Severe acute respiratory illness surveillance for influenza in Kenya: Patient characteristics and lessons learnt

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Abstract

Background: We describe the epidemiology and clinical features of Kenyan patients hospitalized with laboratory-confirmed influenza compared with those testing negative and discuss the potential contribution of severe acute respiratory illness (SARI) surveillance in monitoring a broader range of respiratory pathogens.

Methods: We described demographic and clinical characteristics of SARI cases among children (<18 years) and adults, separately. We compared disease severity (clinical features and treatment) of hospitalized influenza positive versus negative cases among children. Children hospitalized with SARI who had an underlying illness had greater odds of in-hospital death compared with those without (adjusted odds ratio 2.11 95% CI 1.09–4.07). No further analysis was done among adults due to the small sample size.

Results: From January 2014 to December 2018, 11,166 persons were hospitalized with SARI and overall positivity for influenza was ~10%. There were 10,742 (96%) children (<18 years)—median age of 1 year, interquartile range (IQR) = 6 months, 2 years. Only 424 (4%) of the SARI cases were adults (≥18 years), with median age of 38 years (IQR 28 years, 52 years). There was no difference in disease severity comparing influenza positive and negative cases among children. Children hospitalized with SARI who had an underlying illness had greater odds of in-hospital death compared with those without (adjusted odds ratio 2.11 95% CI 1.09–4.07). No further analysis was done among adults due to the small sample size.

Conclusion: Kenya’s sentinel surveillance for SARI mainly captures data on younger children. Hospital-based platforms designed to monitor influenza viruses and associated disease burden may be adapted and expanded to other respiratory viruses to inform public health interventions. Efforts should be made to capture adults as part of routine respiratory surveillance.

Keywords
influenza, influenza hospitalizations, Kenya, respiratory illness, severe acute respiratory illness, surveillance
1 | INTRODUCTION

Globally, each year, influenza epidemics result in 3 to 5 million cases of severe illness and approximately 290,000 to 650,000 influenza-related deaths. A recent modeling study estimated that the highest burden of annual influenza-related deaths was in Sub-Saharan Africa, South East Asia, and Western Pacific regions. The rate of severe disease is highest in young children <2 years, adults ≥65 years, pregnant women, and individuals with underlying chronic medical conditions. In temperate areas, there are distinct influenza seasons during the cold months, but in the tropics, influenza circulates year-round, with multiple, often erratic, periods of increased influenza activity, and a pattern also seen in Kenya.

Due to increased globalization, respiratory disease pandemics are likely to spread widely fast, as seen currently with the COVID-19 pandemic. In 2006, in response to the pandemic threat of avian influenza A (H5N1), influenza surveillance in Sub-Saharan Africa was expanded. Since then, data collected through clinical and virologic surveillance in Africa have contributed to the description of influenza seasonality, characterized genetic make-up of circulating viruses, and provided viruses for vaccine production. In Kenya, influenza sentinel surveillance has been ongoing since 2007 (2008) and over the years has evolved to focus exclusively on hospitalized cases. This paper aims to describe the epidemiology and clinical features of patients hospitalized with influenza in Kenya and highlight the importance of year-round surveillance for severe acute respiratory infections (SARI), especially in tropical countries.

2 | METHODOLOGY

2.1 | Study sites

In 2007, the Kenya Ministry of Health (MOH) in collaboration with the US Centers for Disease Control and Prevention, Kenya, (CDC-K) began sentinel surveillance of influenza in healthcare facilities across the country in order to understand the epidemiology of influenza viruses and detect emerging strains. In Kenya, current influenza surveillance focuses on SARI hospitalizations in seven sentinel sites: five county referral hospitals (Marsabit County Referral Hospital, Kakamega County General Teaching and Referral Hospital, Nakuru County Referral Hospital, Nyeri County Referral Hospital, and Coast General Teaching and Referral Hospital), Kenyatta National Hospital (tertiary academic referral hospital in Nairobi city), and at the International Rescue Committee (IRC) main hospital in Kakuma refugee camp. In Kenyatta National Hospital, surveillance is carried out in pediatric wards only, while in other sites, patients of all ages are included (Figure 1).

2.2 | Surveillance procedures

Trained surveillance officers at each surveillance site identified patients with any signs or symptoms of acute respiratory illness by review of inpatient ward admission registers (new admissions on Monday reviewing those admitted during the weekend and Tuesday through Friday to capture new admissions). The surveillance officers approached all potential patients to assess eligibility, specifically if the patient met the case definition for SARI defined as history of fever (or measured fever of ≥38°C) and cough, with onset of symptoms within 10 days prior to hospitalization.

Patients who met the SARI surveillance case definition were approached for verbal consent, and once consent had been obtained, the surveillance officers assigned a unique number to the patient and interviewed either the patient or guardian using an electronic structured questionnaire stored on a password-protected netbook. Data were collected on demographic and clinical characteristics of patients, including underlying conditions and medical history. A follow-up exit questionnaire was completed for each patient by abstracting data on clinical outcomes of hospitalization from medical charts upon discharge, death, or transfer. All data were stored on a secure central server maintained by the Kenya Medical and Research Institute (KEMRI). No personal identifiers were stored in the data base.

2.3 | Specimen collection and shipment

Surveillance officers collected nasopharyngeal (NP) or nasal (NS) and/or oropharyngeal (OP) swabs from all SARI patients within 48 h of hospital admission during Monday–Wednesday and only the clinical and risk-factor data (without specimens) on Thursdays and Fridays. NP and OP swabs were collected during the period 2014 through 2016 and NS and OP swabs between 2017 and 2018. A dacron-tipped flexible aluminum-shafted swab was inserted through the nose into the posterior nasopharynx (or, if nasal swab, up to the nostril less than 1 inch [about 2 cm] or until you feel resistance), where it was rotated 180° and left in place for 3–5 s. A separate swab was inserted into the oropharynx and swabbed over the lower portion of the oropharynx. The two swabs were placed into a freshly prepared single vial containing viral transport media labeled with the patient’s unique identifier, barcode number, and date of collection. Samples were maintained at 2–8°C in the laboratory of each participating medical facility for up to 36 h and then packaged and shipped to the National Influenza Center (NIC) Laboratory, in Nairobi, for testing every Thursday of the week.

2.4 | Specimen processing

An aliquot of each specimen was tested by real-time reverse transcription polymerase chain reaction (rtRT-PCR) for influenza virus types A and B at the NIC, using protocol, primers, and probes provided by the Influenza Division, CDC-Atlanta, USA, as previously described. Briefly, total ribonucleic acid (RNA) was extracted from 140 mL aliquots of each specimen using a QIAamp viral RNA mini kit (Qiagen GmbH, Germany) according to the manufacturer’s instructions. One-step rtRT-PCR was carried out using the AgPath kit.
Values with a cyclic threshold (CT) reading <40 were recorded as positive. All specimens positive for influenza type A were subtyped for H3 and pH1N1 using rtRT-PCR. Specimens that were positive for influenza A virus by rtRT-PCR but failed to subtype were sent to the WHO Influenza Collaborating Center at CDC-Atlanta, GA, USA, for further antigenic characterization.

2.5 Data management and analysis

Data analysis was performed by epidemiologists at the Division of Disease Surveillance and Response (DDSR) and the NIC at the MOH, KEMRI, and CDC-Kenya. Weekly reports of aggregated clinical and laboratory data were generated and shared with stakeholders including the World Health Organization (WHO) and the national Public Health Emergency Operations Center at the Kenya MOH for situational awareness. For this manuscript, we downloaded data from January 2014 to December 2018 into Microsoft Excel (Microsoft Office, Seattle, USA, 2013), cleaned, and uploaded into Epi info 7.2.3.0 (CDC, Atlanta, 2019) and STATA 14.2 (College Station, Texas 77845 USA, 2018) for analysis.

Because children and adults would likely differ in risk factors and severity, the analysis was done separately for children (<18 years) and adults. We used proportions to describe the demographic and clinical characteristics of SARI cases separately for adults and children. We compared influenza positive cases with those testing influenza negative, for children only due to limited sample size among adults, using Chi-square test statistic (or Fisher’s exact test if applicable) for various demographic, clinical characteristics, and outcomes. Children with no recorded laboratory result were excluded from this analysis. We assessed the severity of disease among children by comparing clinical and treatment characteristics (tachypnea, hypoxia, high fever, intravenous fluids and blood transfusion treatment, admission to intensive care unit [ICU], and death) among influenza positive cases and those testing negative. We used graphs to display trends of influenza positivity for hospitalized children with SARI who were tested for influenza in the 5-year period and showed the types and subtypes detected. Those who had absconded care or refused treatment were excluded as their outcome status could not be confirmed. We then pre-selected variables that were potential confounders (age, sex, length of time from illness onset to hospitalization, and any chronic illness) or with a p value of <0.2 to include in a multivariable logistic regression model to assess predictors of death. Variables that had a p value of <0.05 in the final model were considered statistically significant.

2.6 Ethical considerations

Data from this surveillance were regarded by the Kenya MOH as a routine public health activity and received a non-research project determination by CDC and thus did not require an ethical review. Verbal consent was obtained from all participants before administration of questionnaires and collection of specimens. For children, verbal consent was obtained from the parent/guardian and assent for children ≥ 7 years.

3 RESULTS

3.1 Demographic and clinical characteristics of children and adults hospitalized with severe acute respiratory illness

From 2014 through 2018, 11,166 persons hospitalized with SARI were identified in the seven surveillance sites. Among them there were 10,742 (96%) children aged <18 years and 424 (4%) adults. The median age of children was 1 year (IQR = 6 months, 2 years), 5711 (53.2%) were aged 6–23 months, and 5979 (55.6%) were males. Hospitalizations associated with SARI among adults mostly represented
people 18–64 years (85%), and 61.8% of all adults hospitalized were males. The median age among adults was 38 years (IQR = 28 years, 52 years). Underlying medical conditions were present among 2142 (19.9%) children and 214 (50.4%) among adult SARI cases. The overall influenza positivity among samples tested from two thirds of children and adults was comparable (10.0% and 11.7%, respectively) (Table 1). There were 716 (10.0%) children with laboratory confirmed influenza. Because the number of adult cases was limited, the rest of the analysis was focused only on children from this point forward.

### 3.2 Comparison of children with SARI among those with and those without lab-confirmed influenza

When comparing children with influenza and those without, there were significant differences observed by age group ($p < 0.001$); the <6 months age group was underrepresented among influenza positive cases compared with influenza negative (9.5% vs. 21.1%). Nonetheless, most clinical outcomes and severity were similar, with a small difference in the time from disease onset to hospitalization where influenza negative cases seem to be hospitalized earlier in the course of the disease compared with influenza positive cases (68.8% vs. 63.3%, respectively; $p$ value <0.001), and a lower frequency of tachypnea was reported among the influenza positive cases (36.0% vs. 43.8%; $p < 0.001$). Overall, highest positivity rate of SARI samples in (supporting information Figure S1).

Overall, the median influenza positivity rate of SARI samples tested for the entire period was 7% (IQR = 3.6%–13.9%), with the highest positivity rate of 23% detected in July 2018. There was not any clear pattern of seasonality observed (Figure 2). Overall, highest percentage of influenza positivity was in those aged 5–17 years (16%; 95% CI 12.6, 19.5) and 2–4 years (15%; 95% CI 13.0, 16.6). The temporal distribution of the types and subtypes of influenza viruses among children that were detected during the study period is shown in (supporting information Figure S1).

### 3.3 Comparison of case fatality proportion (CFP) among children with and those without lab-confirmed influenza

Overall, there was no significant difference in the CFP between hospitalized children who tested positive for influenza (3.3%, 95% CI 1.9, 4.5) and those who tested negative (3.6%, 95% CI 3.2, 4.2). Young children aged less than 6 months who were influenza positive had a higher but not statistically significant CFP of 8.8% (95% CI 2.1, 15.6) compared with 4.7% (95% CI 4.7, 5.8) among those who tested negative (Figure 3). No notable differences were observed among older children (6–23 months and 2–4 years). Influenza positive SARI cases who were hospitalized >7 days after illness onset had a higher but not statistically significant CFP of 11.9% (95% CI 3.9, 25.6) compared with 2.9% (95% CI 1.6, 4.9) among those hospitalized early (<4 days from illness onset). Tuberculosis significantly increased CFP in both influenza positive and negative groups: 20% (95% CI 0.5, 71.6) for those influenza positive and 16.5% (95% CI 9.1, 26.5) for those influenza negative. Influenza negative SARI cases with a reported underlying illness had higher CFP 6.9% (5.5, 8.4) compared with 4.3% (1.6, 9.2) among influenza positive SARI cases (supporting information Table S1).
### TABLE 2  
Comparison of demographic and clinical characteristics of laboratory-confirmed influenza positive and negative severe acute respiratory illness (SARI) associated hospitalizations among children, 2014–2018, Kenya

| Characteristic                                      | Influenza positive | Influenza negative | P value |
|-----------------------------------------------------|--------------------|--------------------|---------|
|                                                     | N = 716            | N = 6287           |         |
| Age group                                           |                    |                    |         |
| < 6 months                                          | 68 (9.5)           | 1326 (21.1)        |         |
| 6–23 months                                         | 357 (49.9)         | 3344 (53.2)        |         |
| 2–<5 years                                          | 224 (31.3)         | 1266 (20.1)        |         |
| 5–17 years                                          | 67 (9.4)           | 351 (5.6)          | <0.001  |
| Sex                                                 |                    |                    |         |
| Female                                              | 323 (45.1)         | 2758 (43.9)        |         |
| Male                                                | 393 (54.9)         | 3529 (56.1)        | 0.55    |
| Time from illness onset to hospital admission       |                    |                    |         |
| 0–3 days                                            | 446/705 (63.3)     | 4261/6196 (68.8)   |         |
| 4–7 days                                            | 217 (30.8)         | 1670 (27.0)        |         |
| 8 days                                              | 42 (6.0)           | 265 (4.3)          | 0.001   |
| Median duration of time from illness onset to admission (IQR) | 3 days (IQR = 1, 5) | 2 days (IQR = 1, 4) |         |
| Length of hospital stay                              |                    |                    |         |
| 0–3 days                                            | 253/679 (37.3)     | 2188/5773 (37.9)   |         |
| 4–7 days                                            | 251/679 (37.0)     | 2125 (36.8)        |         |
| > 7 days                                            | 175/679 (25.8)     | 1460 (25.3)        | 0.78    |
| Median length of hospital stay (IQR)                | 5 days (IQR = 3, 8) | 4 days (IQR = 3, 8) |         |
| Comorbidities (yes vs. no)                          |                    |                    |         |
| Presence of any underlying illness<sup>a</sup>      | 139 (19.4)         | 1250 (19.9)        | 0.809   |
| HIV positive<sup>b</sup>                            | 2/152 (1.3)        | 19/988 (1.9)       | 0.846   |
| Malaria positive<sup>c</sup>                        | 32/146 (21.9)      | 222/1130 (19.6)    | 0.591   |
| Tuberculosis treatment                              | 5/706 (0.7)        | 79/6145 (1.3)      | 0.254   |
| Severity of cases (yes vs. no)                      |                    |                    |         |
| Tachypnea<sup>d</sup>                               | 257/714 (36.0)     | 2744/6260 (43.8)   | <0.001  |
| Hypoxia<sup>e</sup>                                 | 71/687 (10.3)      | 597/5966 (10.0)    | 0.838   |
| High fever<sup>f</sup>                              | 271/715 (37.9)     | 2335/6280 (37.2)   | 0.736   |
| Received intravenous fluids                         | 71/295 (24.1)      | 577/2082 (27.7)    | 0.213   |
| Received blood transfusion                          | 15/295 (5.1)       | 103/2082 (4.9)     | 1.000   |
| Admitted to intensive care unit                     | 61/707 (8.6)       | 449/6148 (7.3)     | 0.232   |
| Discharge diagnosis                                 |                    |                    |         |
| Malaria                                             | 35/295 (11.9)      | 239/2082 (11.5)    | 0.923   |
| Pneumonia                                           | 216 (73.2)         | 1564 (75.1)        | 0.527   |
| Sepsis                                              | 11 (3.7)           | 107 (5.1)          | 0.368   |
| Meningitis/encephalitis                             | 24 (8.1)           | 145 (6.9)          | 0.540   |
| Dehydration                                         | 22 (7.5)           | 194 (9.3)          | 0.351   |
| Malnutrition                                        | 40 (13.6)          | 288 (13.8)         | 0.970   |
| Bronchitis                                          | 15 (5.1)           | 125 (6.0)          | 0.620   |
| Asthma exacerbation                                 | 4 (1.4)            | 33 (1.6)           | 0.963   |
| Acute respiratory distress syndrome                 | 3 (1.0)            | 10 (0.5)           | 0.455   |
| Tuberculosis                                        | 7 (2.4)            | 39 (1.9)           | 0.543   |
| Gastroenteritis                                     | 36 (12.2)          | 347 (16.6)         | 0.065   |
| Anemia                                              | 24 (8.1)           | 177 (8.5)          | 0.921   |

(Continues)
Factors associated with in-hospital death among hospitalized children with SARI

The final model accounted for age group, sex, time from illness onset to hospitalization, and presence of any comorbidity. In the multivariable model, children with any reported underlying illness (including TB, HIV/AIDS, malnutrition, diabetes, asthma, cancer, chronic cardiac, and liver or renal disease) had greater odds of dying in the hospital compared with those who did not have any (aOR 2.11, 95% CI 1.09, 4.07). Children who tested positive for HIV during admission had greater odds of dying in the hospital compared with those who tested negative (aOR 9.25, 95% CI 3.17, 26.96) (Table 3).

### DISCUSSION

We analyzed data from patients hospitalized with SARI from country-wide sentinel sites to describe the epidemiology of circulating influenza viruses in Kenya. However, the majority (96%) of hospitalized SARI cases were children aged <18 years, while only 4% were adults.
Among the hospitalized adults, 15% were older adults aged ≥65 years, an age group recognized as being at increased risk for influenza complications and death. Among children with a reported underlying illness, in-hospital death was twice as likely to occur compared with those who did not have any reported. Nonetheless, the data do not show a particularly high risk of death among children with influenza compared with those without. Overall, 10% of children hospitalized with SARI had laboratory-confirmed influenza, with the peak percentage positivity among school age children (aged 5–17 years). SARI surveillance may need to encompass monitoring of other respiratory pathogens that are responsible for healthcare utilization and disease burden to optimize resources.

The surveillance system in Kenya mainly captured children aged <5 years, representing 94% of all SARI cases. In public health facilities countrywide, hospital user fees for children aged <5 years are subsidized by the government, and as a result, young children may be overrepresented in this surveillance due to differentiated care seeking. Adults may be more likely to delay healthcare seeking, and this may result in reduced likelihood of influenza virus detection in this population. The potential delay or refrain in using the healthcare system among adults might have contributed to worse clinical outcomes due to a late clinical intervention, although this could not be assessed in this platform. Moreover, SARI case definitions may not capture older hospitalized patients with laboratory-confirmed influenza who present with atypical signs and symptoms which are not included in standard SARI case definition. Inclusion of private hospitals as sentinel sites may make the system more representative of adult population as subsidized care would have less of an impact on healthcare utilization.

Approximately one tenth of children hospitalized with SARI tested positive for influenza, similar to results from other surveillance sites in Sub-Saharan Africa like Rwanda (6.3%), Zambia (5.5%), Malawi (11.3%), and South Africa (7.3%). This suggests that there is a high rate of other respiratory illness etiologies that could explain some of the hospitalizations associated with cough and fever. Broader testing could allow for identification of common and emerging respiratory pathogens as well as monitoring the impact of public health interventions. During the COVID-19 pandemic, the World Health Organization leveraged influenza surveillance networks and tools to monitor COVID-19. Capitalizing on existing resources can make surveillance networks more sustainable and robust. Local and national governments as well as funders (from the private and public sector) may want to consider broadening objectives of the SARI surveillance by testing samples for a wider range of pathogens and whether adapted case definitions could be used to encompass a larger variety of respiratory pathogen disease presentations. The overall CFP among influenza-associated SARI cases was 3.3%, an increase from the reported CFP of 0.9% in the previous 5 years of surveillance in this system. This is comparable with reported CFPs from studies done in

### Table 3: Predictors of in-hospital death among children admitted with severe acute respiratory illness 2014–2018, Kenya

| Characteristic                      | Death, N = 384 | Discharged alive, N = 10,048 | Crude odds ratio (95%CI) | P value | Adjusted odds ratio (95%CI) | P value |
|-------------------------------------|----------------|------------------------------|--------------------------|---------|-----------------------------|---------|
| **Age group**                       |                |                              |                          |         |                             |         |
| <6 months                           | 110 (28.6)     | 2019 (20.1)                  | 1.89 (1.14–3.14)         | 0.015   | 1.27 (0.43–3.77)            | 0.67    |
| 6–23 months                         | 225 (58.6)     | 5352 (53.3)                  | 1.46 (0.89–2.38)         | 0.15    | 0.7 (0.25–1.95)             | 0.49    |
| 2–<5 years                          | 31 (8.1)       | 2050 (20.4)                  | 0.52 (0.29–0.94)         | 0.045   | 0.47 (0.14–1.63)            | 0.24    |
| 5–17 years                          | 18 (4.7)       | 627 (6.2)                    | Ref                      |         |                             |         |
| **Sex**                             |                |                              |                          |         |                             |         |
| Female                              | 171 (44.5)     | 4445 (44.2)                  | 1.0 (0.82–1.24)          | 0.95    | 0.54 (0.28–1.03)            | 0.06    |
| Male                                | 213 (55.5)     | 5603 (55.8)                  | Ref                      |         |                             |         |
| **Time from illness onset to hospitalization** |                |                              |                          |         |                             |         |
| 0–3                                 | 210/383 (54.8) | 6930/9954 (69.6)             | Ref                      | <0.001  | 1.48 (0.76–2.89)            | 0.25    |
| 4–7                                 | 135 (35.2)     | 2597 (26.1)                  | 1.72 (1.38–2.14)         | <0.001  | 2.14 (1.48–2.68)            | 0.25    |
| >7                                  | 38 (9.9)       | 427 (4.3)                    | 2.90 (2.05–4.20)         | <0.001  | 3.70 (2.82–16.58)           | 0.09    |
| **Comorbidities**                   |                |                              |                          |         |                             |         |
| Any underlying illnessa             | 142 (37.0)     | 1922/9924 (19.4)             | 2.44 (1.97–3.02)         | <0.001  | 2.11 (1.09–4.07)            | 0.03    |
| HIV positiveb                        | 5/44 (11.4)    | 24/1939 (1.2)                | 10.2 (3.7–28.2)          | <0.001  | 9.25 (3.17–26.96)           | <0.001  |
| Malaria positivec                   | 9/47 (19.1)    | 498/2369 (21.0)              | 0.89 (0.43–1.85)         | 0.90    |                             |         |
| Tuberculosis treatmnet               | 15/382 (3.9)   | 139/10,030 (1.4)             | 2.91 (1.69–5.00)         | <0.001  | 1.08 (0.23–5.03)            | 0.91    |
| Laboratory-confirmed influenza      | 23/240 (9.6)   | 678/6554 (10.3)              | 0.92 (0.59–1.42)         | 0.78    |

Abbreviations: IQR, interquartile range; SARI, severe acute respiratory illness.

*a*Includes the following: chronic respiratory illness, chronic neuromuscular or neurological disease, newly diagnosed TB, HIV/AIDS, chronic cardiac, liver or renal disease, malnutrition, diabetes, asthma or cancer, sickle cell disease, and rickets.

*b*Number of positive HIV cases out of 1150 SARI cases tested during hospitalization.

*c*Number of malaria positive cases out of 1282 SARI cases tested during hospitalization.
South Africa (3%) and Egypt (2%). The overall CFP in influenza-associated SARI patients and those who were influenza negative was comparable (3.3% vs. 3.6%). Previously, in Sub-Saharan Africa, among hospitalized patients with SARI, the CFP among influenza-associated SARI cases was described as lower than in those who are influenza negative (1.8% vs. 2.9%), but this could have been influenced by lack of systematic data collection on influenza-associated outcomes among countries participating in that study. The CFP reported in infants aged <6 months with laboratory-confirmed influenza was high, highlighting the importance of vaccinating pregnant women with influenza vaccine to protect newborn infants from influenza virus infection. Higher CFPs were also identified in SARI cases (with or without influenza) with a diagnosis of tuberculosis. In addition, children with reported underlying illness, especially those living with HIV, had greater odds of in-hospital death compared with HIV negative children. In countries with high HIV prevalence in Africa, persons living with HIV and those with chronic lung conditions such as tuberculosis are at risk of influenza-associated severe disease.

The highest influenza percentage positivity in our surveillance data was reported in school aged children 5–17 years, who are known to shed influenza virus for longer periods and to increase community transmission. School-based influenza vaccination programs recommended in the United States and United Kingdom have significant benefits because this reduces transmission to vulnerable older age groups not easy to reach as part of the healthcare system. The burden of healthcare utilization associated with school aged children may need to be taken into account as the Kenya government considers recommendations for the use of influenza vaccines.

Our study had some limitations. We did not have information on the total number of hospital admissions to determine the burden of influenza and SARI hospitalizations in the context of overall hospital admissions. Estimates of disease burden using hospital data in this study should be interpreted cautiously, because in Kenya, there is limited access to care due to economic and logistic reasons. Previously, studies have shown that in countrywide, only 20% of influenza-associated SARI cases are hospitalized even though many severe cases occur in the community. Moreover, the surveillance system captured a small proportion of older patients; therefore, counting influenza cases and associated deaths in the hospital setting may lead to underestimation of disease burden. In this surveillance, we only tested samples for influenza viruses and a large proportion of SARI cases were likely associated with non-influenza etiology which remains unknown. Expanded testing would be helpful to understand the etiology of severe acute respiratory disease in Kenya.

5 | CONCLUSION

We found that the surveillance system mainly captured children aged <5 years. Hospitalized children with SARI who had a reported underlying illness had higher likelihood of in-hospital death compared with those without. A high influenza-associated CFP was reported among infants aged <6 months. These groups are disproportionately affected and may be priority targets for influenza control programs. With the emergence of new respiratory pathogens and the development of new vaccines targeting respiratory illnesses such as the COVID-19 vaccine, hospital-based platforms designed to monitor influenza viruses and associated disease burden should consider adapting their tools and expanding surveillance to capture systematically respiratory viruses that can inform public health interventions and future investments in respiratory disease prevention.

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AUTHOR CONTRIBUTIONS

Linus Ndegwa: Conceptualization; formal analysis; methodology. Gideon O. Emukule: Conceptualization; formal analysis; methodology. Lily Kirui: Data curation. Rosalia Kalani: Data curation. Bonventure Juma: Data curation. Lilian Mayieka: Data curation. Peter Kinuthia: Data curation. Marc-Alain Widdowson: Conceptualization; formal analysis; methodology. Sandra S Chaves: Conceptualization; formal analysis; methodology.

CONFLICT OF INTEREST

The authors have no conflict of interest to disclose.

DISCLOSURE

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention and the Kenya Ministry of Health (MOH).

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/irv.12979.

DATA AVAILABILITY STATEMENT

Some access restrictions apply to the data underlying the findings in this manuscript. For ethical reasons we cannot publish the data sets on line, however requests for the data underlying the findings presented in our manuscript can be made to the Kenya Ministry of Health through Dr. Daniel Langat, Head of Division of Disease Surveillance and Response, Email: langatdoc@gmail.com.
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