RESEARCH ARTICLE

Effects of the COVID-19 pandemic on hospital admissions and inpatient mortality in Kenya: a retrospective cohort study [version 1; peer review: awaiting peer review]

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Abstract

Background

The impact of COVID-19 in Africa remains poorly described. We examined hospitalisation trends for all medical causes, clinician-diagnosed pneumonia admissions, and inpatient mortality in Kenya two years before and across the first six waves of the pandemic.

Methods

We conducted a hospital-based observational study of patients admitted to 13 public referral facilities in Kenya from January 2018 to December 2022. The pre-COVID-19 population included admissions before 1st March 2020. Time series models, adjusted for seasonality and hospital, compared observed and predicted trends. To estimate the impact of the COVID-19 pandemic, we calculated incidence rate

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ratios (IRR) from negative binomial mixed-effects models.

Results

357,631 patients were admitted across the 13 sites (range 15,354 to 67,241 per hospital). 45,349 patients (42.1%) were admitted to the adult medical wards. On the paediatric ward, 163,608 individuals (47.4%) were aged under five years and 36,227 individuals (10.5%) were aged five years and older. In comparison to the pre-pandemic period, hospitalisations reduced for adults (IRR 0.75, 95% CI 0.69–0.82) and paediatric cases (IRR 0.69, 95% CI 0.64–0.75). In-hospital deaths also declined for adults (IRR 0.83, 95% CI 0.77–0.89) and children (IRR 0.85, 95% CI 0.77–0.94). Adult pneumonia admissions increased (IRR 1.59, 95% CI 1.36–1.85), while paediatric cases decreased overall, (IRR 0.78, 95% CI 0.51–1.20), but became elevated in late 2021 compared to the pre-pandemic period.

Conclusions

The COVID-19 pandemic did not cause a surge in hospitalisations in Kenya. However, pneumonia admissions among adults (but not children) increased significantly, with peaks aligning with the pandemic waves. These findings underscore the importance of syndromic inpatient surveillance in detecting and monitoring outbreaks.

Plain Language Summary

There are still relatively few studies on the effects of COVID-19 in Africa. We looked at how COVID-19 affected admissions and outcomes before and during the pandemic. To do this, we studied trends for all reasons people were admitted to hospitals, cases of pneumonia diagnosed by doctors, and how many people died while in hospital.

Our study looked at data from 13 public hospitals in Kenya between January 2018 and December 2022. We compared what happened before COVID-19 (before March 1, 2020) to what happened during the first six waves of the pandemic. We used statistical models to see if there were changes in hospital admissions and outcomes.

More than 350,000 patients were admitted to these hospitals during the study period. The admissions were approximately evenly divided between the adult and children's wards. During the pandemic, fewer adults and children were admitted to hospitals compared to before. Also, fewer people died in hospitals during the pandemic. However, more adults were admitted for pneumonia during the pandemic. While fewer children were admitted for pneumonia overall, there was a rise in cases towards the end of 2021.

In conclusion, we found that COVID-19 didn't lead to more hospital admissions in Kenya, but it was associated with an increase in adult

pneumonia admissions. Our study highlights the need for good hospital data to spot and manage outbreaks.

Keywords
Hospital surveillance, COVID-19, pneumonia

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Research in context

Evidence before this study

We searched PubMed, Google Scholar, and MedRxiv for original research articles, to understand the existing evidence regarding the impact of COVID-19 on hospitalisations, pneumonia admissions, and inpatient mortality in Africa. Our search covered the duration from December 1, 2019, to June 27, 2023. We used combinations and variations of the terms "COVID-19", "hospitalisation", "pneumonia", "inpatient mortality", and "Africa". No language restrictions were applied. Our search yielded three studies focusing on service utilisation and five studies reporting inpatient outcomes all of which were conducted in tertiary facilities and restricted to the pandemic period. We found no studies examining trends in inpatient admissions and outcomes spanning the pre-pandemic and pandemic periods from primary referral level hospitals in Africa.

Added value of this study

This research reports hospitalisation trends due to all medical causes, clinician-diagnosed pneumonia admissions, and inpatient mortality two years before, and three years into the COVID-19 pandemic in Kenya. Contrary to expectations, our findings indicate that the pandemic did not result in an overall surge in hospitalisations in the country. Hospital admissions and in-hospital deaths, both in adult and paediatric wards, declined during this period. However, a notable increase was observed in pneumonia-specific admissions among adults, which peaked corresponding to the pandemic waves. Paediatric pneumonia cases, though initially lower during the first year of the pandemic, saw an elevation towards the end of 2021.

Implications of all the available evidence

The lack of a surge in hospitalisations suggests that healthcare facilities in Kenya were not overwhelmed to the extent anticipated by the pandemic. The differential patterns observed in adult versus paediatric pneumonia cases indicate age-specific impacts, warranting tailored strategies in health responses. Our findings underscore the significance of continuous syndromic inpatient surveillance in efficiently detecting and monitoring outbreaks in the region.

Introduction

Crucial questions regarding the impact of COVID-19 in Africa remain unanswered. By the end of 2022, Africa had reported only 9,111 cases per million compared to 91,468 per million people globally, and there is limited data on hospital admission numbers[1]. There is a wide discrepancy, across Africa, between the high seroprevalence of SARS-CoV-2 antibodies and low frequency and severity of COVID-19 cases and their attendant mortality[2–4]. Limited testing capacity only partly explains the under-ascertainment of cases in the community and in hospitals[5]. Reliable estimates of severe cases and deaths for COVID-19 in Africa are essential for effective public health response, resource allocation, and policy formulation. However, national routine health information and vital registration systems are subject to incomplete reporting[6–8]. The World Health Organization recommended that countries adapt and strengthen existing hospital-based sentinel surveillance to track the severity of the COVID-19 pandemic[9]. Hospitals serve large and diverse populations, offering a convenient source of data for studying the clinical presentation, severity, and impact of epidemics on different demographic groups. The proportion of confirmed COVID-19 cases among patients hospitalised with acute respiratory infections can serve as a proxy for the trends in COVID-19 cases over time. Hospital data are also essential to detect signs of the pandemic overwhelming the capacity of healthcare systems, and to guide policy decisions that balance virus containment measures with their societal and economic impacts[10]. Here, we describe the impact of COVID-19 on hospital admissions and inpatient mortality using data from a large hospital-based clinical surveillance platform.

Methods

Study design and setting

We undertook a retrospective cohort study in 13 public hospitals in Kenya distributed in the densely populated central (highland), western (malaria-endemic) and coastal regions (Figure 1). Among the surveillance sites, 12 are part of a paediatric clinical information network (CIN) established in 2013 as a partnership between researchers, the Ministry of Health and paediatricians to promote the generation and use of routine data to improve care, understand patient outcomes, and to evaluate interventions[11]. In April 2020, the Ministry of Health requested the network investigators to expanded surveillance activities to include adult medical inpatient departments as part of the national efforts towards COVID-19 response. At each CIN hospital, one or two full-time clinical officers (non-physician clinicians)[12] take responsibility for the coordination of surveillance activities, including providing active feedback to clinical teams on the completion of surveillance forms. One additional surveillance site, Kilifi County Hospital (KCH), is located on the Kenyan Coast and hosts the KEMRI-Wellcome Trust Research Programme. Paediatric and adult inpatient surveillance was established at KCH in 1989 and 2007, respectively. Hospital-based surveillance occurs alongside clinical and laboratory research linked to population-based surveillance in the surrounding community[13]. The paediatric department at KCH includes a general ward, newborn unit, and a 6-bed high-dependency unit staffed by research clinicians, nurses, and data clerks. At the beginning of the pandemic, six of the 13 surveillance sites were designated COVID-19 treatment centres by the Ministry of Health[14]. The study hospitals are typical of "district-level" health facilities in the region, offering primary care and referral services. High patient numbers and staff shortages are common, and facilities for advanced critical care are limited.

In Kenya, the first confirmed case of COVID-19 was reported on March 13, 2020. Subsequently, the government implemented a series of control measures, including movement restrictions and limitations on public gatherings to mitigate the virus's spread. By December 2022, the country had experienced six distinct waves of infections. The initial two waves, driven by wild-type variants, peaked in August and

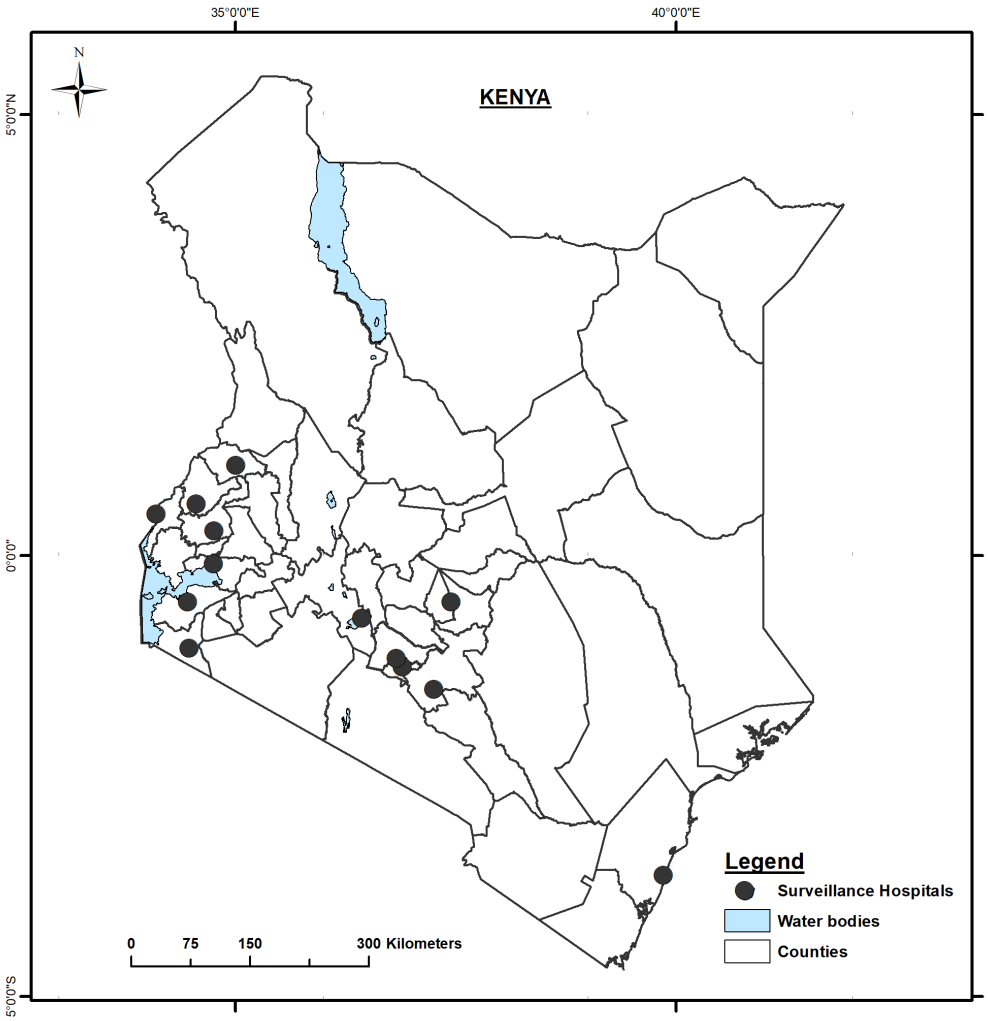

Figure 1. Map of Kenya showing geographical distribution of surveillance hospitals.

November 2020. The third wave, dominated by the Beta and Alpha variants, reached its peak in April 2021. The fourth wave, dominated by the Delta variant, peaked in August 2021, while the fifth wave, associated with the Omicron BA.1 variant, reached its peak in December 2021. A sixth wave, during which the Omicron BA.5 variant was predominant, peaked in June 2022[15].

Study participants and recruitment

We included all patients who were either discharged from the paediatric (generally 0–12 years) and adult (generally 13 years and above) medical wards or who died as inpatients between January 2018 and December 2022. We excluded patients with admitted to the surgical ward, neonates (aged less than 1 month) as well as those admitted to maternity units from this analysis. The primary aim of the study was to examine the effect of COVID-19 on hospitalisation and inpatient deaths. Admission decisions are made by government-employed clinical officers or medical officers, who also prescribe initial patient care. Inpatient management is typically delivered by a team consisting of medical officers and medical officer interns, and nurses under the supervision of one or more specialist physicians. Throughout the duration of admission, scheduled medical ward rounds are conducted daily, during which observations are documented, and clinical plans and diagnoses are updated in the inpatient medical records until the time of discharge. It is important to note that during December 2020 and January 2021, a nationwide health care workers' strike resulted in the suspension of inpatient services in public health facilities, including all 13 hospitals involved in our surveillance, which significantly curtailed admissions and surveillance.

Data collection

The data collection and analysis methods utilised in the CIN and KCH have been described in detail in separate

publications[16–18]. In summary, these hospitals employ structured data collection tools, namely admission and discharge forms, to gather relevant information. These tools capture data on patient clinical characteristics, basic laboratory tests conducted upon admission, assigned diagnoses, prescribed treatments, and clinical outcomes.

The classification of pneumonia in this analysis was determined based on clinician diagnoses documented in the in-patient charts. Our study did not directly provide resources for RT-PCR testing specifically for COVID-19. Instead, we relied on the existing testing capacity at the hospitals and within the respective administrative regions (counties). A diagnosis of suspected COVID-19 was assigned based on the national case definition, which required the presence of severe acute respiratory illness (fever or cough or shortness of breath) that necessitated hospitalisation, and in the absence of an alternative diagnosis that fully explained the clinical presentation[19]. Confirmed cases of COVID-19 were defined by the detection of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) through a positive result from a real-time reverse transcription-polymerase chain reaction (RT-PCR) or rapid antigen test conducted on a respiratory sample, either during or before admission.

To ensure accuracy and consistency, trained staff followed standard operating procedures to extract data from inpatient paper records using an electronic tool. Data collection for adults admitted to CIN hospitals prior to April 2020 was conducted retrospectively by extracting information from archived medical records. The electronic data capture tool incorporates error validation checks. De-identified data from all hospitals were synchronised daily to the central servers at KEMRI. At the central level, additional quality checks were performed, enabling the supervisory team to provide feedbackand address any discrepancies through weekly data review meetings with individual sites or collectively.

Statistical methods

Data were collected from 13 hospitals, encompassing patients admitted to both paediatric and adult wards, during the period from January 1, 2018, to December 31, 2022. However, patients admitted during the healthcare workers' strike that occurred in December 2020 and January 2021 were excluded from the analysis.

The primary exposure variable of interest was the period of admission, which was categorised as either pre-COVID-19 for patients admitted before March 1, 2020, or during the COVID-19 pandemic for patients admitted at any time between March 1, 2020, and December 31, 2022.

Statistical analyses

We analysed trends over the study period and estimated the effect of the pandemic on the following outcomes 1) adult admissions, 2) paediatric admissions, 3) adult deaths, 4) paediatric deaths, 5) adult pneumonia admissions and case fatality, and 6) paediatric pneumonia admissions and case fatality.

To study trends, we used data from patients admitted between January 1, 2018, and December 31, 2019, to develop time series models for each outcome that accounted for seasonality and hospital identity. The models were trained to forecast monthly counts with corresponding 95% prediction intervals for patients admitted from January 1, 2020, to December 31, 2021. To visually compare observed and predicted numbers, line charts were generated using the *forecast* R package.

We estimated the impact of the COVID-19 pandemic using negative binomial mixed-effects models. These models accounted for over-dispersion in the monthly counts of each outcome and included hospital identity as a random effect. The correlation structure within the models was determined by examining autocorrelation factor (ACF) and partial autocorrelation factor (PACF) plots. The glmmPQL function from the MASS (Modern Applied Statistics with S) package was employed to fit the models[20]. We reported the results as adjusted incidence rate ratios and corresponding 95% confidence intervals and p-values. All statistical analyses were performed using R statistical programming language version 3.6.3[21]. The map showing locations of the surveillance hospitals were generated in ArcGIS Pro V.3.0.3 (ESRI, Redlands, California, USA)

Kenya Medical Research Institute (KEMRI) Scientific and Ethics Review Unit approved the study. This manuscript is formatted in accordance with STROBE guidelines for observational studies.

Results

During the period from January 2018 to December 2022, the surveillance hospitals admitted 357,631 patients (range for individual hospitals from 15,354 to 67,241 admissions). Patients included 163,608 (47.4%) aged under five years and 36, 227 (10.5%) aged above five years admitted to the paediatric wards, and 145349 (42.1%) admitted to the adult medical wards. Overall, during the study period, 44,997 patients (12.6%) died while receiving inpatient care. Crude mortality varied across hospitals, ranging from 8.8% (2.522 deaths out of 28,519 admissions) to 16.1% (2,471 deaths out of 15,354 admissions). (Table 1). From 1 April to 31 December 2020 in the six surveillance sites that were designated COVID-19 treatment centres, testing of suspected COVID-19 cases ranged from 73/896 (8.1%) to 599/700 (85.6%), with test positivity ranging from 116/374 (31.0%) to 262/333 (78.7%) (Table 2).

Trends in all-cause hospitalisation

Among adults there appeared to be a seasonal variation in hospitalisation rates with peak admissions occurring in July during the pre-pandemic period. However, in March 2020, when the first COVID-19 cases and restrictions were announced, there was a sharp decline in the number of adult patients hospitalised with medical diagnoses across the hospitals, and this lower-than-predicted level persisted until February 2021. In March 2021, there was a rebound to predicted levels. (Figure 2a). Overall, we observed a 25% decline in adult

Table 1. Hospital and patient population characteristics.

Characteristics	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	All sites
Has intensive care unit*	Yes	No	Yes	No	Yes	Yes	No	No	Yes	No	No	No	No	
Designated COVID-19 treatment facility	No	No	No	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	
Total inpatients	23388	32532	24165	15354	24840	32766	67241	19332	30118	18016	28519	18058	23302	357631
Male, n (%)	12255 (52.4%)	17729 (54.5%)	13218 (54.7%)	8951 (58.3%)	13413 (54%)	17791 (54.3%)	22391 (33.3%)	10226 (52.9%)	15872 (52.7%)	10233 (56.8)	15400 (54%)	9968 (55.2%)	11953 (51.3%)	178457 (49.9%)
Paediatric wards < 5 years (%)	6160 (29.6%)	14125 (44.1%)	11087 (50.7%)	3057 (20.8%)	12215 (51.9%)	19499 (62.6%)	26472 (39.4%)	7872 (43.3%)	13439 (44.9%)	9998 (55.7%)	23369 (83.3%)	11552 (65.2%)	4763 (21.6%)	163608 (47.4%)
Paediatric wards >5 years (%)	2505 (12%)	5730 (17.9%)	1293 (5.9%)	1227 (8.3%)	4717 (20%)	1666 (5.3%)	6915 (10.3%)	2589 (14.2%)	3527 (11.8%)	1273 (7.1%)	2529 (9%)	1440 (8.1%)	816 (3.7%)	36227 (10.5%)
Adult wards (%)	12150 (58.4%)	12193 (38%)	9493 (43.4%)	10413 (70.9%)	6604 (28.1%)	9982 (32%)	33785 (50.3%)	7713 (42.4%)	12964 (43.3%)	6691 (37.3%)	2145 (7.6%)	4724 (26.7%)	16492 (74.7%)	145349 (42.1%)
Crude case fatality ratio (%)	2996 (12.8%)	3379 (10.4%)	3866 (16%)	2471 (16.1%)	3285 (13.2%)	4510 (13.8%)	7652 (11.4%)	1882 (9.7%)	4219 (14%)	2903 (16.1%)	2522 (8.8%)	2898 (16%)	2414 (10.4%)	44997 (12.6%)

*In March 2021

Table 2. COVID-19 suspected and confirmed cases in six COVID-19 treatment centres from April to December 2020.

	H5	H6	H7	H9	H11	H12
Total admissions	3152	5396	3885	1933	1298	6103
Suspected COVID-19 (% of total admissions)	1041 (33.0)	2829 (52.4)	896 (23.1)	700 (36.2)	782 (60.2)	1337 (21.9)
Total tested (% of suspected COVID-19)	391 (37.6)	1077 (38.1)	73 (8.1)	599 (85.6)	333 (42.6)	374 (28.0)
COVID-19 positive (% of admissions)	214 (6.8)	399 (7.4)	30 (0.8)	194 (10)	262 (20.2)	116 (1.9)
Test positivity: % COVID-19 positive of total tested	54.7	37.0	41.1	32.4	78.7	31.0

hospitalisation rate during the pandemic period up to December 2022 compared to the pre-pandemic period (IRR 0.75, 95% CI 0.69 to 0.82; P<0.001) (Table 3).

Paediatric admissions also displayed a seasonal pattern, with the highest numbers occurring from March to July. Similar to the pattern seen in adult admissions, there was a decrease starting in April 2020 that persisted for almost a year. Admissions briefly returned to the expected range in March 2021 before declining again from April 2021 onwards. This depressed trend persisted until December 2022 (Figure 3a). Paediatric hospitalisation numbers reduced by 31% during the pandemic (IRR 0.69, 95% CI 0.64 to 0.75; P<0.001) (Table 3).

Trends in inpatient death

The number of adult inpatient deaths reduced in April 2020 but remained within predicted limits until March 2021, after which the observed deaths rebounded and remained slightly above the predicted counts for all subsequent months (Figure 2b). Statistically, there was no difference in all-cause inpatient deaths among adults before and during the pandemic (IRR 1.04, 95% CI 0.96 to 1.12; P=0.39) (Table 3).

Paediatric inpatient deaths also declined sharply in April 2020 and, in parallel with the reduction in numbers of admissions, remained below the predicted counts over the remainder of the duration of the study. (Figure 3b). Inpatient paediatric mortality was significantly lower during the pandemic compared to the study interval before the pandemic (IRR 0.85, 95% CI 0.78 to 0.93; P<0.001) (Table 3).

Trends in pneumonia hospitalisation

Adult pneumonia cases increased between January and March 2020, returned to predicted levels in April and May 2020, and

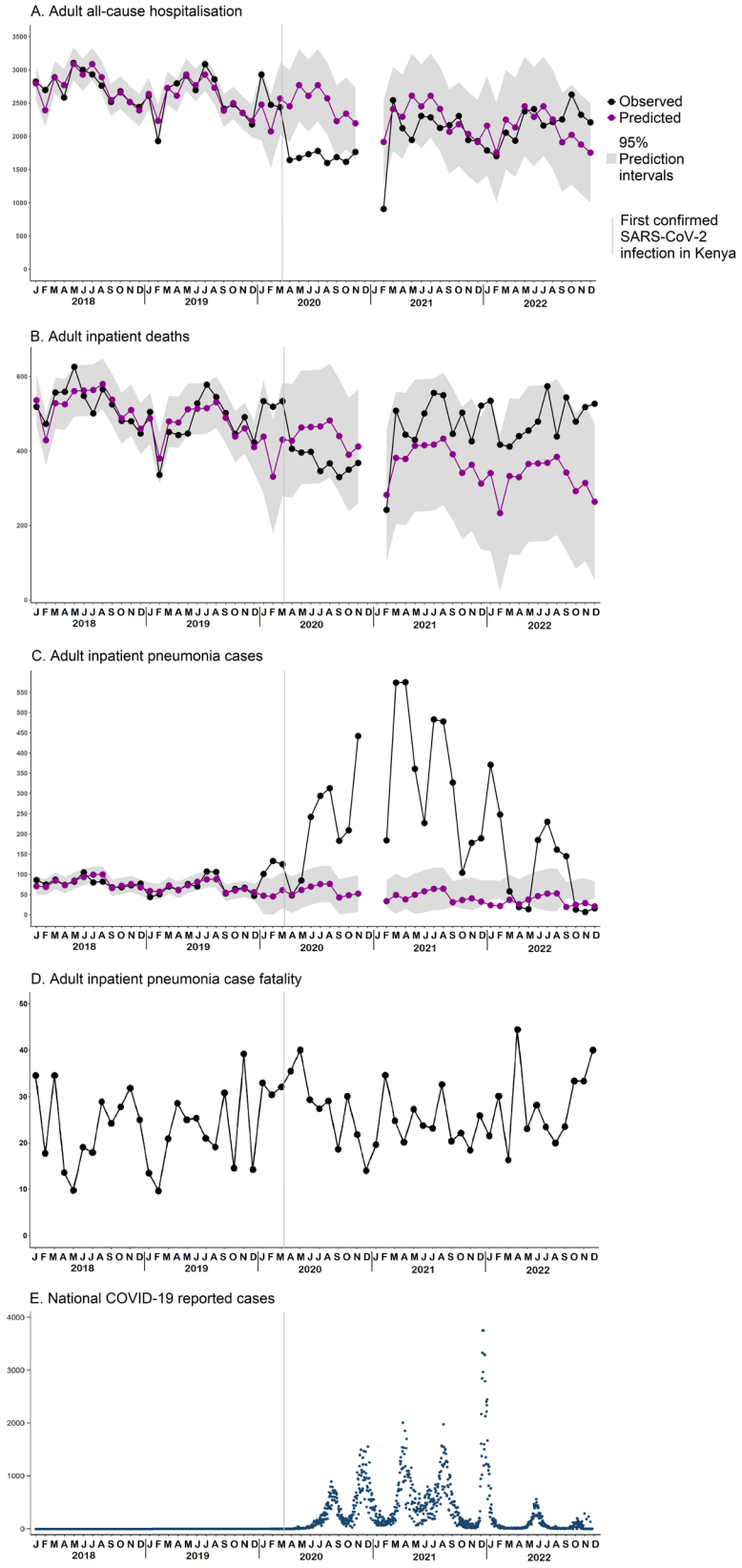

Figure 2. Adult all-cause hospitalisation (**A**), inpatient deaths (**B**), in-patient pneumonia cases (**C**), in-patient pneumonia case fatality (**D**), and national COVID-19 reported cases (**E**).

Table 3. Adjusted* incidence rate ratios for associations between study outcomes and COVID-19 pandemic.

Outcome	Incidence rate ratio	95% Confidence Interval	P value
Adult all cause hospitalisation	0.75	0.69, 0.82	<0.001
Paediatric all cause hospitalisation	0.69	0.64, 0.75	<0.001
Adult all-cause inpatient death	1.04	0.96, 1.12	0.39
Paediatric all-cause inpatient death	0.85	0.78, 0.93	<0.001
Adult pneumonia hospitalisation	1.59	1.36, 1.85	<0.001
Paediatric pneumonia hospitalisation	0.78	0.51, 1.20	0.26

*Adjusted for seasonality and hospital

rose again thereafter, remaining high throughout most of the pandemic. Peaks coincided with the pandemic waves reported nationally. Reductions in case numbers were then observed from March to May 2022, and from October to December 2022 (Figure 2c). Overall, adult pneumonia admissions increased by 59% during the pandemic (IRR 1.59, 95% CI 1.36 to 1.85; P<0.001) (Table 3).

We observed a decrease in paediatric pneumonia admissions shortly after the beginning of the pandemic in April 2020 until February 2021. Subsequently, there was a rise in case numbers, which remained consistently higher than the projected counts over the majority of the remaining study duration. However, this increase was not as prominent as the one observed for adult pneumonia and was (Figure 3c). Paediatric inpatient pneumonia case fatality appeared to increase over the period coinciding with the decline in admissions and deaths (Figure 3d). The net effect of the pandemic on paediatric pneumonia admissions was not statistically significant (IRR 0.78, 95% CI 0.51 to 1.20; P=0.26) (Table 3).

Discussion

In this five-year longitudinal analysis, we observed significant reductions in all-cause hospitalisation rates among both adults and children during the COVID-19 pandemic. These findings are contrary to initial expectations of a strain on hospital systems[22,23]. We propose several possible explanations for these trends.

One possible explanation is the decreased utilisation of outpatient health services during the pandemic, as demonstrated by various studies[24–27]. Although healthcare providers and patients accessing healthcare were exempt from the lockdowns, the movement restrictions and perceived higher risk of contracting COVID-19 in healthcare settings may have limited access to transportation and led to reduced or delayed care-seeking behaviour[28,29]. Interestingly, the reductions in the number of admissions were greater than the reduction in the number of deaths, particularly among children, where an increase in pneumonia case fatality was evident during the containment period. This observation suggests that whilst lockdown may have prevented mild cases of any disease from coming to hospital, it had less of an impact on the presentation of severe (and likely fatal) disease cases. Our findings confirm observations from previous studies demonstrating a rebound in service utilisation by early 2021[24–26]. Similar patterns have been observed during national strikes[30]. Notably, adult deaths peaked in July and August 2021, coinciding with the peak of the Delta variant. This finding aligns with a population-based study conducted in coastal Kenya, which observed excess mortality among individuals aged 45–64 years and ≥65 years only during July 2021[31]. Furthermore, we observed a modest increase in hospitalisation due to pneumonia during this period, further corroborating an impact of COVID on the hospitalisation patterns.

An alternative explanation for the unexpectedly low hospitalisation and mortality observed may be reduced infection rates in the Kenyan population. However, seroprevalence studies indicate a progressive spread of the pandemic in the Kenyan population starting in early 2020[2], approaching 50% among blood donors by March 2021[32]. Even after the launch of the National COVID-19 vaccination programme in March 2021, the role of vaccine-derived immunity is likely to have contributed only partially to mitigating the burden of severe disease. Seroprevalence had reached 85% among unvaccinated individuals in the general population by early 2022[33] and only 37 % of adults were fully vaccinated as of 31 December 2022.

Despite the widespread transmission of infection, the relatively young population structure in Africa, with a higher proportion of asymptomatic and mild cases, may have led to a reduced burden of disease requiring hospital admission compared to regions with different population demographics[34–38]. A high prevalence of asymptomatic infection has been noted in routine testing[39] and in longitudinal follow up of cohorts[40].

On the other hand, a cross-sectional postmortem study conducted in a tertiary hospital in Zambia during the peak of the pandemic confirmed SARS-CoV-2 infection in a

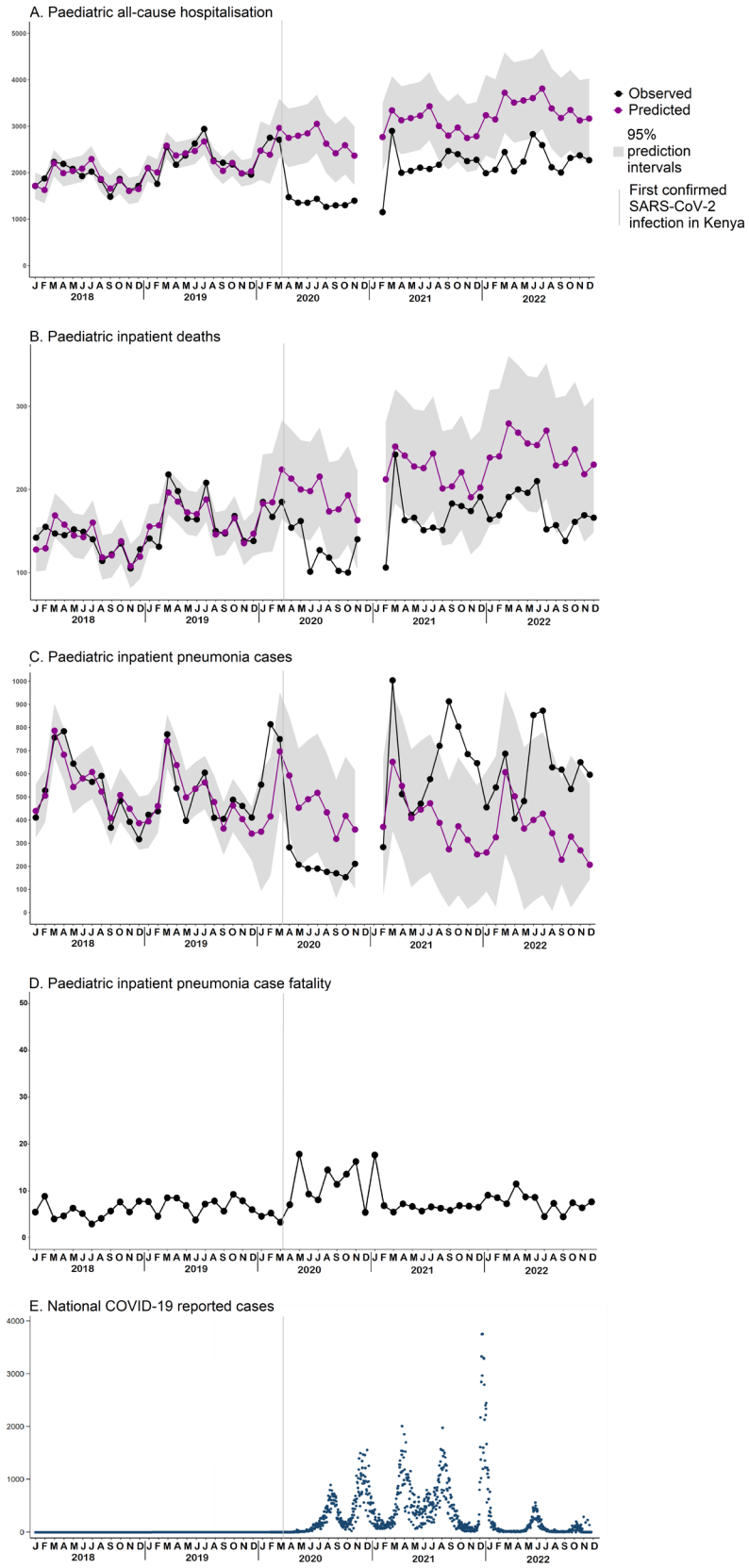

Figure 3. Paediatric all-cause hospitalisation (**A**), inpatient deaths (**B**), in-patient pneumonia cases (**C**), in-patient pneumonia case fatality (**D**), and national COVID-19 reported cases (**E**).

subset of participants, with a majority of them having died in the community, suggesting that many deaths due to COVID may have occurred outside hospital without a formal diagnosis. However, without a control group for comparison, it is difficult to determine the additional contribution of COVID-19 to overall mortality in the study. The diagnosis of SARS-CoV-2 infection in corpses included may have been an incidental finding during postmortem examinations in an urban setting experiencing prevalent infection in the community[41]. In our study, we observed similar trends in hospitalisation for both adults and children, despite the lower burden of severe COVID-19 among children. This suggests that the indirect effects of the pandemic on health service utilisation were substantial, since COVID-19 would be expected to have much lower direct effects on children compared with adults. Furthermore, emerging evidence from Health and Demographic Surveillance sites suggests that mortality in Africa may be lower than initially projected[31,42].

There was a sharp rise in adult admissions due to pneumonia, accompanied by higher-than-predicted inpatient deaths, starting from early 2021 with sustained high case fatality. As COVID-19 case numbers fell, pneumonia cases then declined to pre-pandemic levels. Notably, the peaks in adult (but not paediatric) pneumonia cases closely correlated with the waves of the pandemic as reported in the national case-based surveillance, suggesting that a portion of this burden was due to COVID-19. This pattern confirms the utility of syndromic surveillance for pneumonia in detecting, investigating, and monitoring outbreaks of acute respiratory infections within the community, even when severe cases contribute only minimally to the overall case count.

We also observed an upsurge in admissions for both adult and paediatric pneumonia in the months preceding the officially reported onset of the pandemic in Kenya. The relevance of this rise remains uncertain; it could indicate an outbreak of a different respiratory infection or the potential introduction of COVID-19 to Kenya before the detection of the first confirmed case.

The strengths of this study lie in its multi-centre longitudinal design and robust quality assurance for the administrative data analysed. This study, to the best of our knowledge, is the first of its scale in sub-Saharan Africa to describe trends in all-cause hospital outcomes during the COVID-19 pandemic for both adults and children.

The study had several limitations. Unmeasured variables are likely to have contributed to trends, and the incidence rate ratios presented should only be interpreted as quantifying change over time rather than specific associations with COVID-19. Although the surveillance sites are located in densely populated regions of the country, they do not represent the full range of hospitals in Kenya and the short duration of baseline surveillance may have compromised the validity of the predictive trends. We relied on the routine health system capacity for SARS-CoV-2 testing. Almost one-third of adult patients hospitalised during the pandemic met the case definition for suspected COVID-19, and the disease was confirmed in approximately one-third of those tested but testing was done infrequently, hence our reliance on syndromic surveillance rather than test results.

Conclusions

In this study, we utilised a surveillance platform integrated into a hospital-based network to reveal reduced hospitalisation rates and in-hospital deaths during the COVID-19 pandemic, despite a rise in pneumonia admissions among adults. These overall trends persisted even after the withdrawal of containment measures that had previously disrupted essential health services. Admissions for pneumonia among adults remained elevated throughout the pandemic period. In contrast, paediatric pneumonia cases initially declined during the first year of the pandemic but rebounded following the relaxation of government control measures. These findings expose the need to study the interplay of diverse factors that impact hospitalisation and mortality rates during public health emergencies and demonstrate a role for hospital-based syndromic surveillance for monitoring disease outbreaks.

Ethics and consent

This Scientific and Ethical Review Committee of the Kenya Medical Research Institute (approval number: KEMRI/SERU/CGMR-C/203/4085) (7 September 2020), the Oxford Tropical Research Ethics Committee (44–20) (21 August 2020), and the London School of Hygiene and Tropical Medicine Research Ethics Committee (26950) (11 February 2022) gave ethical approval for this work. Additionally, the study was approved by the Ministry of Health, and participating counties, with the Medical Superintendents of hospitals giving consent for participation. Individual consent for access to de-identified patient data was waived by the ethics committees.

Data availability

Underlying data

The data utilised in this work was made available to the research team by the participating hospitals and the Ministry of Health, and thus we are not the primary data owners; our use for these routine hospital data is approved as part of a specific ethical review process. Further access to the data can be sought through a request to KEMRI Wellcome Trust Research Programmes's Data Governance Committee through email: dgc@kemri-wellcome.org. For the purpose of Open Access, the author has applied a CC-BY public copyright license to any accepted manuscript version arising from this submission.

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