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Confirmed SARS-CoV-2 infection in Scottish neonates 2020–2022: a national, population-based cohort study

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ABSTRACT

Objectives To examine neonates in Scotland aged 0–27 days with SARS-CoV-2 infection confirmed by viral testing; the risk of confirmed neonatal infection by maternal and infant characteristics; and hospital admissions associated with confirmed neonatal infections.

Design Population-based cohort study.

Setting and population All live births in Scotland, 1 March 2020–31 January 2022.

Results There were 141 neonates with confirmed SARS-CoV-2 infection over the study period, giving an overall infection rate of 153 per 100 000 live births (141/92 009, 0.15%). Among infants born to women with confirmed infection around the time of birth, the confirmed neonatal infection rate was 1812 per 100 000 live births (15/828, 1.8%). Two-thirds (92/141, 65.2%) of neonates with confirmed infection had an associated admission to neonatal or (more commonly) paediatric care. Six of these babies (6/92, 6.5%) were admitted to neonatal and/or paediatric intensive care; however, none of these six had COVID-19 recorded as their main diagnosis. There were no neonatal deaths among babies with confirmed infection.

Implications and relevance Confirmed neonatal SARS-CoV-2 infection was uncommon over the first 23 months of the pandemic in Scotland. Secular trends in the neonatal confirmed infection rate broadly followed those seen in the general population, although at a lower level. Maternal confirmed infection at birth was associated with an increased risk of neonatal confirmed infection. Two-thirds of neonates with confirmed infection had an associated admission to hospital, with resulting implications for the baby, family and services, although their outcomes were generally good. Ascertainment of confirmed infection depends on the extent of testing, and this is likely to have varied over time and between groups: the extent of unconfirmed infection is inevitably unknown.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ SARS-CoV-2 infection in neonates appears uncommon, but some studies have suggested that neonates are at higher risk than older children of severe infection.

⇒ Population-based data on neonates with confirmed infection are lacking: most studies to date have only included babies of infected mothers or those admitted to the hospital.

WHAT THIS STUDY ADDS

⇒ Confirmed SARS-CoV-2 infection in all neonates in Scotland from 1 March 2020 to 31 January 2022 was uncommon, occurring in 0.15% (141/92 009) of live births.

⇒ Confirmed maternal SARS-CoV-2 infection around the time of birth was associated with an increased risk of confirmed neonatal infection at 1.8% (15/828) of live births.

⇒ 65.2% (92/141) of neonates with confirmed infection had an associated hospital admission with 6.5% (6/92) involving neonatal/paediatric intensive care: there were no neonatal deaths.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Ascertainment of confirmed infection depends on the extent of testing, and this is likely to have varied over time and between groups.

⇒ Continued data collection and vigilance will be important to assess the ongoing impact of SARS-CoV-2 in the neonatal population as the pandemic evolves.

INTRODUCTION

Confirmed neonatal infection with SARS-CoV-2, defined as a positive viral test in the first 27 days after birth, is uncommon.[1–4] A UK study identified 66 neonates with confirmed infection admitted to the hospital between 1 March and 30 April 2020, giving an estimated infection/admission rate of 5.6/10 000 live births.[1] Less than 2% of babies born to women with confirmed infection around the time of birth develop confirmed infection themselves.[5] However, babies born to women with confirmed infection are more likely to be born prematurely or be admitted to the neonatal unit, regardless of infant SARS-CoV-2 status.[5–8] Neonates with confirmed

infection can develop severe disease; however, reports on the proportion of SARS-CoV-2 positive neonates requiring admission to intensive care vary, depending on the definition of intensive care.[1 2 9 10]

To date, most neonatal SARS-CoV-2 studies have focused on the risk and consequences of transmission to the neonate from an infected mother.[5 11] However, in the neonatal period, babies are exposed to multiple other potential sources of infection, for example, other caregivers and healthcare professionals. Previous studies have included neonates admitted to the hospital with a positive SARS-CoV-2 test[1]; however, population-level data including those testing positive in the community are lacking.[4] The aim of this study was to examine all confirmed cases of SARS-CoV-2 infection in infants aged 0–27 days in Scotland from 1 March 2020 to 31 January 2022.

METHODS

Study population

Detailed methods are provided as online supplemental material. In brief, data were obtained from the 'COVID-19 in Pregnancy in Scotland' (COPS) study dataset.[12 13] COPS contains data on all ongoing and completed pregnancies to women in Scotland, and liveborn babies resulting from those pregnancies, from 1 January 2015 onwards linked to information on SARS-CoV-2 viral testing, admissions to neonatal and paediatric care, and deaths.[12] For this study, we included all live births in Scotland between 1 March 2020 and 31 January 2022 with a valid Community Health Index (CHI) number available within the COPS dataset.

Identifying confirmed SARS-CoV-2 infections

COPS includes information on all positive SARS-CoV-2 viral tests undertaken on women and babies within the cohort.[12 14] Up to and including 5 January 2022, confirmed SARS-CoV-2 infection was defined as a positive viral reverse transcription–polymerase chain reaction (RT-PCR) test result. From 6 January 2022 onwards, confirmed infection was defined as a positive viral RT-PCR or a positive lateral flow device (LFD) test (unless the positive LFD result was followed by a negative RT-PCR result within 48 hours). For any individual, the date that their first positive test sample was taken was used as the date of onset of their first episode of infection. Confirmed neonatal infection was defined as a positive test with date of onset from birth to 27 days old inclusive. Maternal infection at the time of birth was defined as a confirmed infection with date of onset in the 14 days leading to birth, on the day of birth or the day after giving birth.

For all babies with confirmed neonatal infection, data were obtained from the COPS database regarding the age of the baby in days at date of onset of infection; maternal age, socioeconomic level, ethnicity, and infection status at the time of birth: and the baby's sex and gestation at birth. Maternal socioeconomic level was based on the Scottish Index of Multiple Deprivation quintile.[15]

Identifying hospital admissions associated with confirmed neonatal SARS-CoV-2 infection

A hospital admission associated with confirmed neonatal SARS-CoV-2 infection was defined as an admission of a baby with confirmed neonatal infection to neonatal or paediatric care (1) where the date of onset of infection was in the 7 days prior to, or during, the admission (hence date of admission at up to 27+7=34 days old inclusive), or (2) where the admission occurred at any point in the neonatal period (hence date of admission at up to 27 days old inclusive) if COVID-19 was recorded as the main diagnosis (International Classification of Diseases, 10th Revision, code U07.1 or U07.2). An 'admission' was defined as an entire hospital stay from admission to discharge. The main diagnosis was taken from the first episode of care during an admission.[16]

Admissions to neonatal units were identified through the Scottish Birth Record[17] and admissions to paediatric wards through hospital inpatient and day-case discharge records (SMR01[18]). SARS-CoV-2-associated admission records were analysed to identify the highest level of care provided in the neonatal unit or whether they included an episode in a paediatric intensive care unit (PICU) ('significant facility' coded to 13[19]), length of stay, whether COVID-19 was listed as the main diagnosis and whether the infection was likely to be nosocomial. A probable nosocomial infection was defined as when the first positive viral test was taken on day 7 or later of an ongoing admission.

Calculation of rates and CIs

All data reported here are descriptive only with no formal statistical comparisons. Rates were calculated using the number of babies with confirmed neonatal infection and the total number of live births during the study time period. The CIs were calculated using Wilson score estimates. The analysis and generation of figures were carried out using R V.3.6.1 and RStudio V.1.1.463, and codes are available online (https://github.com/Public-Health-Scotland/COPS-public.git).

RESULTS

Overall, 92 032 live births in Scotland between 1 March 2020 and 31 January 2022 were included in the COPS dataset, of whom 92 009 had a valid CHI number. One-hundred and forty-two neonates with confirmed SARS-CoV-2 were identified from the national viral testing data. Of these, 141 neonates were within the COPS cohort and were included in the analysis. The remaining baby was presumed to have been born outside of Scotland and was excluded.

Neonatal infection rates

Across the study period, the overall neonatal confirmed SARS-CoV-2 infection rate was 153 per 100 000 live births; however, this varied by month from 0 to 665 per 100 000 live births (figure 1A and online supplemental table S1). For context, figure 1B shows the neonatal confirmed infection rate alongside the rates for older children (drawing on other population-based data held by Public Health Scotland) (online supplemental table S2). The neonatal infection rate was consistently the lowest, though all paediatric age groups showed similar peaks of infection in autumn 2021 and December 2021/January 2022. The monthly rates of confirmed infection in pregnant women are presented in online supplemental table S3.

Infant and maternal characteristics and confirmed neonatal SARS-CoV-2 infection

The infant and maternal characteristics of neonates with confirmed SARS-CoV-2 infection are shown in tables 1 and 2. Rates of confirmed neonatal infection were highest among babies born to younger women and to women from more deprived areas, although CIs overlapped. Rates of confirmed neonatal infection among babies born to women from minority ethnic groups were uncertain due to low numbers. The rate of confirmed neonatal infection was substantially higher in babies born to women with (compared with without) confirmed

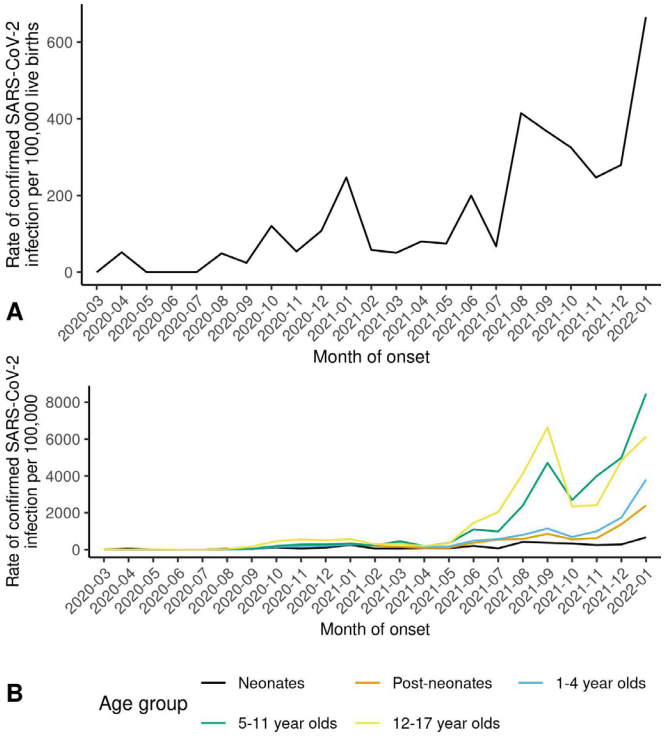

Figure 1 Scotland, March 2020–January 2022. (A) Monthly rate of confirmed SARS-CoV-2 infection in neonates (babies aged 0–27 days) per 100 000 live births. (B) Monthly rates of confirmed SARS-CoV-2 infection in neonates, postneonates (babies aged 28–364 days) and children aged 1–4 years, 5–11 years and 12–17 years per 100 000 live births (neonates) or population (older age groups). For further details on data sources and estimates, see online supplemental table S2.

infection at the time of birth; however, the absolute risk of confirmed neonatal infection was low in both groups (table 2).

Age in days at date of first positive test

The incidence of confirmed infection over the neonatal period followed a linear trend (figure 2 and online supplemental table S4). Of the 15 babies with confirmed neonatal infection who were born to a woman with confirmed infection at birth, none tested positive at <2 days of age, 9 first tested positive between days 2 and 7, and 6 on day 8 or later. Thus, none of these babies met the WHO criteria for confirmed or possible in utero or intrapartum transmission, and would be classified as 'indeterminate' status for early postnatal SARS-CoV-2 maternal to child transmission.[11]

Hospital admission and outcomes of babies with confirmed neonatal SARS-CoV-2 infection

Of the 141 babies with confirmed neonatal infection, 92 (92/141, 65.2%) had a total of 101 admissions to neonatal and/or paediatric care that were temporally associated with their positive SARS-CoV-2 test (first positive test taken in the 7 days prior to, or during, the admission). There were no additional associated admissions in the neonatal period with COVID-19 coded as the main diagnosis that did not meet the temporal association criteria.

None of the six SARS-CoV-2-associated admissions to a neonatal unit had COVID-19 coded as the main diagnosis, and three involved probable nosocomial infection. By contrast, 66% (64/97) of the SARS-CoV-2-associated admissions to paediatric care had COVID-19 coded as the main diagnosis, and only one involved probable nosocomial infection. Six of the babies with an associated admission (6/92, 6.5%) had a total of six admissions involving an episode of care in neonatal and/or paediatric intensive care (with two involving a transfer between neonatal and paediatric intensive care). None of these admissions had COVID-19 coded as the main diagnosis (table 3). Over the 23-month study period, the proportion of babies with confirmed neonatal infection that were admitted to hospital remained broadly consistent (online supplemental table S5 and online supplemental figure S1).

There were no neonatal deaths among the 141 babies with confirmed neonatal infection. The background neonatal mortality rate in March 2020–January 2022 was 2.2/1000 live births (206/91 864, 95% CI 2.0 to 2.6) among uninfected babies.

DISCUSSION

These results show that confirmed neonatal SARS-CoV-2 infection was uncommon in Scotland over the first 23 months of the pandemic, with only 141 neonates having confirmed infection between 1 March 2020 and 31 January 2022. The secular trend in the confirmed neonatal infection rate followed that seen in older age groups, although at much lower levels. Factors associated with higher infection rates among pregnant women, such as young maternal age and living in a more deprived area, were associated with higher neonatal infection rates. The rate of confirmed neonatal infection was significantly higher in babies born to women with (compared with without) confirmed infection at the time of birth. Two-thirds of neonates with confirmed SARS-CoV-2 infection had an associated hospital admission, primarily to paediatric care. However, only 6.5% of admitted babies required intensive care, and none of these babies had COVID-19 coded as their main diagnosis. There were no neonatal deaths among babies with confirmed infection.

Table 1 Infant characteristics and confirmed neonatal SARS-CoV-2 infection

	Total live births (n)	Neonates SARS-CoV-2 positive (n)	Rate per 100 000 live births	Lower CI	Upper CI
Infant sex					
Male	47 232	79	167	133	210
Female	44 777	62	138	107	179
Gestation at birth					
Preterm (22–36 weeks)	7231	17	235	142	385
Earlier preterm (22–33 weeks)	1946	3	154	40	490
Later preterm (34–36 weeks)	5285	14	265	151	456
Term+ (37–44 weeks)	84 735	124	146	122	175
Unknown	43	0	–	–	–
Total	92 009	141	153	129	181

Table 2 Maternal characteristics and confirmed neonatal SARS-CoV-2 infection

	Total live births (n)	Neonates SARS-CoV-2 positive (n)	Rate per 100 000 live births	Lower CI	Upper CI
Maternal age (years)					
≤19	3248	12	369	200	664
20–24	12 886	26	202	135	300
25–29	26 723	41	153	111	210
30–34	30 837	47	152	113	204
35–39	15 471	12	78	42	140
≥40	2744	3	109	28	348
Unknown	100	0	–	–	–
Maternal deprivation level (SIMD quintile)					
1—most deprived	21 189	47	222	165	298
2	18 501	29	157	107	228
3	16 860	21	125	79	194
4	19 374	26	134	90	200
5—least deprived	16 018	18	112	69	181
Unknown	67	0	–	–	–
Maternal ethnicity					
White	77 481	118	152	127	183
South Asian	3073	8	260	121	534
Black/Caribbean/African	1431	3	210	54	666
Mixed or other ethnic group	3222	5	155	57	384
Unknown	6802	7	103	45	222
Maternal SARS-CoV-2 infection status at birth					
Confirmed SARS-CoV-2 infection	828	15	1812	1055	3042
No confirmed SARS-CoV-2 infection	91 181	126	138	116	165
Total	92 009	141	153	129	181

SIMD, Scottish Index of Multiple Deprivation.

These data align with previous studies on admission rates for neonatal SARS-CoV-2[1 4] and give an insight into the total burden of confirmed neonatal infection in the UK. A strength of this study is that it takes a population-level view of neonatal SARS-CoV-2 infection, rather than confining results to only those born to infected women, or only those admitted to hospital. Our data also encompass almost 2 years of the pandemic, including the emergence of new viral variants and the introduction of COVID-19 vaccines. In keeping with published rates,[5] we found just under 2% of babies born to women with confirmed infection at the time of birth had confirmed neonatal infection. Not all babies of infected women were tested (see further), and rates may have been higher if all were screened.[20]

This was an observational study, with cases of confirmed infection identified through the results of 'real-world' testing carried out in the community and hospitals across Scotland. Not all babies will have been tested, and some infections may therefore have been missed. The extent of unconfirmed infection is inevitably unknown. The proportion of all infections that are confirmed will be influenced by the extent of testing, and this is likely to have varied over time and between groups.

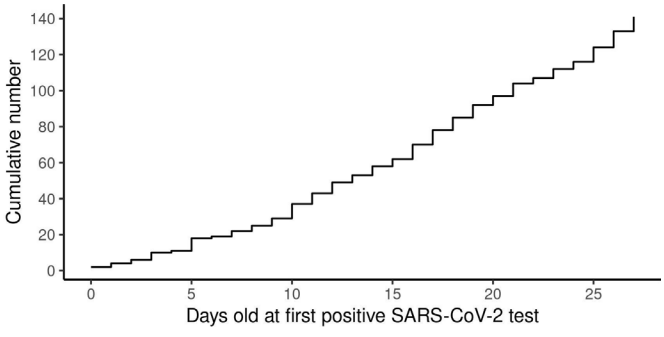

Figure 2 Cumulative number of confirmed SARS-CoV-2 infections in neonates by age at time of first positive test.

During the study period, infants may have been tested due to having clinical signs of infection, having contact with a case, or as part of routine hospital admission testing.[21] Around half of neonates with SARS-CoV-2 infection appear well or show mild clinical signs which may not prompt testing.[1 2 10 22–25] Scottish policy recommended testing of all emergency hospital admissions (including to paediatric and maternity care) from early December 2020.[26] Guidance on testing of neonates varies between countries.[22] In the UK, professional guidance on testing in neonatal care in place throughout our study period recommended testing babies born to mothers with confirmed infection who required admission, those readmitted from the community, those with clinically suspected COVID-19 and weekly testing for those receiving respiratory support. Testing neonates less than 72 hours old was not recommended due to difficulties interpreting results. Routine testing of newborns, including those born to mothers with confirmed infection, who were well and remained in postnatal settings was not recommended.[27] Access to community-based RT-PCR testing became widely available (including for children) from August 2020 and free home LFD testing was available from April 2021.

It is likely that over the study period, babies showing more severe clinical signs, those born to mothers with confirmed infection and those admitted to neonatal or paediatric care (for whatever reason) are more likely to have undergone testing, and hence ascertainment of confirmed infection is likely to have

Table 3 Hospital admissions temporally associated with a positive SARS-CoV-2 test among babies with confirmed neonatal infection

	COVID-19 coded as main diagnosis		
	Yes	No	All
Admissions to neonatal unit (n=6)			
Maximum level of care			
Intensive care	0	2	2
High dependency or special care only	0	4	4
Probable nosocomial infection			
Yes	0	3	3
No	0	3	3
Total	0	6	6
Mean LOS in days (median, lower–upper quartile)	NA	28.8 (22.5, 17.0–34.8)	28.8 (22.5, 17.0–34.8)
Admissions/transfers to paediatric care (n=97)			
Maximum level of care			
PICU	0	6	6
No PICU	64	27	91
Probable nosocomial infection			
Yes	0	1	1
No	64	32	96
Total	64	33	97
Mean LOS in days (median, lower–upper quartile)	1.6 (1, 0.8–2.3)	4.1 (2, 1–3)	2.4 (1, 1–3)

There were 101 separate admissions to neonatal or paediatric care of 92 neonates (two admissions involved a transfer from neonatal to paediatric intensive care).
PICU, paediatric intensive care unit; LOS, length of stay; NA, not applicable.

been more complete in these groups. However, this is unlikely to account for the greater than 10-fold increased risk of confirmed neonatal infection seen in babies born to mothers with confirmed infection at the time of birth.

Reassuringly, we demonstrate that the clinical outcomes of neonates with confirmed SARS-CoV-2 infection are good, with no deaths and no intensive care admissions for which COVID-19 was the main diagnosis. Other studies have recorded higher rates of critical care admissions; Swann reported that up to 33% of UK neonates with confirmed infection early in the pandemic required critical care,[9] and a subsequent study over a longer period found that 20% of neonates required critical care.[25] However, these studies only included admitted babies, and the definition of critical care included admission to a PICU or any level of care in a neonatal unit.[25] Our data suggest that a much lower proportion of neonates with SARS-CoV-2 infection truly require intensive care.

Despite these positive outcomes, around two-thirds (92/141, 65.2%) of neonates with confirmed SARS-CoV-2 infection had a temporally associated hospital admission. This is perhaps not surprising, as fever is a common sign of SARS-CoV-2 infection in neonates,[1 2 10 20 23 24 28] and according to UK guidelines,[29] a temperature above 38°C should prompt blood and urine tests, lumbar puncture and intravenous antibiotics. This demonstrates the indirect effects of SARS-CoV-2 on infants who may receive invasive investigations and treatments aimed at potential bacterial infections. This study was limited in that detailed information on signs and treatments received in hospital was lacking. However, detailed information on the care of babies admitted with SARS-CoV-2 early in the pandemic in the UK is available.[30]

In summary, confirmed SARS-CoV-2 infection in neonates was uncommon over the first 23 months of the pandemic in Scotland. Two-thirds of neonates with confirmed infection had an associated hospital admission. There were no neonatal deaths among babies with confirmed infection. Continued vigilance will be important to assess the ongoing impact of SARS-CoV-2 in the neonatal population as testing, isolation requirements and vaccination programmes continue to evolve, and new viral variants emerge.

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Competing interests CG and JJK are lead investigators for the British Paediatric Surveillance Unit study 'Neonatal complications of COVID-19' and coinvestigators for the 'SARS-CoV-2 infection in neonates or in pregnancy: outcomes at 18 months (SINEPOST)' study.

Patient consent for publication Not applicable.

Ethics approval COPS has ethical approval from the National Research Ethics Service Committee, South East Scotland 02 (REC 12/SS/0201: SA 2) and information governance approval from the Public Benefit and Privacy Panel for Health and Social Care (2021–0116). A preanalysis study protocol was developed and is available online (https://github.com/Public-Health-Scotland/COPS-public.git). RECORD[31] and STROBE[32] were used to guide reporting.

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Confirmed SARS-CoV-2 infection in Scottish neonates 2020-2022: a population-based cohort study

Supplementary data and figures

Supplementary methods

Study population

We derived and analysed data from the "COVID-19 in Pregnancy in Scotland" (COPS) study dataset as updated in mid-May 2022. The COPS dataset is described in detail elsewhere (1, 2). In brief, it comprises a population-based, dynamic cohort which includes data on all ongoing and completed pregnancies to women in Scotland, and live born babies resulting from those pregnancies, from 1 January 2015 onwards. The dataset is based on linkage of health service and statutory national datasets, including those relating to pregnancy-related care and births, SARS-CoV-2 viral testing and COVID-19 vaccinations, admissions to neonatal and paediatric care, and deaths (1). All individuals in Scotland who receive care from the National Health Service (NHS) (which will include essentially all pregnant women and neonates as there is no private maternity care in Scotland) are assigned a unique patient identifier, the Community Health Index (CHI) number (3) which allows for linkage of medical records relating to an individual. Within the COPS database, the CHI number for both the mother and the baby are included on NHS live birth notification records, further allowing intergenerational linkage of records relating to mothers and their babies. For this study, we included all live born babies born in Scotland between 1st March 2020 and 31st January 2022 who had a valid CHI number available within the COPS dataset.

Identifying confirmed SARS-CoV-2 infections

COPS includes information on all positive SARS-CoV-2 viral tests undertaken on women and babies within the cohort from the NHS Scotland Corporate Data Warehouse. The warehouse includes results of all Reverse Transcription Polymerase Chain Reaction (RT-PCR) SARS-CoV-2 tests processed

through NHS Scotland and UK Government Regional Testing Centre ('Lighthouse') laboratories. It also includes information on all SARS-CoV-2 Lateral Flow Device (LFD) tests where the result has been logged by the individual taking the test (or their parent/carer) on the UK Government website (1, 4). Up to and including 5 Jan 2022, confirmed SARS-CoV-2 infection was defined as a positive viral RT-PCR test result. From 6 Jan 2022 onwards, confirmed infection was defined as a positive viral RT-PCR test result or a positive LFD test result (unless the positive LFD result was followed by a negative viral RT-PCR result within 48 hours). This is consistent with the contemporaneous case definition in Scotland (5).

For any individual, the date that their first positive test sample was taken was used as the date of onset of their first episode of infection. Information on the presence of clinical signs, and date of onset of signs, was not always available on testing records. Subsequent positive samples taken within 90 days of a first positive sample were discounted. A subsequent positive sample taken more than 90 days after a first positive result was taken as indicating a subsequent confirmed infection.

Confirmed neonatal infection was defined as a confirmed infection with date of onset at any point from birth to 27 days old inclusive. By this definition, each infected baby can therefore only have one episode of confirmed infection during the neonatal period. Maternal infection at the time of childbirth was defined as a confirmed infection with date of onset in the 14 days leading to birth, on the day of childbirth, or on the day after giving birth.

For all babies with confirmed neonatal infection, data were obtained from the COPS database regarding: the age of the baby in days at date of onset of infection; maternal age, socioeconomic status, ethnicity, infection status at the time of childbirth; the baby's sex and gestation at birth. Maternal socioeconomic status was based on the Scottish index of multiple deprivation (SIMD) quintile. SIMD is an area-based measure of material deprivation derived from the postcode of residence (6)).

Identifying admissions of neonates with SARS-CoV-2

Neonates requiring hospital inpatient care may be cared for alongside their mother in a postnatal ward or admitted to a neonatal unit or paediatric ward (including paediatric intensive care units, PICU). Babies who have been discharged home after birth - who then require readmission to hospital -will generally be admitted to a paediatric ward (rather than a neonatal unit) to avoid importing and transmitting infections to neonatal units.

We first identified all admissions to neonatal units and paediatric wards in the neonatal period (date of admission from birth to 27 days old inclusive) for babies in our study population. Admissions to neonatal units were identified through the Scottish Birth Record (SBR, (7)), and admissions to paediatric wards through the Scottish Morbidity Record hospital inpatient and day-case discharge records (SMR01, (8)). A stay in neonatal care was defined as any SBR admission record which included at least one episode in intensive care, high dependency care, or special care. Any SMR01 record in the relevant period was included as a paediatric admission. Of note, this method does not capture neonates who were readmitted from home to a postnatal unit, rather than to a neonatal unit or paediatric care. Therefore, it is possible that some admissions may have been missed.

For babies with confirmed neonatal SARS-CoV-2 infection, we then identified SARS-CoV-2-associated admissions for further analysis. A SARS-CoV-2 associated admission was defined as an admission of a baby with confirmed neonatal infection to neonatal or paediatric care (a) where the date of onset of infection was in the 7 days prior to, or during, the admission (hence date of admission at up to 27+7=34 days old inclusive), or (b) where the admission occurred at any point in the neonatal period (hence date of admission at up to 27 days old inclusive) if COVID-19 was recorded as the main diagnosis (ICD10 code U07.1 or U07.2). An ‘admission’ was defined as an entire hospital stay from admission to discharge, which may have involved sequential episodes of care in different settings or locations. The main diagnosis recorded for an admission was taken from the diagnostic coding on the first episode of care. Usually, the main diagnosis recorded on an episode record reflects the main condition treated during that episode, however from the start of the pandemic to May 2021 inclusive, a temporary amendment to national coding guidance advised that COVID-19 (ICD10 code

U07.1 or U07.2) should always be coded as the main diagnosis if present during an episode of care (9).

Neonatal and paediatric admission records for these SARS-CoV-2-associated admissions were analysed to identify the highest level of care provided in the neonatal unit (intensive care, high dependency, or special care) or whether the admission included an episode in a paediatric intensive care unit, length of stay for the entire admission, whether COVID-19 was recorded as the main diagnosis, and whether the infection was likely to be nosocomial. A probable nosocomial infection was defined as when the first positive test was taken on day 7 of an ongoing admission or later.

Calculation of rates and confidence intervals

Due to the relatively small numbers involved, all data reported here are descriptive only and no formal statistical comparisons have been made. Rates were calculated using the number of babies with confirmed neonatal infection (numerator) and the total number of live births (denominator) during the relevant time period (individual months or the full study period 1 March 2020 to 31 January 2022), with confidence intervals calculated using Wilson score estimates. This approach to calculating rates supports production of the timeliest results, however it does allow a mismatch between numerator and denominator. For example, in any one month some of the babies with confirmed infection during that month may have been born in the previous month. Given the number of live births is fairly consistent month to month, we believe that this mismatch should have minimal impact on the interpretation of our findings.

Table S1

Monthly rate of confirmed SARS-CoV-2 infection in babies aged 27 days and under per 100,000 live births, Scotland 1 March 2020 to 31 January 2022.

Month	Total number of live births	Number of confirmed SARS-CoV-2 infections in neonates with date of onset in month	Overall rate of confirmed SARS-CoV-2 infection in neonates (per 100,000 live births)	Lower CI	Upper CI
Mar-20	4,001	0	0.0	0.0	119.6
Apr-20	3,857	2	51.9	9.0	208.9
May-20	3,888	0	0.0	0.0	123.1
Jun-20	4,083	0	0.0	0.0	117.2
Jul-20	4,282	0	0.0	0.0	111.8
Aug-20	4,078	2	49.0	8.5	197.6
Sep-20	4,106	1	24.4	1.3	158.0
Oct-20	4,152	5	120.4	44.3	298.4
Nov-20	3,703	2	54.0	9.4	217.6
Dec-20	3,707	4	107.9	34.6	296.4
Jan-21	3,641	9	247.2	120.7	487.1
Feb-21	3,447	2	58.0	10.1	233.7
Mar-21	3,966	2	50.4	8.7	203.2
Apr-21	3,742	3	80.2	20.7	255.2
May-21	4,022	3	74.6	19.3	237.4
Jun-21	4,006	8	199.7	92.9	410.1
Jul-21	4,445	3	67.5	17.4	214.9

Aug-21	4,342	18	414.6	253.5	668.5
Sep-21	4,339	16	368.8	218.3	612.4
Oct-21	4,308	14	325.0	185.0	559.3
Nov-21	4,048	10	247.0	125.6	470.1
Dec-21	3,937	11	279.4	147.0	515.9
Jan-22	3,909	26	665.1	443.9	988.0
Total	92,009	141	153.3	129.5	181.3

CI = 95% confidence interval.

Table S2

Rates of confirmed SARS-CoV-2 infection in post neonatal infants and children up to 17 years of age, Scotland 1 March 2020 to 31 January 2022. Estimated number of children in each age group (denominator for rates) taken from National Records of Scotland, Mid-2020 Population Estimates Scotland and is kept constant throughout (10). Number of post neonatal infants (under 1 year) estimated using the Mid-2020 Population Estimate minus 4,000 (the average number of live births per month). Number of positive tests obtained from NHS Scotland Corporate Data Warehouse (4).

Month	Estimated no. of post-neonates, under 1yr (d28 to d364)	No. confirmed SARS-CoV-2 infection post-neonates	Overall rate post-neonates (per 100,000)	Estimated no. of children aged 1-4 years	No. confirmed SARS-CoV-2 infection aged 1-4 years	Overall rate aged 1-4 years (per 100,000)	Estimated no. of children aged 5-11 years	No. confirmed SARS-CoV-2 infection aged 5-11 years	Overall rate children aged 5-11 years (per 100,000)	Estimated no. of children aged 12-17 years	No. confirmed SARS-CoV-2 infection children aged 12-17 years	Overall rate of children aged 12-17 years (per 100,000)
Mar-20	44,646	8	17.9	215,171	8	3.7	418,842	8	1.9	344,274	12	3.5
Apr-20	44,646	1	2.2	215,171	14	6.5	418,842	23	5.5	344,274	39	11.3
May-20	44,646	1	2.2	215,171	4	1.9	418,842	27	6.6	344,274	44	12.8
Jun-20	44,646	0	0.0	215,171	3	1.4	418,842	5	1.2	344,274	11	3.2
Jul-20	44,646	0	0.0	215,171	2	0.9	418,842	7	1.7	344,274	2	0.6
Aug-20	44,646	10	22.4	215,171	27	12.6	418,842	55	13.1	344,274	115	33.4
Sep-20	44,646	11	24.6	215,171	67	31.1	418,842	178	42.5	344,274	550	159.8
Oct-20	44,646	71	159.0	215,171	323	150.1	418,842	828	197.7	344,274	1,580	458.9
Nov-20	44,646	77	172.5	215,171	363	168.7	418,842	1,164	277.9	344,274	1,903	552.8
Dec-20	44,646	101	226.2	215,171	420	195.2	418,842	1,176	280.8	344,274	1,733	503.4
Jan-21	44,646	154	344.9	215,171	599	278.4	418,842	1,322	315.6	344,274	1,977	574.3
Feb-21	44,646	89	199.4	215,171	524	243.5	418,842	892	213.0	344,274	970	281.8

Mar-21	44,646	67	150.1	215,171	768	356.9	418,842	1,932	461.3	344,274	1,038	301.5
Apr-21	44,646	41	91.8	215,171	296	137.6	418,842	755	180.3	344,274	645	187.4
May-21	44,646	44	98.6	215,171	363	168.7	418,842	1,465	349.8	344,274	1,135	329.7
Jun-21	44,646	162	362.9	215,171	1,039	482.9	418,842	4,602	1098.7	344,274	5,003	1453.2
Jul-21	44,646	242	542.0	215,171	1,225	569.3	418,842	4,128	985.6	344,274	7,011	2036.5
Aug-21	44,646	258	577.9	215,171	1,720	799.4	418,842	10,034	2395.7	344,274	14,200	4124.6
Sep-21	44,646	380	851.1	215,171	2,470	1147.9	418,842	19,740	4713.0	344,274	22,843	6635.1
Oct-21	44,646	247	553.2	215,171	1,470	683.2	418,842	11,279	2692.9	344,274	8,054	2339.4
Nov-21	44,646	277	620.4	215,171	2,149	998.7	418,842	16,748	3998.6	344,274	8,311	2414.1
Dec-21	44,646	615	1377.5	215,171	3,753	1744.2	418,842	20,901	4990.2	344,274	16,654	4837.4
Jan-22	44,646	1,071	2398.9	215,171	8,182	3802.6	418,842	35,480	8471.0	344,274	21,149	6143.1
Total	44,646	3,927	8795.9	215,171	25,789	11985.4	418,842	132,749	31694.3	344,274	114,979	33397.5

Table S3:

Rates of confirmed SARS-CoV-2 infection in pregnancy, Scotland 1 March 2020 to 31 January 2022. Data obtained from COPS cohort.

Month	Estimated No. women in Scotland with an ongoing pregnancy at start of month*	No. women with confirmed SARS-CoV-2 infection in pregnancy with date of onset in month**	Rate per 100,000 pregnant women***
Mar-20	38,018	18	47.4
Apr-20	37,557	35	93.2
May-20	37,017	23	62.1
Jun-20	36,698	2	5.5
Jul-20	36,536	3	8.2
Aug-20	36,183	14	38.7
Sep-20	36,086	61	169.0
Oct-20	36,003	286	794.4
Nov-20	36,254	261	719.9
Dec-20	36,837	324	879.6
Jan-21	37,647	476	1264.4
Feb-21	38,311	235	613.4
Mar-21	38,773	189	487.5
Apr-21	38,490	90	233.8
May-21	38,626	145	375.4
Jun-21	38,491	488	1267.8
Jul-21	38,363	796	2074.9
Aug-21	37,893	820	2164.0
Sep-21	37,229	975	2618.9
Oct-21	36,708	634	1727.1

Nov-21	36,131	688	1904.2
Dec-21	36,169	2,436	6735.1
Jan-22	36,514	2,986	8177.7
Total	151,230	10,552	6,977.5

* The total for this column is the number of women who were pregnant at some point during the study period.

** The total for this column is the number of women with confirmed SARS-CoV-2 infection in pregnancy during the study period.

*** The total for this column is the overall rate of confirmed SARS-CoV-2 infection in pregnancy during the study period.

Table S4

Date of onset of first positive test for neonates who had a confirmed SARS-CoV-2 infection at or below 27 days of age, Scotland 1 March 2020 to 31 January 2022.

Date of onset of infection	Number of confirmed SARS-CoV-2 infection in neonates	Cumulative number of confirmed SARS-CoV-2 infection in neonates
d0 (date of birth)	2	2
d1	2	4
d2	2	6
d3	4	10
d4	1	11
d5	7	18
d6	1	19
d7	3	22
d8	3	25
d9	4	29
d10	8	37
d11	6	43
d12	6	49
d13	4	53
d14	5	58
d15	4	62
d16	8	70
d17	8	78
d18	7	85
d19	7	92
d20	5	97

d21	7	104
d22	3	107
d23	5	112
d24	4	116
d25	8	124
d26	9	133
d27	8	141

Table S5

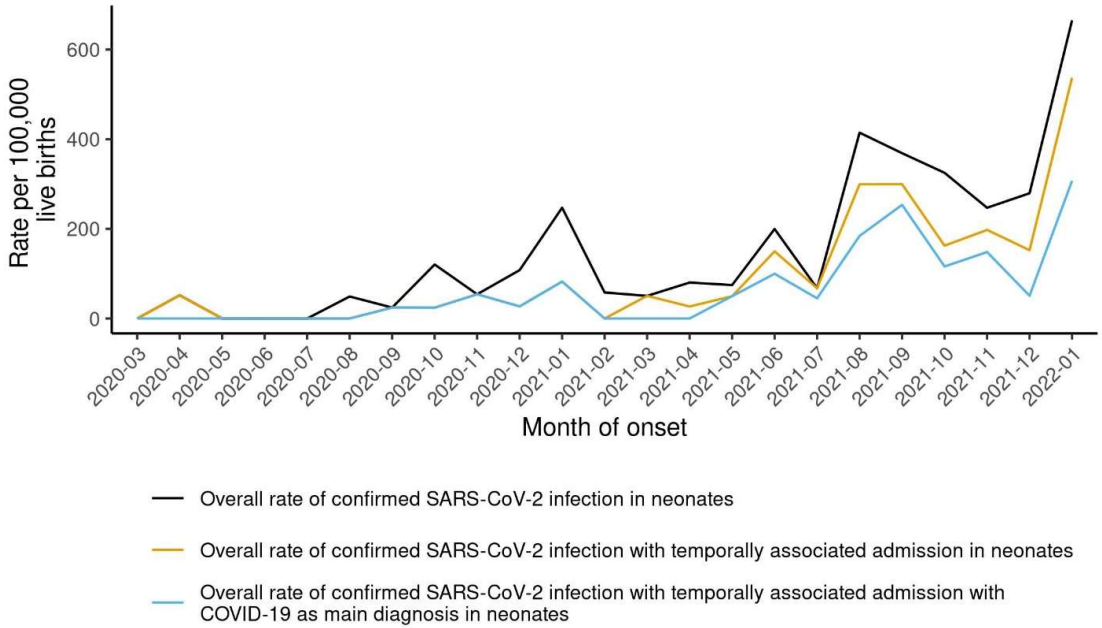
Admission rates for neonates with confirmed SARS-CoV-2 infection, Scotland 1 March 2020 to 31 January 2022. Rounded to 1 decimal place.

Month	Total number of live births	No. neonates with confirmed SARS-CoV-2 infection	No with associated hospital admission	No with associated admission with COVID-19 as main diagnosis	Overall rate of confirmed SARS-CoV-2 infection in neonates (per 100,000 live births)	Rate of confirmed neonatal infection with associated admission (per 100,000 live births)	Rate of confirmed neonatal infection with associated admission with COVID-19 as main diagnosis (per 100,000 live births)
Mar-20	4,001	0	0	0	0.0	0.0	0.0
Apr-20	3,857	2	2	0	51.9	51.9	0.0
May-20	3,888	0	0	0	0.0	0.0	0.0
Jun-20	4,083	0	0	0	0.0	0.0	0.0
Jul-20	4,282	0	0	0	0.0	0.0	0.0
Aug-20	4,078	2	0	0	49.0	0.0	0.0
Sep-20	4,106	1	1	1	24.4	24.4	24.4
Oct-20	4,152	5	1	1	120.4	24.1	24.1

Nov-20	3,703	2	2	2	54.0	54.0	54.0
Dec-20	3,707	4	1	1	107.9	27.0	27.0
Jan-21	3,641	9	3	3	247.2	82.4	82.4
Feb-21	3,447	2	0	0	58.0	0.0	0.0
Mar-21	3,966	2	2	0	50.4	50.4	0.0
Apr-21	3,742	3	1	0	80.2	26.7	0.0
May-21	4,022	3	2	2	74.6	49.7	49.7
Jun-21	4,006	8	6	4	199.7	149.8	99.9
Jul-21	4,445	3	3	2	67.5	67.5	45.0
Aug-21	4,342	18	13	8	414.6	299.4	184.3
Sep-21	4,339	16	13	11	368.8	299.6	253.5
Oct-21	4,308	14	7	5	325.0	162.5	116.1
Nov-21	4,048	10	8	6	247.0	197.6	148.2
Dec-21	3,937	11	6	2	279.4	152.4	50.8
Jan-22	3,909	26	21	12	665.1	537.2	307.0
Total	92,009	141	92	60	153.3	100.0	65.2

Figure S1

Trends in overall rate of confirmed neonatal SARS-CoV-2 infection compared to rate of neonatal infection with associated hospital admission, and with associated admission with COVID-19 coded as main diagnosis, Scotland 1 March 2020 to 31 January 2022. Per 100,000 live births.



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