Virological Characteristics of Hospitalized Children With SARS-CoV-2 Infection

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abstract

BACKGROUND AND OBJECTIVES: In children with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection, virological characteristics and correlation with disease severity have not been extensively studied. The primary objective in this study is to determine the correlation between SARS-CoV-2 viral load (VL) in infected children with age, disease severity, and underlying comorbidities.

METHODS: Children <21 years, screened for SARS-CoV-2 at the time of hospitalization, who tested positive by polymerase chain reaction were included in this study. VL at different sites was determined and compared between groups.

RESULTS: Of the 102 children included in this study, 44% of the cohort had asymptomatic infection, and children with >1 comorbidity were the most at risk for severe disease. VL in children with symptomatic infection was significantly higher than in children with asymptomatic infection (3.0×10^5 vs 7.2×10^3 copies per mL; $P = .001$). VL in the respiratory tract was significantly higher in children <1 year, compared with older children (3.3×10^7 vs 1.3×10^4 copies per mL respectively; $P < .0001$), despite most infants presenting with milder illness. Besides the respiratory tract, SARS-CoV-2 RNA was also detectable in samples from the gastrointestinal tract (saliva and rectum) and blood. In 13 children for whom data on duration of polymerase chain reaction positivity was available, 12 of 13 tested positive 2 weeks after initial diagnosis, and 6 of 13 continued to test positive 4 weeks after initial diagnosis.

CONCLUSIONS: In hospitalized children with SARS-CoV-2, those with >1 comorbid condition experienced severe disease. SARS-CoV-2 VL in the respiratory tract is significantly higher in children with symptomatic disease and children <1 year of age.

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Dr Pinninti designed the study, conducted the initial data analysis, drafted the initial manuscript, reviewed and revised the manuscript, was responsible for patient enrollment in the study, and was responsible for data collection and database management; Dr Boppana conceptualized and designed the study, analyzed the data, critically reviewed the manuscript for important intellectual content, and was responsible for patient enrollment in the study; Ms Latting and Dr Arora were responsible for patient enrollment in the study; Ms Yarbrough and Dr Poole were responsible for data collection and database management; Drs Britt, Seleme, and Pati were responsible for laboratory assay development, validation, and performance; and all authors reviewed and revised the manuscript, approve of the final manuscript as submitted, and agree to be accountable for all aspects of the work.

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WHAT'S KNOWN ON THIS SUBJECT: Data on clinical characteristics of children with severe acute respiratory syndrome coronavirus 2 are widely available, compared with the limited information on virological characteristics, particularly in children with asymptomatic and mild infections.

WHAT THIS STUDY ADDS: Children with coronavirus disease 2019 are predominantly asymptomatic or have mild illness, despite high viral load levels in the respiratory tract and at other sites, irrespective of age, severity of illness, and underlying comorbidities.

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Infections caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) have been reported from 192 countries, with >107 million individuals infected worldwide, and are responsible for >2 million deaths to date.[1] The spectrum of illness in adults has ranged from mild upper respiratory tract symptoms to multisystem involvement (severe lower respiratory tract, cardiac, renal, thrombotic, and neurologic), with significant morbidity and mortality,[2–7] particularly in individuals with underlying risk factors.[8–11] Interestingly, most infected children either lack symptoms (asymptomatic infection) or experience mild disease,[12–15] whereas few experience either a severe lower respiratory tract infection or multisystem inflammatory disorder (MIS-C), with overlapping features of Kawasaki disease and toxic shock syndrome.[16–19]

The reasons for the distinctly different clinical presentations and outcomes between adults and children with SARS-CoV-2 infection are largely unknown. Some of the hypotheses proposed to explain these differences include (1) under-expression of angiotensin-converting enzyme 2, the binding receptor for SARS-CoV-2 spike protein in children, (2) lower respiratory tract viral load (VL) levels in children compared with adults, and (3) preexisting cross-reactive immunity conferred by exposure to seasonal coronaviruses.[20–22] Pediatric data so far have been focused predominantly on the description of demographic and clinical characteristics of hospitalized children with SARS-CoV-2,[14,23,24] with limited information on virological characteristics,[25,26] particularly in children with asymptomatic and mild infections. Defining the virological characteristics of children with SARS-CoV-2 infection is important to facilitate identification of biomarkers of severe infection and adverse outcomes, understand transmission dynamics within families and communities, and develop effective management and prevention strategies. The objectives in this study are to describe the virological characteristics of hospitalized children with SARS-CoV-2 and examine the relationship of VL with age, disease severity, and underlying comorbidities.

METHODS

Subjects and Specimens

The study cohort consists of 102 children <21 years evaluated and/or admitted to Children's of Alabama and tested positive for SARS-CoV-2 RNA by reverse transcription polymerase chain reaction (RT-PCR) performed on nasopharyngeal samples between March 24 and August 20, 2020. Between March 24 and April 26, 2020, SARS-CoV-2 testing was only performed on hospitalized children suspected to have coronavirus disease 2019 (COVID-19) on the basis of symptoms and exposure. Screening of all hospitalized children and those scheduled for elective procedures was initiated on April 27, 2020. Nasopharyngeal swabs for SARS-CoV-2 polymerase chain reaction (PCR) were collected by trained personnel, and children who tested SARS-CoV-2 PCR positive were approached for collection of additional swabs (midturbinate nasal, saliva, or rectal) and whole blood. Of the 102 children included in this study, 61.7% (63 of 102) consented for additional sample collection.

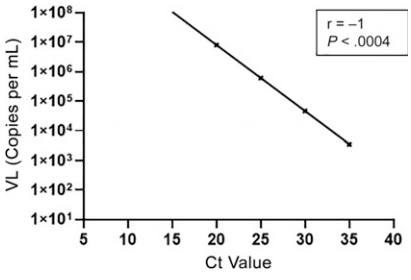

FIGURE 1
Correlation between Ct and VL. There was a strong inverse correlation between Ct value and VL loads in samples obtained from children with COVID-19 ($r = -1$).

Specimen Processing and Laboratory Analysis

Nasopharyngeal, nasal, saliva, or rectal swabs and blood were collected by trained medical staff (respiratory therapists, nurses, physicians, and/or phlebotomists), as described in the Supplemental Information. The swabs were placed in viral transport media (VTM) and processed within 24 hours or stored at −80°C. The details of the collection, processing, and analysis of samples and data extraction from the electronic medical record (EMR) are provided in the Supplemental Information and in a previous publication.[27] Briefly, RT-PCR was performed for the detection of SARS-CoV-2 RNA, and a specimen was considered positive if ≥1 copies per reaction were detected before 40 PCR cycles. Quantitation of VL was accomplished by generating a standard curve on the basis of dilutions of known SARS-CoV-2 genomic RNA, and results were expressed as copies per mL of VTM. A strong inverse correlation between cycle threshold (Ct) and VL was observed ($r = -1$; $P < .0004$; Fig 1). The study was approved by the institutional review board for human use, and informed consent was obtained from all study participants or their legally authorized representatives.

The cohort was categorized on the basis of age, disease severity, and comorbidities, as follows.

Age

The age categorizations were as follows: (1) <1 year, (2) 1 to 5 years, (3) 6 to 17 years, and (4) 18 to 21 years.

Disease Severity

On the basis of published data,[28–30] the cohort was categorized as (1) asymptomatic (no clinical signs or symptoms attributable to COVID-19), (2) mild (fever or chills, cough, nasal congestion or runny nose, new loss of taste or smell, sore throat, difficulty breathing ± noninvasive supplemental oxygenation [nasal cannula], diarrhea, nausea or vomiting, abdominal pain, fatigue, headache, myalgias, poor appetite, or poor feeding), or (3) moderate-severe illness (pneumonia with hypoxemia requiring ventilatory support, ± abnormal chest imaging, respiratory failure, shock, or multiorgan dysfunction). Children who tested negative for SARS-CoV-2 RNA at the time of hospital admission with a COVID-related illness (MIS-C) were excluded from this study.

Comorbidities

The cohort was divided into groups with 0, 1, or >1 comorbid condition for comparing VL and disease severity.

Statistical Analysis

The frequency of PCR positivity for each sample type was determined and compared among study children of different age groups (<1, 1–5, 6–17, and 18–21 years) and with varying degrees of disease severity. Continuous variables were compared by using the Kruskal–Wallis test. Fisher's exact test was used to compare categorical variables. Statistical significance between outcomes was assessed by using the Mann–Whitney *U* test, and Spearman's rank test was used to determine the correlation between variables. GraphPad Prism 8 was used for statistical analysis and to create figures.

RESULTS

Demographic Characteristics

Between March 24 and August 20, 2020, 102 patients <21 years of age who tested positive for SARS-CoV-2 by PCR and were either hospitalized (91%; 93 of 102) or screened before procedures (8.8%; 9 of 102) were included. The mean age of the study children was 9.8 years (±6.6 years), and about one-half were female (49 of 102). Race and ethnicity composition of the study cohort consisted of 41% Black non-Hispanic, 32% white non-Hispanic, and 27% white Hispanic children (Table 1).

Clinical Findings

A total of 44% (45 of 102) were categorized as asymptomatic, whereas 44% (45 of 102) and 11.7% (12 of 102) were categorized as mild and moderate-severe disease, respectively (Table 1). Of those with symptoms, 72% (41 of 57) reported fever and 40.3% (23 of 57) reported cough at initial presentation, whereas most reported nonspecific symptoms like abdominal pain, headache, and fatigue. Of the 93 hospitalized children, more than one-third (34 of 93; 36.5%) reported close contact with an individual diagnosed with COVID-19, and 19.3% (18 of 93) required invasive or noninvasive ventilatory support. Radiologic imaging of chest was not routinely obtained in all infected children, but more than one-half of the children in whom a chest radiograph was obtained had bilateral patchy

TABLE 1 Demographic and Clinical Characteristics of Children With SARS-CoV-2 Infection

Characteristic	No. (%)
Mean age	9.78 ± 6.56 y
Female, *n* (%)	49 of 102 (48)
Race and ethnicity, *n* (%)	
Black non-Hispanic	42 of 102 (41.1)
White Hispanic	26 of 102 (25.5)
White non-Hispanic	33 of 102 (32.3)
Asian American	1 of 102 (0.9)
Disease severity, *n* (%)	
Asymptomatic	45 of 102 (44)
Mild	45 of 102 (44)
Moderate-severe	12 of 102 (11.7)
Noninvasive ventilation, *n* (%)	9 of 93 (9.6)
Invasive ventilation, *n* (%)	9 of 93 (9.6)
Comorbidities, *n* (%)	
None	48 of 102 (47)
1 comorbid condition	36 of 102 (35.3)
>1 comorbid condition	18 of 102 (17.6)
Obesity	20 of 102 (19.6)
Endocrine: T1DM or T2DM	14 of 102 (13.7)
Hematology:HbSS, HbSC, or Fanconi's	8 of 102 (7.8)
Chemotherapy or immunomodulatory treatment	12 of 102 (11.7)
Pulmonary: asthma or chronic lung disease	12 of 102 (11.7)
Hypertension	4 of 102 (3.9)
COVID and contact, *n* (%)	34 of 93 (36.5)
Symptoms at presentation, *n* (%)	
Fever	41 of 57 (71.9)
Cough	23 of 57(40.3)
Median hospital stay, d	
Asymptomatic	1
Mild	3 ($P < .0001$)
Moderate-severe	15
CXR obtained, *n* (%)	36 of 102 (35.3)
Abnormal CXR, *n* (%)	19 of 36 (52.7)

CXR, chest radiograph; T1DM, type 1 diabetes mellitus; T2DM, type 2 diabetes mellitus.

opacities suggestive of multifocal pneumonia (Table 1).

Of the 53% of children with underlying comorbidities, 35.3% reported 1 comorbid condition and 17.6% had >1 comorbidity, with obesity most frequently reported in 19.6% (20 of 102) of children (Table 1). Other notable comorbidities were type 1 or type 2 diabetes mellitus in 13.7% and an underlying hematologic disorder (hemoglobin SS [HbSS], hemoglobin SC [HbSC], or Fanconi anemia) in 7.8%. Children with comorbidities were no more at risk of developing moderate-severe disease compared with those without underlying comorbidities (P = .14). The median hospital stay was significantly longer for children with moderate-severe infection compared with children with asymptomatic or mild infection (15 vs 1 vs 3 days respectively; $P < .0001$).

Virological Characteristics

VL by Age

Comparison of nasopharyngeal VL between different age groups revealed significantly higher VL levels in children <1 year than all other age groups (P = .0004). The median VL in children <1 year was 3.3×10^7 copies per mL (median Ct: 17), compared with 9.3×10^3 copies per mL (median Ct: 33) in the 1 to 5 years age group, 1.2×10^4 copies per mL (Ct: 33) in the 6 to 17 years group, and 1.4×10^5 copies per mL (Ct: 28) in the 18 to 21 years group (Fig 2A). Children <1 year of age had a significantly higher median VL than the rest of the cohort (3.3×10^7 copies per mL [Ct: 17] vs 1.3×10^4 copies per mL [Ct: 33], respectively; $P < .0001$; Fig 2B). Of note, except for 2 neonates with severe illness, the remaining children in the <1 year age group presented with either mild illness or were asymptomatic.

VL by Disease Severity

Asymptomatic children (7.2×10^3 copies per mL; median Ct: 34) had a significantly lower median VL than those with symptomatic infection (3.0×10^5 copies per mL; median Ct: 26; P = .001; Fig 3A). This difference in VL between the groups persisted even after the exclusion of children <1 year of age, who predominantly presented with asymptomatic or mild disease but had high VL in the respiratory tract (P = .02; Supplemental Fig 7). Among children with symptomatic infection, there was no significant difference in the median VL between those with mild or moderate-severe disease (2.9×10^5 copies per mL (Ct: 26) vs $5.5.0 \times 10^5$ copies per mL (Ct: 25) respectively (P = .5; Fig 3B).

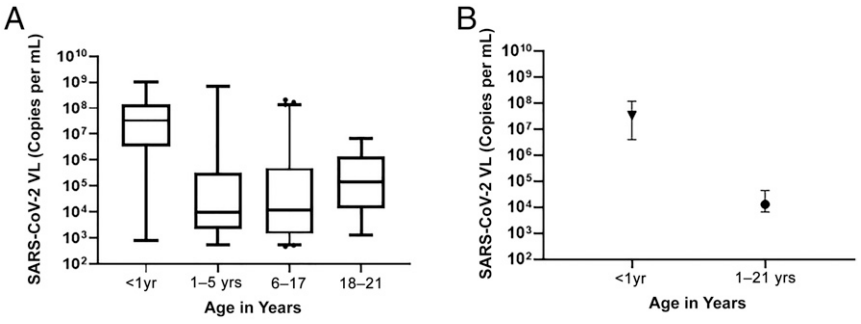

FIGURE 2

Nasopharyngeal VL comparison by age. A, VL comparison in children on the basis of age revealed significantly higher VL levels in children ≤1 of age, compared with children 1 to 5 (P = .01), 6 to 17 (P = .0002), or 18 to 21 (P = .001) years of age. The midlines represent medians, and the boxes represent interquartile ranges. The whiskers represent data points within the fifth to 95th percentile for the group. B, VL comparison between children <1 year of age and those 1 to 21 years of age revealed significantly higher VLs in children <1 year of age ($P < .0001$). The symbols for each group represent medians, and the whiskers represent 95% confidence intervals.

VL Based on Underlying Comorbidities

There was no significant difference in the median VL between children with 0, 1, or >1 comorbid condition (1.5×10^4 copies per mL [Ct: 32] vs 4.6×10^4 copies per mL [Ct: 29] vs 6.2×10^4 copies per mL [Ct: 30], respectively; P = .8), as shown in Fig 4. Although children receiving chemotherapy or immunomodulatory treatment had a higher median VL than those not receiving such treatments, the difference was not

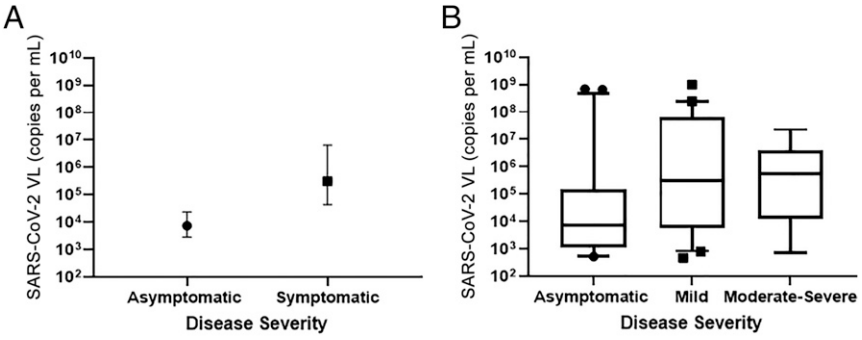

FIGURE 3

Nasopharyngeal swab VL comparison by disease severity. A, Children with symptomatic infection had significantly higher VLs than those with asymptomatic infection (P = .001). The symbols represent medians, and the whiskers represent 95% confidence intervals. B, Children with either mild or moderate-severe infection were noted to have higher VL levels, compared with children with asymptomatic infection. There was no significant difference in VL levels between mild and moderate-severe disease (P = .9). The midlines represent medians, and the boxes represent 95% confidence intervals. The whiskers represent the fifth to 95th percentile for the group, and outliers are represented by circles.

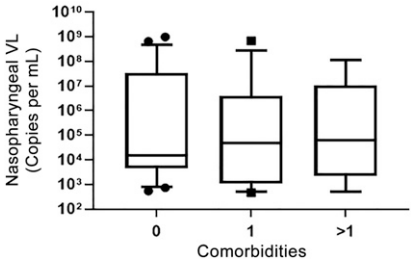

FIGURE 4

Nasopharyngeal VL comparison by underlying comorbidities. Nasopharyngeal VL comparison between groups with 0, 1, or >1 underlying comorbid conditions did not reveal a significant difference between groups (P = .8). The midlines represent medians, and the boxes represent 95% confidence intervals. The whiskers represent the fifth to 95th percentile for the group, and outliers are represented by circles.

statistically significant (2.3×10^5 copies per mL [Ct: 27] vs 2.3×10^4 copies per mL [Ct: 31]; P = .33).

Sites of Detection and VL

In addition to nasopharyngeal swabs, nasal, saliva, rectal, and blood samples were available from 52, 53, 26, and 24 children, respectively. Of those, 65% (34 of 52) of nasal swabs, 38% (20 of 53) of saliva swabs, 61% (16 of 26) of rectal swabs, and 50% (12 of 24) of blood samples were positive for SARS-CoV-2 RNA. Although samples from the respiratory tract had a higher VL, there were no significant differences between the compartments (Fig 5). A comparison between paired nasopharyngeal and nasal samples,

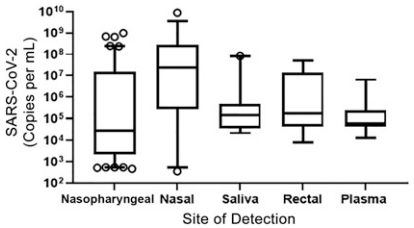

FIGURE 5

VL comparison by site of detection. Comparison of VL at different sites did not reveal a significant difference between sites. The midlines represent medians, and the boxes represent 95% confidence intervals. The whiskers represent the fifth to 95th percentile for the group, and outliers are represented by circles.

available in 51 children, revealed no significant difference in VL (P = .5), with strong correlation between the 2 sample types (r = 0.81; Fig 6A). A similar comparison between nasopharyngeal and saliva swabs in 53 children revealed a significantly higher VL in nasopharyngeal swabs ($P < .001$), with only a modest correlation (r = 0.59; Fig 6B). A comparison of VL between paired nasopharyngeal and rectal swabs available in 26 children revealed a significantly higher VL in nasopharyngeal swabs ($P < .0001$), with only a modest correlation between these sample types (r = 0.61; Fig 6C), suggesting viral replication in the gastrointestinal tract may be independent of the respiratory tract involvement. A similar comparison between saliva and rectal swabs, available in 25 children, did not reveal significant differences in VL between the sample types (P = .35; Fig 6D).

Of the 63 children with multiple sample types, ≥3 samples were available in 52 (82.5%) children, and the presence of SARS-CoV-2 RNA in ≥1 site was not associated with symptomatic infection or disease severity (P = .18). In the 24 children from whom blood samples were available, 50% (12 children) were viremic: 2 with asymptomatic infection, 1 with mild infection, and 9 with moderate-severe infection, with no significant difference in VL between the groups.

Duration of Shedding

Data for shedding duration beyond 2 and 4 weeks from the initial diagnosis were only available in 13 children from this cohort who were hospitalized beyond 2 weeks or managed as outpatients. All except 1 newborn had underlying comorbid conditions, with one-half of this cohort (6 of 12) receiving chemotherapy and immunomodulatory treatment. Most children (12 of 13) continued to test positive for SARS-CoV-2 RNA in nasopharyngeal swabs at 2 weeks, and 6 of 13 (46%) were PCR-positive beyond 4 weeks, with decreasing VL in samples obtained serially (Supplemental Fig 8; see also Supplemental Table 2). The detection of viral RNA at 2 and 4 weeks was not associated with symptomatic disease or severity of infection at initial presentation.

DISCUSSION

In this cohort of mostly hospitalized children with SARS-CoV-2 infection, 44% of the study children were asymptomatic, and the majority of those with symptomatic infection had nonspecific findings at the time of presentation. We document high VL in the respiratory tract in children with symptomatic infection and in infants. Although children with >1 comorbid condition had a higher risk for development of severe disease, we did not see an association between SARS-CoV-2 VL in the respiratory tract and the severity of illness. In one-half of the children from whom blood samples were available, we document SARS-CoV-2 viremia, suggesting disseminated infection. The finding of viral RNA in samples from the gastrointestinal tract (saliva and rectal), suggesting independent viral replication at these sites in children who were tested, has implications for the spread of infection through routes other than respiratory tract. Additionally, in a smaller group of children with underlying hematologic disorders or those receiving chemotherapy or immunomodulatory treatment, it is not uncommon for the persistence of SARS-CoV-2 RNA beyond 2 weeks.

Despite the worldwide spread of SARS-CoV-2, the incidence rates in children have continued to be low, with substantially lower morbidity and mortality compared with adults. Although the initial reports of COVID-19 from China included limited

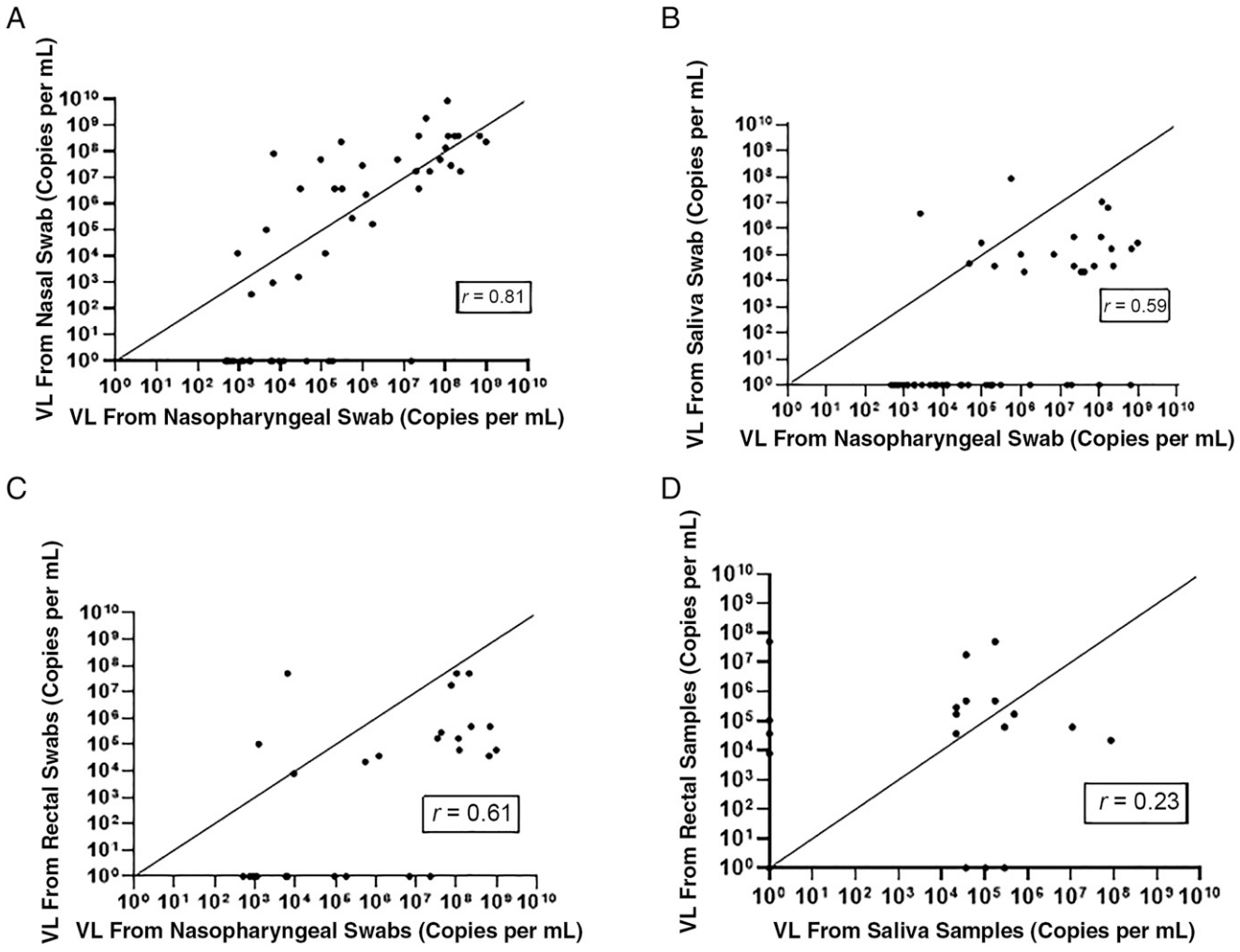

FIGURE 6

Correlation between respiratory and gastrointestinal samples. A, VL comparison between paired nasopharyngeal and nasal swabs. B, VL comparison between paired NP and saliva swabs. C, VL comparison between paired NP and rectal swabs. D, VL comparison between paired saliva and rectal swabs.

pediatric data, subsequent reports have been focused on clinical and demographic factors of SARS-CoV-2 infections in children, however, with limited information on virological characteristics.[13–15,28,31–33]

Contrary to the belief that children are less likely to spread the infection, we document high VL in the respiratory tract in children, with significantly higher levels in children with symptoms, compared with asymptomatic children, similar to recently published reports.[34] Data from small cohorts of adults admitted to ICUs have suggested an association between high respiratory tract SARS-CoV-2 VL and the severity of illness or risk of progression in severe COVID-19.[35–37] However, we did not find an association between VL in the respiratory tract and severity of illness, possibly because of the inclusion of more children with asymptomatic and milder illnesses in this study. A major strength of this study is that almost one-half of the cohort is asymptomatic and identified by screening of all hospitalized children for SARS-CoV-2, thus providing a better description of virological characteristics in children who were underrepresented in previous studies. Another strength of our study is the availability of samples other than nasopharyngeal swabs in about two-thirds of the study children.

An intriguing finding in this study is the presence of significantly high VL in the respiratory tract of children <1 year with predominantly asymptomatic or mild disease, corroborating findings from a recent report that documented high VL in children <5 years compared with older children and adults.[25] However, that study did not include VL information in infants or VL as

a correlate of disease severity. We speculate that passively transferred maternal antibodies against seasonal coronaviruses may provide cross-reactive protective immunity, leading to a lower severity of illness in infants despite high VL.

Our findings, together with other reports, contradict the belief that young children are less susceptible to SARS-CoV-2 infection or do not significantly contribute to SARS-CoV-2 transmission.[38–40] However, one of the shortfalls of this study is that we did not examine the transmission dynamics of SARS-CoV-2 within the families or communities of children enrolled in this study. Although the discordance between VL levels and disease severity needs further study, this observation suggests that a vigorous immune response and the resulting hyperinflammatory state in older children and adults may play a role in the severity of SARS-CoV-2 infection.

In this study, we also present evidence of gastrointestinal involvement, with detection of SARS-CoV-2 RNA in saliva and rectal swabs in the majority of children from whom samples were available, with VL comparable to that in the respiratory tract. Although the testing of nasopharyngeal swabs for SARS-CoV-2 RNA is currently considered the standard for diagnosis, we show a strong correlation between nasopharyngeal and nasal swab VL during acute infection. However, the finding of significantly lower VL in saliva and rectal samples suggests that viral replication in the gastrointestinal tract is independent of the respiratory tract. However, the lower VL in the gastrointestinal tract suggests that saliva and rectal swabs are not appropriate samples for the identification of children with COVID-19. Although we did not conduct cell culture experiments to recover infectious SARS-CoV-2 in these specimens (nasopharyngeal, nasal, saliva, and rectal), higher RNA levels have been associated with an ability to recover the virus,[41] suggesting that young children in the acute phase of infection could spread the virus to contacts through activities such as feeding and diaper changes, with implications for infection control practices not just during hospitalization but also at home, child care settings, and school settings.

Viremia, suggesting systemic infection and dissemination, has been reported in patients with SARS-CoV-2, but the significance of this finding remains unclear.[42] Although blood samples were obtained from only 25% of the children in this cohort, we document viremia in 50% of the samples analyzed. There was no association between viremia and severity of illness at initial presentation, but the small sample size limits the value of this finding. The documentation of viremia during acute infection could be of significance because of the emergence of MIS-C in some infected children during the convalescent phase[17–19] and findings of adults with cardiac involvement on follow-up after COVID-19,[43,44] highlighting the need for prospective follow-up to examine the role of viremia during acute infection and long-term adverse outcomes, irrespective of severity of initial illness.

Although most individuals with SARS-CoV-2 infection are believed to be infectious for 10 to 14 days from diagnosis, studies have documented shedding duration beyond 14 days.[33,45] We document shedding beyond 4 weeks in children receiving chemotherapy or immunomodulatory therapy. Although it is not clear whether these children continue to shed infectious virus for prolonged periods, this finding does raise questions for infection control practices during hospitalization. However, consistent with published data, we did not document increased morbidity in children with underlying hematologic and oncological conditions.[46,47]

This study is one of the few to be focused on the virological characteristics of SARS-CoV-2 infection in children. Because our cohort predominantly includes hospitalized children, these data might not be representative of SARS-CoV-2–infected children in the community. However, nearly one-half the cohort was identified because of the screening of all hospitalized children, suggesting that the findings of this study are generalizable. A major limitation of this study is the inability to correlate VL to time from infection because of inclusion of children with asymptomatic infection.

CONCLUSIONS

The findings of this study suggest that children with SARS-CoV-2 are predominantly asymptomatic or have mild illness with high VL in the respiratory tract and at other sites. In addition, significantly high VL was documented in the respiratory tract of infants compared with all other age groups. There remain a number of unanswered questions about long-term outcomes and the association between virological characteristics and adverse clinical outcomes in children with SARS-CoV-2 infection, highlighting the need for prospective follow-up studies.

ABBREVIATIONS

COVID-19: coronavirus disease 2019
Ct: cycle threshold
EMR: electronic medical record
HbSC: hemoglobin SC
HbSS: hemoglobin SS
MIS-C: multisystem inflammatory disorder
PCR: polymerase chain reaction
RT-PCR: reverse transcriptase polymerase chain reaction
SARS-CoV-2: severe acute respiratory syndrome coronavirus 2
VL: viral load
VTM: viral transport media

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