting for the 726.8 fewer diagnoses in 2020 compared to the mean of 2015–2019 (Fig. 4A). Infective illnesses and ‘likely sequelae of infective illness’ accounted for 79.5% of diagnoses ‘missing’ from lockdown (Fig. 4B). Amongst infective illnesses, unspecified viral infections accounted for a third of missing diagnoses (Fig. 4C), whilst wheezing, nausea, and vomiting and unspecified asthma together constitute 72% of decreased diagnoses amongst sequelae of infective illnesses (Fig. 4D).

## Discussion

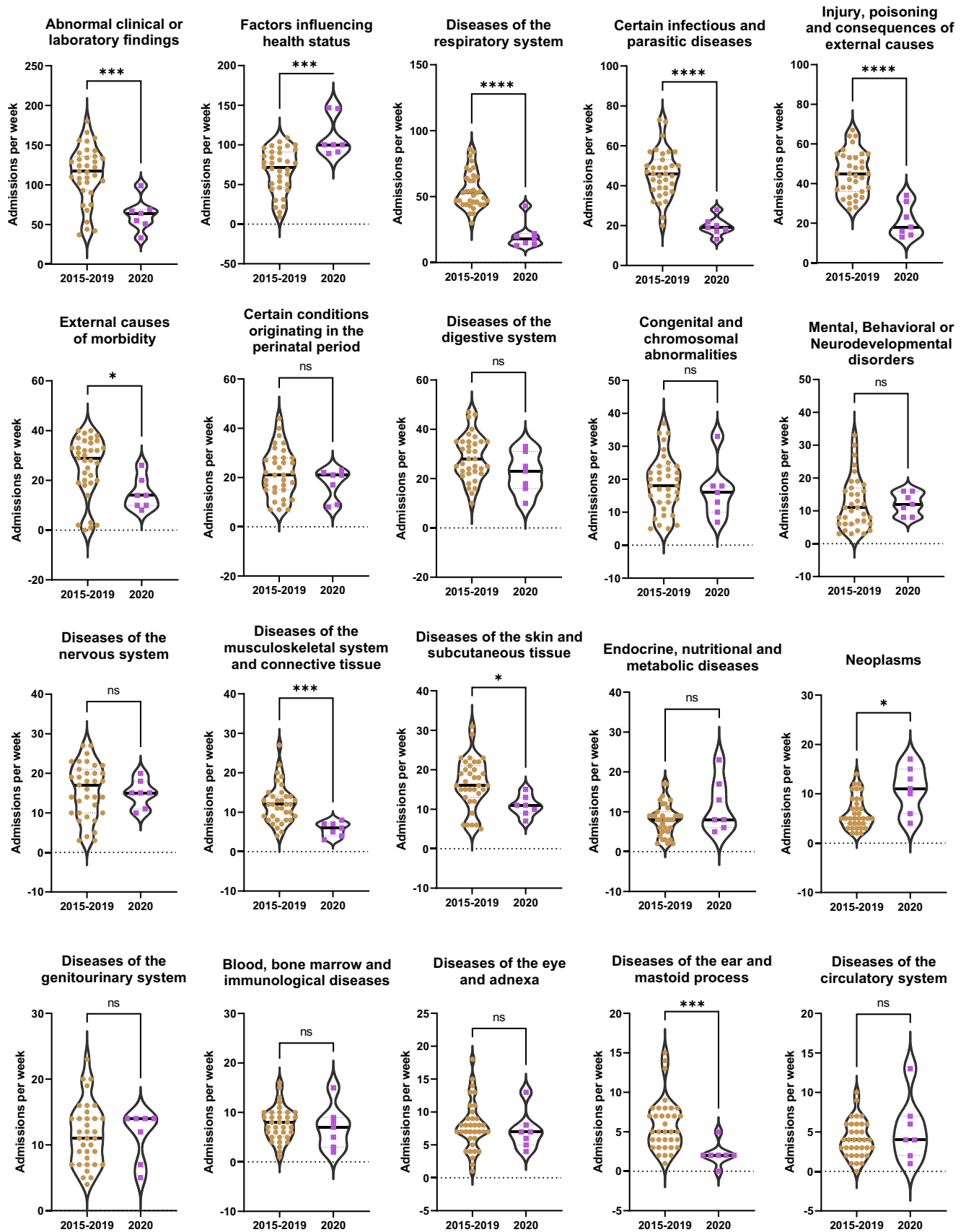
Public health measures have varied widely internationally, even across the devolved UK nations. As a result, our data may not directly translate to every lockdown scenario. Our

data included all acute paediatric admissions but precluded ED diagnoses, which are not classified by ICD-10 criteria. Therefore, extremely rare events or short ED attendances/observation periods will be under-reported in our data. Our study furthers others published to date (supplemental table 5), in performing a systematic examination of all paediatric inpatients and diagnoses using standardised ICD-10 criteria.

We reviewed 2843 diagnoses associated with 1416 admissions during the first lockdown period in 2020, compared with 12,458 admissions and 19,946 diagnoses across matched dates 2015–2019. We demonstrate decreased paediatric admissions and ED attendances throughout lockdown, with increased numbers of diagnoses per patient. Contrary to others [5, 12], the proportions of children admitted from ED were similar in all study years, suggesting comparable clinical severity of ED presentations across all 6 years. However, amongst those admitted a greater proportion received  $\geq 10$  diagnoses, suggesting an enrichment of children with complex/severe disease. Diagnoses which significantly increased during lockdown fit three main groups (1) increased documentation of co-morbidities/incidental findings, (2) pandemic screening, and (3) greater detection of ‘other’ diagnoses. Other diagnoses included benign and malignant neoplasms, similarly observed in German ED patients during their first national lockdown [5]. Urgent admissions increased for patients with malignancies, possibly due to reductions in face-to-face primary care capacity, and/or adaptations to tertiary oncology services during the pandemic, with elective admissions restricted.

Our findings have similarities to Germany’s first national lockdown, where paediatric diagnoses in Hanover were significantly reduced compared with 2019 for overall hospital admissions, communicable/non-communicable diseases, including intoxication [5]. In contrast, Dopfer et al. found greater proportions of ED patients were admitted, but with similar lengths of stay to 2019.

Significant reductions in infective diseases and personal injuries during international lockdown-like measures are recently reported [7–13]. Our data suggests 80% of ‘missing’ diagnoses during lockdown were infective disease or sequelae of infective illness. These most likely resulted from public health pandemic advice, with population adherence to infection control measures, compounded by restricting geographic movement and school closures throughout the first lockdown. Equivalent stringent measures in other countries also resulted in significant reductions in COVID-19 transmission as well as other circulating infectious diseases amongst children, including respiratory and gastrointestinal diseases [18, 19]. Similar to our findings, reductions in infectious diseases, their sequelae, and personal injuries were reported in paediatric presentations across the UK, Germany, Belgium, France, Italy, USA, South Africa, and Singapore [5, 7, 9, 12, 13, 18, 19]. We observed significant reductions in non-specific asthma and wheezing, despite historically high pollen counts during

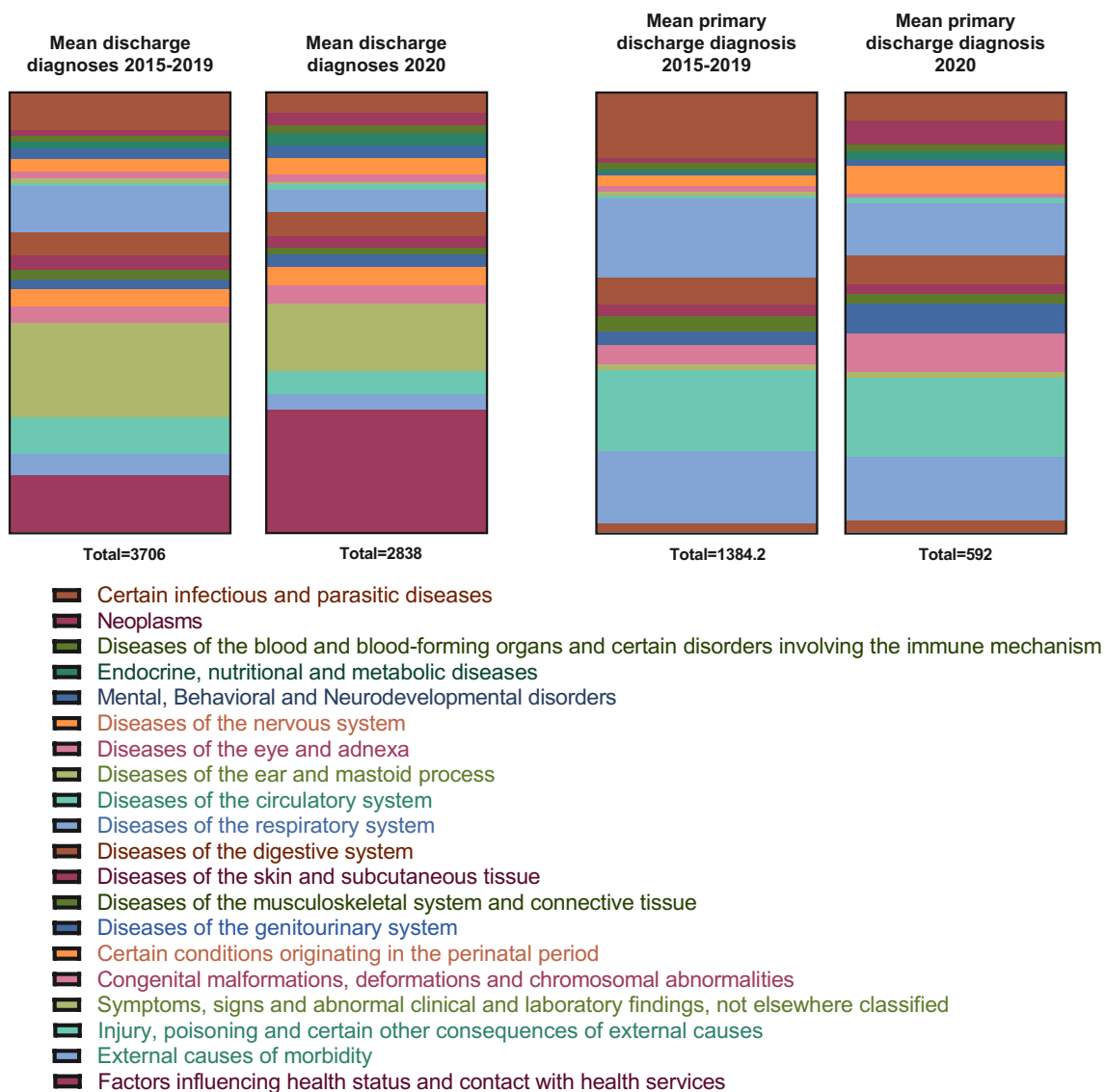


**Fig. 2** Changes in numbers of diagnoses made in 2020 compared to 2015–2019 by ICD-10 chapter. Diagnoses by ICD-10 chapter headings. Discharge diagnoses (maximum 10) are shown per week for the first national lockdown period ( $n = 7$  weeks, 2020), compared to matched periods during the previous 5 years ( $n = 35$  weeks, 2015–2019). Statistical results from Mann-Whitney  $U$  test. ns = not significant,  $*P < 0.05$ ,  $**P < 0.01$ ,  $***P < 0.001$ ,  $****P < 0.0001$

lockdown (Met Office UK, personal communication), reflected by increases in allergic rhinitis ( $p = 0.0828$ ) and allergic asthma ( $p = 0.0613$ ) amongst our data. Both asthma and wheezing are predominantly triggered by infection in children [20, 21], so were categorised as sequelae of infectious diseases. However, as these respiratory symptoms are also

affected by air quality and pollution [22, 23], which significantly improved during lockdown [24, 25] alongside reduced environmental contacts due to a ‘stay at home’ policy, multiple factors may have contributed to the reduced asthma and wheeze admissions we observed.

With reduced exposure to infections, parent/carer confidence may increase in treating mildly unwell children with non-specific temperature/pain/aches/malaise for longer periods. Consistent with this hypothesis is an Italian study demonstrating reductions of 84–92% in paediatric ED patients triaged as having ‘minor injuries not requiring a doctor’ during lockdown [6]. Furthermore, a US study demonstrated increased high-severity ED attenders at triage during a state-



**Fig. 3** Changes in relative proportions of diagnoses seen during the 2020 lockdown period. Differences in diagnoses by ICD-10 chapter headings for patients admitted during the first national lockdown period, compared to matched periods during the previous 5 years (2015–2019). Totals show

mean numbers for the matched lockdown period (2015–2019) or total number for 2020. Shown for all diagnoses given on discharge (left panels) and ‘primary’ diagnosis only (right panels)

**Table 1** ICD-10 diagnoses with significant changes during lockdown assigned to broad diagnostic groups

ICD-10 diagnosis	Admissions during lockdown period: 2015–2019 Median (range)	Admissions during lockdown period: 2020	Direction of change in admissions in 2020 (compared with 2015–2019)	Absolute change during lockdown compared to median 2015–2019	<i>P</i> value*
<b>Infective illnesses</b>					
Viral infection, unspecified	128 (122–164)	27	↓	−101	0.0000
Acute tonsillitis, unspecified	50 (36–58)	9	↓	−41	0.0001
Acute upper respiratory infection, unspecified	62 (54–76)	24	↓	−38	0.0005
Unspecified acute lower respiratory infection	54 (44–59)	22	↓	−32	0.0007
Acute bronchiolitis, unspecified	36 (18–47)	7	↓	−29	0.0006
Gastroenteritis and colitis of unspecified origin	46 (42–56)	18	↓	−28	0.0009
Viral intestinal infection, unspecified	22 (6–30)	1	↓	−21	0.0004
Otitis media, unspecified	21 (10–32)	5	↓	−16	0.0046
Acute obstructive laryngitis (croup)	17 (14–28)	1	↓	−16	0.0002
Varicella without complication	14 (3–21)	2	↓	−12	0.0285
Lobar pneumonia, unspecified	14 (9–25)	3	↓	−11	0.0045
Conjunctivitis, unspecified	8 (4–10)	1	↓	−7	0.0072
Acute nasopharyngitis (common cold)	6 (4–27)	0	↓	−6	0.0075
Meningitis in viral diseases classified elsewhere	5 (1–11)	0	↓	−5	0.0476
Acute lymphadenitis of face, head and neck	5 (1–10)	0	↓	−5	0.0291
Enteroviral meningitis	4 (1–7)	0	↓	−4	0.0459
Other specified bacterial intestinal infections	0 (0–0)	1	↑	1	0.0253
Whooping cough, unspecified	0 (0–0)	1	↑	1	0.0253
Other infectious mononucleosis	0 (0–0)	1	↑	1	0.0253
Enterovirus infection, unspecified site	0 (0–0)	1	↑	1	0.0253
Echinococcosis, other and unspecified	0 (0–0)	1	↑	1	0.0253
Coronavirus as the cause of diseases classified to other chapters	0 (0–0)	1	↑	1	0.0253
Typhoid fever	0 (0–0)	2	↑	2	0.0014
Salmonella enteritis	0 (0–0)	2	↑	2	0.0014
Superficial mycosis, unspecified	0 (0–1)	2	↑	2	0.0172
Other specified bacterial agents as the cause of diseases classified to other chapters	2 (1–5)	6	↑	4	0.0285
Sepsis due to other Gram-negative organisms	0 (0–5)	5	↑	5	0.0021
COVID-19, virus identified	0 (0–0)	5	↑	5	0.0000
Total Infective illnesses	494	148	↓	−346	N/A
<b>Likely sequelae of infective illness</b>					
Wheezing	105 (81–132)	20	↓	−85	0.0001
Nausea and vomiting	91 (69–129)	37	↓	−54	0.0003
Asthma, unspecified	70 (62–79)	20	↓	−50	0.0001
Fever, unspecified	93 (71–114)	61	↓	−32	0.0313
Rash and other nonspecific skin eruption	36 (31–51)	13	↓	−23	0.0006
Hypertrophy of tonsils	12 (4–34)	2	↓	−10	0.0102
Transient synovitis	10 (3–14)	1	↓	−9	0.0146
Mixed asthma	0 (0–0)	1	↑	1	0.0253
Renal and perinephric abscess	0 (0–0)	3	↑	3	0.0001
Total likely sequelae of infective illness	417	158	↓	−259	N/A
<b>Accidental injury/poisoning</b>					
Fall involving playground equipment	18 (10–28)	7	↓	−11	0.0362



**Table 1** (continued)

ICD-10 diagnosis	Admissions during lockdown period: 2015–2019 Median (range)	Admissions during lockdown period: 2020	Direction of change in admissions in 2020 (compared with 2015–2019)	Absolute change during lockdown compared to median 2015–2019	<i>P</i> value*
Unspecified injury of head	11 (7–25)	2	↓	–9	0.0069
Fracture of lower end of humerus	10 (4–14)	3	↓	–7	0.0203
Open wound of finger(s) with damage to nail	8 (3–11)	1	↓	–7	0.0099
Fracture of other finger	8 (4–12)	1	↓	–7	0.0064
Caught, crushed, jammed or pinched in or between objects	8 (7–11)	1	↓	–7	0.0039
Open wound of other parts of head	8 (5–14)	2	↓	–6	0.0324
Foreign body entering into or through eye or natural orifice	8 (6–9)	2	↓	–6	0.0086
Superficial injury of other parts of head	9 (7–20)	4	↓	–5	0.0390
Superficial injury of head, part unspecified	5 (2–10)	0	↓	–5	0.0376
Fall on and from stairs and steps	5 (3–7)	0	↓	–5	0.0037
Unspecified fall	6 (2–9)	1	↓	–5	0.0215
Hit, struck, kicked, twisted, bitten or scratched by another person	5 (3–7)	0	↓	–5	0.0220
Fall involving ice-skates, skis, roller-skates or skateboards	3 (2–8)	0	↓	–3	0.0284
Striking against or struck by sports equipment	3 (2–6)	0	↓	–3	0.0458
Striking against or struck by other objects	5 (5–10)	2	↓	–3	0.0382
Other injuries of eye and orbit	0 (0–0)	1	↑	1	0.0253
Multiple superficial injuries of shoulder and upper arm	0 (0–0)	1	↑	1	0.0253
Multiple open wounds of shoulder and upper arm	0 (0–0)	1	↑	1	0.0253
Dislocation of radial head	0 (0–0)	1	↑	1	0.0253
Sprain and strain of elbow	0 (0–0)	1	↑	1	0.0253
Multiple superficial injuries of lower leg	0 (0–0)	1	↑	1	0.0253
Other specified injuries of lower leg	0 (0–0)	1	↑	1	0.0253
Unspecified injury of lower limb, level unspecified	0 (0–0)	1	↑	1	0.0253
Poisoning: Benzodiazepines	0 (0–0)	1	↑	1	0.0253
Poisoning: Local antifungal, anti-infective and anti-inflammatory drugs, not elsewhere classified	0 (0–0)	1	↑	1	0.0253
Contact with other powered hand tools and household machinery	0 (0–0)	1	↑	1	0.0253
Discharge from other and unspecified firearms	0 (0–0)	1	↑	1	0.0253
Multiple superficial injuries of forearm	0 (0–1)	2	↑	2	0.0172
Toxic effect of soaps and detergents	0 (0–1)	2	↑	2	0.0172
Inhalation and ingestion of food causing obstruction of respiratory tract	0 (0–1)	2	↑	2	0.0172
Other specified injuries of hip and thigh	0 (0–0)	3	↑	3	0.0001
Total accidental injury/poisoning	120	47	↓	–73	N/A
Non-specific pains, aches, malaise					
Other and unspecified abdominal pain	35 (25–51)	7	↓	–28	0.0003
Headache	27 (24–30)	8	↓	–19	0.0009
Pain in joint	16 (10–20)	3	↓	–13	0.0011
Malaise and fatigue	17 (10–19)	6	↓	–11	0.0334
Pain in limb	7 (6–11)	1	↓	–6	0.0032

**Table 1** (continued)

ICD-10 diagnosis	Admissions during lockdown period: 2015–2019 Median (range)	Admissions during lockdown period: 2020	Direction of change in admissions in 2020 (compared with 2015–2019)	Absolute change during lockdown compared to median 2015–2019	<i>P</i> value*
Pain localized to upper abdomen	3 (2–7)	0	↓	–3	0.0356
Other symptoms and signs concerning food and fluid intake	3 (0–14)	0	↓	–3	0.0293
Total Non-specific pains, aches, malaise	108	25	↓	–83	N/A
Likely related to pandemic screening					
Observation for other suspected diseases and conditions	9 (7–15)	97	↑	88	0.0000
Special screening examination for other viral diseases	0 (0–0)	47	↑	47	0.0000
Total likely related to pandemic screening	9	144	↑	135	N/A
Likely incidental finding or co-morbidity					
Personal history of allergy, other than to drugs and biological substances	8 (2–38)	25	↑	17	0.0203
Family history of diseases of the respiratory system	1 (0–4)	17	↑	16	0.0000
Personal history of long-term (current) use of other medicaments	5 (1–8)	17	↑	12	0.0001
Cardiac murmur, unspecified	8 (1–13)	19	↑	11	0.0280
Family history of diabetes mellitus	3 (1–7)	14	↑	11	0.0111
Personal history of irradiation	0 (0–2)	10	↑	10	0.0001
Other transplanted organ and tissue status	1 (0–5)	11	↑	10	0.0029
Personal history of major surgery, not elsewhere classified	19 (13–21)	28	↑	9	0.0404
Family history of other endocrine, nutritional and metabolic diseases	1 (0–2)	9	↑	8	0.0014
Personal history of chemotherapy for neoplastic disease	4 (2–7)	12	↑	8	0.0091
Family history of diseases of the skin and subcutaneous tissue	1 (0–5)	8	↑	7	0.0036
Acidosis	7 (2–9)	13	↑	6	0.0064
Family history of other diseases of the genitourinary system	0 (0–5)	6	↑	6	0.0020
Personal history of allergy to other antibiotic agents	1 (1–5)	7	↑	6	0.0087
Personal history of allergy to other drugs, medicaments and biological substances	5 (0–10)	11	↑	6	0.0118
Family history of other infectious and parasitic diseases	1 (0–3)	6	↑	5	0.0043
Family history of other specified conditions	0 (0–1)	5	↑	5	0.0009
Personal history of endocrine, nutritional and metabolic diseases	0 (0–2)	5	↑	5	0.0001
Acquired absence of genital organ(s)	0 (0–2)	5	↑	5	0.0156
Haemangioma, any site	3 (1–4)	6	↑	3	0.0313
Abnormal results of cardiovascular function studies	0 (0–0)	3	↑	3	0.0014
Personal history of diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	0 (0–2)	3	↑	3	0.0062
Personal history of allergy to analgesic agent	0 (0–1)	3	↑	3	0.0062
Family history of eye and ear disorders	0 (0–1)	2	↑	2	0.0172
Personal history of other specified conditions	0 (0–1)	2	↑	2	0.0172
Personal history of allergy to anaesthetic agent	0 (0–0)	2	↑	2	0.0014
Personal history of allergy to narcotic agent	0 (0–0)	2	↑	2	0.0014

**Table 1** (continued)

ICD-10 diagnosis	Admissions during lockdown period: 2015–2019 Median (range)	Admissions during lockdown period: 2020	Direction of change in admissions in 2020 (compared with 2015–2019)	Absolute change during lockdown compared to median 2015–2019	P value*
Acquired absence of other organs	0 (0–0)	2	↑	2	0.0014
Abnormal findings on diagnostic imaging of liver and biliary tract	0 (0–0)	1	↑	1	0.0253
Total likely co-morbidity or incidental finding	68	254	↑	186	N/A
Other diagnoses					
Psychotherapy, not elsewhere classified	0 (0–15)	12	↑	12	0.0006
Essential (primary) hypertension	1 (0–3)	11	↑	10	0.0002
Dietary counselling and surveillance	1 (0–5)	11	↑	10	0.0002
Strabismus, unspecified	1 (0–4)	9	↑	8	0.0058
Malignant neoplasm: Cerebellum	0 (0–1)	7	↑	7	0.0000
Acute renal failure, unspecified	1 (1–3)	8	↑	7	0.0172
Other specified diabetes mellitus	0 (0–1)	6	↑	6	0.0036
Myopathy, unspecified	0 (0–0)	6	↑	6	0.0001
Unspecified appendicitis	1 (0–5)	7	↑	6	0.0007
Glucocorticoids and synthetic analogues	0 (0–0)	6	↑	6	0.0001
Bradycardia, unspecified	3 (1–5)	8	↑	5	0.0063
Combined immunodeficiency, unspecified	0 (0–4)	4	↑	4	0.0346
Atopic dermatitis, unspecified	0 (0–1)	4	↑	4	0.0140
Other specified disorders of male genital organs	2 (0–4)	6	↑	4	0.0464
Other specified congenital malformations of heart	0 (0–1)	4	↑	4	0.0001
Congenital hydronephrosis	1 (0–2)	5	↑	4	0.0328
Follow-up examination after unspecified treatment for other conditions	0 (0–3)	4	↑	4	0.0069
Malignant neoplasm of other and ill-defined sites: Abdomen	0 (0–4)	3	↑	3	0.0244
Secondary malignant neoplasm of lung	2 (0–2)	5	↑	3	0.0047
Other and unspecified adrenocortical insufficiency	1 (0–3)	4	↑	3	0.0075
Obsessive-compulsive disorder, unspecified	0 (0–3)	3	↑	3	0.0244
Polyneuropathy, unspecified	0 (0–0)	3	↑	3	0.0001
Pre-excitation syndrome	0 (0–0)	3	↑	3	0.0001
Other specified disorders of nose and nasal sinuses	0 (0–1)	3	↑	3	0.0156
Chronic periodontitis	0 (0–0)	3	↑	3	0.0014
Congenital absence of ovary	0 (0–0)	3	↑	3	0.0001
Undescended testicle, bilateral	0 (0–1)	3	↑	3	0.0011
Ataxic gait	0 (0–1)	3	↑	3	0.0156
Other complications of procedures, not elsewhere classified	0 (0–1)	3	↑	3	0.0062
Malignant neoplasm: Connective and soft tissue of head, face and neck	0 (0–0)	2	↑	2	0.0014
Malignant neoplasm: Spinal cord	0 (0–0)	2	↑	2	0.0014
Secondary malignant neoplasm of brain and cerebral meninges	0 (0–0)	2	↑	2	0.0014
Other adrenocortical overactivity	0 (0–0)	2	↑	2	0.0253
Tic disorder, unspecified	0 (0–0)	2	↑	2	0.0014
Spinal muscular atrophy, unspecified	0 (0–2)	2	↑	2	0.0211
Syringomyelia and syringobulbia	0 (0–1)	2	↑	2	0.0172

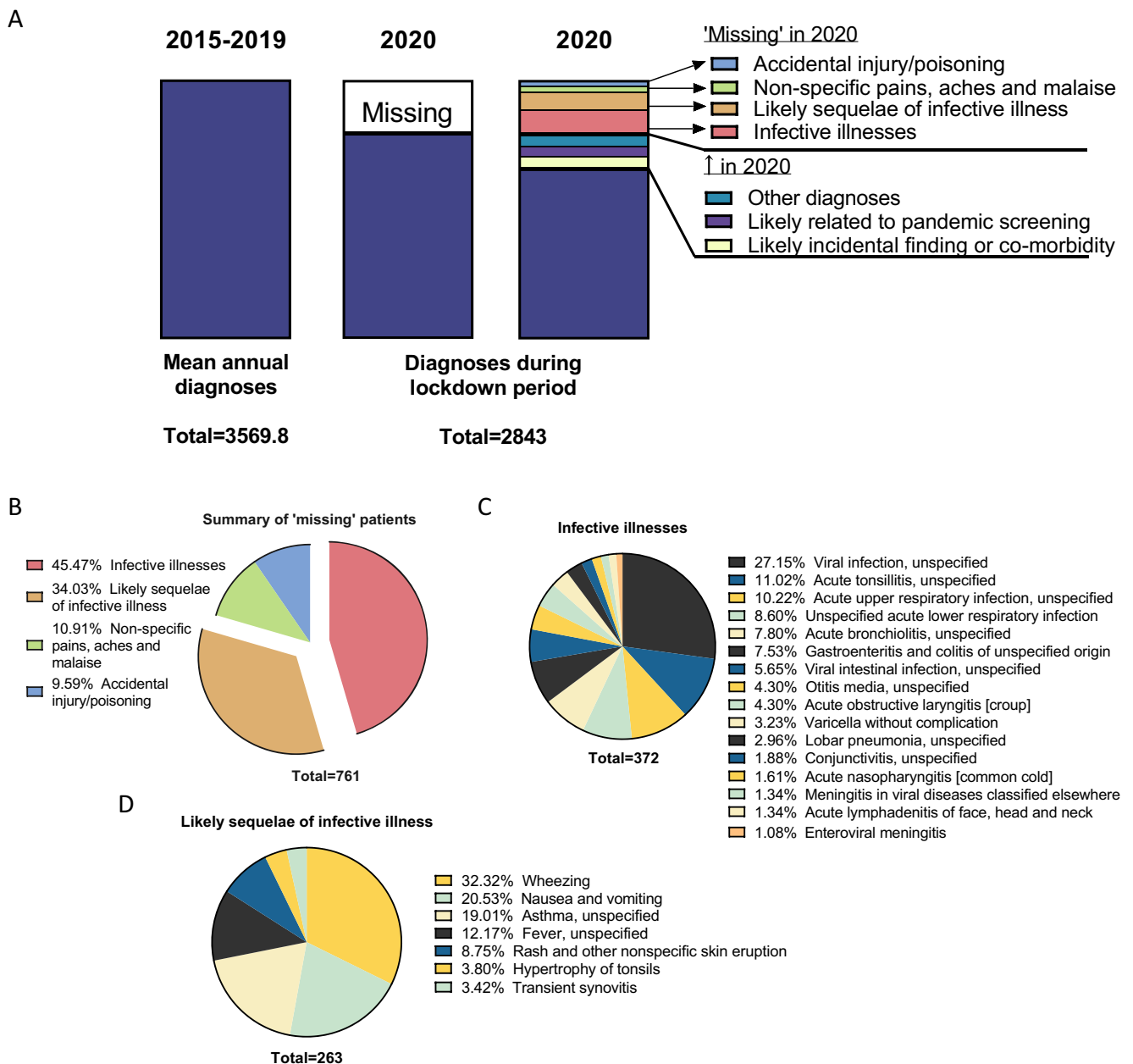
**Table 1** (continued)

ICD-10 diagnosis	Admissions during lockdown period: 2015–2019 Median (range)	Admissions during lockdown period: 2020	Direction of change in admissions in 2020 (compared with 2015–2019)	Absolute change during lockdown compared to median 2015–2019	<i>P</i> value*
Other specified diseases of spinal cord	0 (0–0)	2	↑	2	0.0014
Intracerebral haemorrhage, intraventricular	0 (0–0)	2	↑	2	0.0014
Respiratory failure, unspecified - Type unspecified	0 (0–0)	2	↑	2	0.0014
Pilonidal cyst without abscess	0 (0–1)	2	↑	2	0.0172
Acne, unspecified	0 (0–1)	2	↑	2	0.0172
Other specified intervertebral disc displacement	0 (0–0)	2	↑	2	0.0014
Neuralgia and neuritis, unspecified	0 (0–0)	2	↑	2	0.0014
Other specified disorders of kidney and ureter	2 (0–3)	4	↑	2	0.0408
Disorder of male genital organs, unspecified	0 (0–0)	2	↑	2	0.0014
Other specified congenital malformations of brain	1 (0–2)	3	↑	2	0.0442
Cervical spina bifida with hydrocephalus	0 (0–0)	2	↑	2	0.0014
Cleft soft palate	0 (0–0)	2	↑	2	0.0253
Hypospadias, balanic	0 (0–0)	2	↑	2	0.0014
Haemoptysis	0 (0–1)	2	↑	2	0.0172
Ataxia, unspecified	0 (0–1)	2	↑	2	0.0172
Hyperglycaemia, unspecified	0 (0–1)	2	↑	2	0.0172
Glycosuria	0 (0–0)	2	↑	2	0.0014
Removal from home in childhood	0 (0–0)	2	↑	2	0.0253
Diagnoses occurring only once in 2020 <i>n</i> = 63**	0 (0–0)	1	↑	63	0.0253
Other specified soft tissue disorders	4 (1–6)	0	↓	−4	0.0450
Neuromuscular dysfunction of bladder, unspecified	4 (2–10)	0	↓	−4	0.0166
Retention of urine	4 (3–9)	0	↓	−4	0.0224
Intentional self-harm by sharp object	4 (0–9)	0	↓	−4	0.0285
Hypoglycaemia, unspecified	8 (6–17)	3	↓	−5	0.0150
Cerebral palsy, unspecified	5 (4–7)	0	↓	−5	0.0124
Down's syndrome, unspecified	7 (3–10)	2	↓	−5	0.0405
Haemorrhage and haematoma complicating a procedure, not elsewhere classified	8 (6–12)	1	↓	−7	0.0195
Removal of other organ (partial) (total)	9 (8–13)	2	↓	−7	0.0095
Anorexia	10 (1–30)	1	↓	−9	0.0048
Other and unspecified convulsions	20 (14–40)	10	↓	−10	0.0254
Spontaneous ecchymoses	32 (22–36)	2	↓	−30	0.0001
Total other diagnoses	132	294	↑	162	N/A

Table of changes in numbers of admissions between the first national lockdown period in 2020 and matched period during the previous years for differences which reached significance ( $p < 0.05$ ). Diagnoses are divided into categories of infective illnesses, likely sequelae of infective illness, accidental injury, nonspecific pains/aches/malaise, likely related to pandemic screening, likely incidental finding, or co-morbidity and other diagnoses. \**P* value calculated using admissions per week with given diagnosis for the 7 weeks of lockdown (2020) or the matched 7 weeks in each of 2015–2019 ( $n = 35$  weeks). *P* values represent independent-samples Kruskal-Wallis test, controlled for multiple comparisons with stepwise step-down.  $P < 0.05$  were taken as significant and are highlighted in bold. \*\*Diagnoses which occurred only once (all in 2020) were redacted for clarity; these are all fully stated in supplemental table 3,  $n = 63$  individual diagnoses met this category

wide stay-at-home period compared to the previous 3 years [12], suggesting low severity patients were kept at home. A small proportion of children may have not been brought to

hospital due to documented anxieties surrounding hospital attendance during the pandemic [26], although current evidence suggests this group is small or negligible [27].



**Fig. 4** Comparing diagnoses made in 2015–2019 to 2020, identifies ‘missing’ diagnoses of the first UK lockdown. The ‘missing’ patients are shown (white bar) as difference in mean annual diagnoses examined in 2015–2019 (A–left panel), against all diagnoses made in 2020 (A–middle panel). All ICD-10 diagnoses during the first national lockdown period in 2020 and matched dates in 2015–2019 are shown only where the diagnosis occurred annually (mean  $\geq 1$ ) in 2015–2019, or at least once in 2020,  $n = 1117$  ICD-10 codes. Net changes for diagnostic groups with

significant increases in diagnoses in 2020 and decreases (‘missing’) in 2020 are shown (A–right panel). The breakdown of ‘missing’ diagnoses (groups with a net significant decrease in diagnoses during the first 2020 lockdown period compared to 2015–2019) are shown by assigned group (B). The proportions of individual diagnoses which had a net decrease are shown amongst infective illnesses (C) and likely sequelae of infective illness (D)

Reassuringly, a national study across Scotland found no difference in childhood inpatient mortality during lockdown, compared to the previous four years [14]. Therefore, reductions in infectious disease-related admissions likely result from (1) reduced infectious disease burden due to COVID-19 public health measures, (2) tolerating/monitoring children

with mild and self-limiting illness at home due to greater parental supervision whilst locked down and/or information campaigns to avoid unnecessary healthcare utilisation, and (3) healthcare anxieties during the COVID-19 pandemic.

Non-specific pains/aches/malaise were significantly reduced during lockdown, many of which are likely benign

and self-limiting. An Italian study also demonstrated significant reductions of children brought to ED with pain during lockdown [10]. We reiterate these authors' concern that a proportion of these non-attenders may have concerning or red flag features, including safeguarding concerns.

Increased parental supervision, school closures, fewer opportunities for sports, and playground closures may account for the 9.6% reduction in accidental injuries/poisonings. Findings internationally support the reductions of all fractures [11, 28, 29], accidental injuries/poisoning [5, 8], and burns [30] during lockdowns. Our data corroborated a decrease in superficial injuries and lacerations, fractures, falls, and accidental poisoning, with a 74.5% reduction in childhood injuries. It remains of concern that some children who sustain injuries are not brought to medical attention but may later transpire to be more serious, requiring social/forensic or safeguarding investigations.

## Recommendations

We propose communication pathways which

- (1) Establish the duration and nature of symptom morbidity, and level of parent/carer anxiety, prior to patients attending for emergency care, to provide feedback and reinforce health education;
- (2) Improve the immediacy of 'telemed' health advice, empowering parents/carers in managing mild and self-limiting illnesses at home;
- (3) Promote health information for parents/carers of children of all ages, including raising awareness of red flag symptoms, and alleviating healthcare anxieties throughout the pandemic.

## Conclusions

Oxfordshire paediatric ED attendances and hospital admissions were markedly reduced by up to 62% during the first 2020 lockdown. By controlling for the activity within one region and using five historical years, our data encompasses the use of steady demographics and natural behaviours of the population when utilising emergency services over the 6-year study period, and better controls for year-to-year fluctuations.

By using hypothesis-independent standardised ICD-10 diagnostic codes, our findings demonstrate infectious diseases, or their sequelae, account for the majority (80%) of reductions in paediatric inpatients during lockdown. This is likely driven by reductions in infectious disease transmission due to public health measures. A further 20% of 'missing' diagnoses were accidental injuries/poisonings or non-specific pains/aches/malaise. We postulate that some 'missing' presentations may

represent patients with concerning or evolving conditions, safeguarding concerns, and require attention but did not present to healthcare services. Hence, we emphasise that some children with concerning features of physical, social emotional, or mental illness may be missed.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s00431-021-04123-x>.

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**Authors' contributions** JEGC conceived and designed the study, collated and analysed the data, generated the figures/tables, drafted the manuscript, and revised the manuscript. RB assisted with study design and data analysis, revised, and critically reviewed the manuscript. RP provided senior speciality input, revised, and critically reviewed the manuscript. All authors verify the underlying data used for analysis. All authors approved the final manuscript.

**Data Availability** Raw data from this study can be made available to interested parties on request. All data sharing requests will require approval from Oxford University Hospitals NHS Foundation Trust prior to release. Data screening will be required prior to release, to ensure no individual patient can be identified.

## Declarations

**Ethics approval/Consent to participate/Consent for publication** Data was gathered for clinical audit purposes following the first national lockdown. Trust procedures were followed for access to anonymised patient data, completed in May 2020. This study does not meet criteria set out by the NHS Health Research Authority for requiring research ethics committee review and approval.

**Conflict of interest** The authors declare no competing interests.

**Abbreviations** CNS, Central nervous system; COVID-19, Coronavirus Disease 2019; ED, Emergency Department; ICD-10, International Statistical Classification of Diseases and related health problems 10; LOS, Length of stay; SARS-CoV-2, Severe Acute Respiratory Syndrome Coronavirus 2; UK, United Kingdom; US, United States; USA, United States of America

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