Spatial And Spatio-Temporal Epidemiological Approaches To Inform Covid-19 Surveillance And Control: A Review Protocol

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Protocol

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Abstract

Introduction: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pathogen/infections that cause coronavirus disease 2019 (Covid-19) have afflicted millions worldwide. Understanding the underlying spatial and temporal dynamics can help orient timely public health policies and optimize the targeting of non-pharmaceutical interventions and vaccines to the most vulnerable populations, particularly in resource-constrained settings such as Sub-Saharan Africa (SSA). The review systematically summarises important methodological aspects and specificities of spatial approaches applied to Covid-19 in SSA.

Methods: Thematically selected keywords will systematically search for refereed studies in the following electronic databases PubMed, SCOPUS, MEDLINE, CINHAL, and Coronavirus Research Database for peer-reviewed articles from January 2020 to October 2021. Two independent reviewers will screen the title, abstracts, and full texts against predefined eligibility criteria based on methodological relevance and quality. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 procedures will be adhered to during the reporting process.

Discussion: A wealth of studies employing spatial and spatio-temporal methodology have appeared in literature in diverse contexts; however, Covid-19 modeling remains in its infancy, and research is needed to characterize uncertainty and validate various modeling regimes appropriately. It is anticipated that the review will aid spatial, spatio-temporal modeling decisions necessary for mitigating the current and future pandemics.

Systematic review registration: CRD42021279767

Background

The rapid and devastating spread of the novel Covid-19 pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pathogen was first discovered in Wuhan, Hubei Province, China, in the latter part of 2019. Covid-19 continues to spread worldwide and has 234 million confirmed cases, and more than 4.8 million deaths have been reported worldwide. In Africa, 6 million confirmed cases and 146,980 deaths had been reported as of October 4 2021[1]. Its spread has led to a dual health and economic burden resulting in a substantial cost. The International Monetary Fund (IMF) estimates a $ 20 trillion increase in government debt between September 2019 to September 2020[2]. In mitigating this burden, governments have realigned their healthcare services (cutting down routine testing of other diseases, regulating elective surgeries, and limiting access to non-urgent circumstances) and resources, depriving the most vulnerable populations of essential medical services[3-5].

Although the pandemic continues to overwhelm health systems globally, Africa remains disproportionately affected[6]. The disproportionate spread of Covid-19 across and within countries in SSA has not followed a homogenous pattern with the heterogeneity attributed to a country's ability to prevent, detect and mount response strategies[7-9]. This has been exacerbated by incomplete

documentation on Covid-19 cases and deaths across the continuum of care [10] due to inefficient and unreliable disease surveillance systems, scarce critical care resources, grossly underfunded and inadequate healthcare facilities, insufficient training of healthcare workers[11-13]. Additionally, its interaction with poverty-related non-communicable diseases (NCDs) has led to adverse medical outcomes/attributable deaths that are yet to be fully quantified[14-16]. Furthermore, the attributed burden of SSA remains affected by the unacceptable inequalities in vaccine access and rollout, putting at risk high-risk groups and healthcare workers[12, 17]. Amidst these challenges, concerns on the ability of SSA countries to achieve the United Nations sustainable development goals (SDGs) continue to be raised[18].

As more transmissible variants continue to spread across SSA, driven in part by high human mobility, vaccine hesitancy, low rates of mask utility, supply chain constraints, and distribution inequalities, there is an urgent need of obtaining epidemiologically meaningful dynamics at relevant thresholds[13, 19]. Epidemiological surveillance has been an essential tool for understanding the Covid-19 burden. Different approaches have been employed to unmask the trends and drivers of Covid-19 in space and time since its declaration as a global pandemic. The utility of spatial and spatio-temporal models has become relevant and greatly improved the estimation of Covid-19 fine-scale risk[13]. These models have been sustained by the enhanced computational ability creating an ideal environment for identifying and visualizing the regional and global trends of Covid-19 risk. The availability of these models has contributed to informed and timely public decision-making enabling the optimal allocation of scarce resources, effective control and containment initiatives, particularly in areas where variants are circulating.

Over the past year, there has been an increase in the literature regarding Covid-19 modeling in space and time[20-23]. However, substantial uncertainty and diverging methodologies of estimation and forecasting have resulted in essential differences in the projections and inference in the SSA context. There has been an ongoing concern about the availability and quality of the data that have been used to generate critical metrics for quantifying the progress made. This review seeks to appraise the data sources, assess the modeling covariates and methodological rigor of studies employing spatial, spatio-temporal methods. The review can potentially enhance the framework of infectious disease modeling, essential for informing modeling decisions for future pandemics.

Methods

Study registration and protocol

This review has been registered with the International Prospective Register of Systematic Reviews (PROSPERO Reference: CRD42021279767). The review will also follow the reporting guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement (PRISMA 2020)[24, 25] in its procedures to enhance its rigor (Additional file 1).

Search strategy

In consultation with the Head of Research for William & Mary Libraries, a rigorous, phased, and transparent process will be undertaken to search for relevant studies, iteratively select eligible studies, and extract data from the studies. The relevant studies will be searched using the following bibliographic databases, namely PubMed, SCOPUS, MEDLINE, CINHAL, and Coronavirus Research Database using the search terms. In order to improve the comprehensiveness of the search, thematic keywords will be funneled using Boolean operators, and a combination of medical sub-headings (MeSH) will be used and modified where necessary for each database (Table 1). The snowball technique will be used to manually trace relevant studies in the list of references of the eligible studies up to the point of saturation (i.e., no new information emerged from subsequent articles manually searched). Gray literature will also be searched via Google scholar and authors contacted for any missing publications. After that, eligible studies will be imported into RefWorks management software . Considering that on January 30, 2020 the World Health Organization officially declared Covid-19 a Public Health Emergency of International Concern , the literature search will be limited to original studies published from January 30 2020 to October 2021 (Figure 1).

The keyword frequency in the included studies will also be analyzed and a word cloud diagram constructed. Additionally, the search record will be documented: Search date, database searched, keywords, and the total number of retrieved studies. (Additional file 1)

Table 1: Preliminary search string

Theme	Search string
Covid-19	(Betacoronavirus OR Betacoronaviruses), (Corona Virus OR Corona Viruses OR Coronavirus OR Coronaviruses), (COVID OR COVID19 OR Covid-19), (CoV OR CoV2 OR HCoV-19 OR nCoV OR 2019nCoV), (Severe Acute Respiratory Syndrome CoV OR severe acute respiratory syndrome coronavirus 2 OR SARS CoV 2 OR SARS-CoV-2 OR SARSCoV OR SARS-CoV OR SARS2)
Model	Spati* OR geospatial OR space-time OR geographic OR mapping OR geospatial OR cluster
Location	Africa

Inclusion and exclusion criteria

A calibration exercise will ensure that only the correct studies are included, and that relevant study information is consistently and accurately captured. This approach improves the methodological rigor and will involve two independent reviewers independently screening the title and abstract of a random sample comprising 5% of the studies. Studies will be eligible for review if they apply one or more of the following spatial or spatio-temporal analysis: exploration (using statistical tools to monitor trends), visualization (cluster analysis to quantify the geographic variation), and modeling (utilizing data to

explore Covid-19 risk factors and develop space-time predictive models). We define a spatial model to explicitly incorporate a geographic index for a given area/observations, whereas a temporal model will include a time index. (Table 2)

Studies will be excluded if their abstract or full-text is not available. Articles that are not peer-reviewed, such as letters, editorials, comments, book/book sections, conference proceedings, or conceptual papers without findings; studies that did not focus on Covid-19 ; or did not use GIS, or geospatial techniques will also be ineligible for inclusion. Experimental design studies, case series/reports, and studies on the genetic characterization of Covid-19 will also be excluded.

The review team will resolve emerging discrepancies until a consensus is reached. If consensus is not reached, then an independent arbitrator will be consulted for possible inclusion or exclusion. The eligibility criteria will be modified if a kappa statistic lower than 50% is observed between the reviewers, indicating low agreement.

Table 2: Study inclusion criteria

Criteria	Description
Study type	Original peer-reviewed journal article utilizing spatio-temporal modeling approaches
Analytical approach	Spatial and spatio-temporal model.
Context	Geography: Africa Language: No language restriction Time frame: All publications from January 30 – December 2021 will be included.

Data abstraction

Using a predesigned abstraction form to be developed using Microsoft Excel/Google docs, two reviewers will independently and iteratively abstract data on a random sample of 10 articles (i.e., reading the full text of each article and extracting the relevant information). Emerging discordance between the reviewers concerning information extracted will be resolved by consensus among the reviewers and by discussions with a third reviewer. For each eligible study, the following information will be extracted (Table 3):

Table 3: Data Abstraction Form

1. ***Bibliographic information***

- Study ID
- Author, Year
- Country
- Article Title
- Language study period (Start-End)
- Data Source
(Medical records, multiple sources, others)
- Type of publication
(Journal article, book chapter, grey literature).
- The primary unit of analysis
(cluster, individual, more than one unit, other)
- Study population/Spatial unit
(Household, national, province, district facility, malaria case, census tract, other)

2. ***Aims***

Study aims and objectives (primary and secondary)

3. ***Methodology***

- Data sources used, multiples sources employed, different study designs and sampling frames employed
- Visualization techniques
- Cluster Detection Techniques
- Covariate(s) Selection
- Spatial-temporal modelling approach

4. ***Results*** (Does the paper report data relating to the following?)

Key findings

Unexpected results

5. ***Discussion***

Key findings

Unexpected results

Modeling gap(s)

Limitations

6. ***Conclusions and Recommendations***

Modeling issues requiring further attention

Suggestions for improved analytical approaches for future studies

i. Bibliographic information (Author, year, country of origin, spatial and temporal resolution)

ii. Study objective (s) (Primary and secondary)

iii. Data sources and modeling covariates

iv. Modeling approach(es) (Assumptions, structure, cluster detection techniques, model validity test, statistical software)

v. Results and discussions (Findings, study limitations, implication for future research)

Data synthesis and analysis

This phase will involve three distinct steps: analysis, reporting, and interpreting the review findings. Thematic content analysis will be used to cluster studies based on their spatio-temporal methodological approaches, spatial and temporal resolution, data sources, and modeling approaches to identify the dominant findings and make generalizations. Descriptive summary tables will be used to assess studies based on their geographic location, publication year, data sources, visualization, modeling approaches, covariates. Results will be reported based on the review objectives, with the practical implications for policy and modeling practices discussed. The current gaps in the spatio-temporal modeling of Covid-19 will also be outlined concerning future research.

Quality appraisal and risk of bias assessment

The review quality appraisal will be independently done by two reviewers, who will outline the strengths and weaknesses of each paper using an adopted tool for assessing quality[26, 27]. This tool will comprise 8-point scoring criteria used to determine the quality of the individual studies based on their study objectives, data source, model validity, results, and conclusions (Supplementary Table 1). Four broad categories will namely: very high (>13), high (11–13), medium (8–10) and low (<8) will be used to assess the overall quality level of individual studies. Additionally, screening questions/criteria will guide the scoring process, ranging from 0 (poor) to 2 (good) on each criterion.

Discussion

SSA response strategy has mainly been placed on the World Health Organization (WHO) lead Covax Facility, which set an ambitious target of fully vaccinating 10% of the world population by September 30, 2021[28]. In its bid to achieve this target, the WHO advocates for the equitable distribution of vaccines. This advocation has triggered the demand for timely and comparable in-country, national and global estimates. Policymakers continue to rely on diverse data sources and methodology to generate metrics critical for monitoring progress. In the era of reproducible science, spatial epidemiological tools continue to be employed to improve our understanding of the control and treatment options available and to bolster public health adherence to health measures. Our review will potentially impact policy and practice and contribute to the Covid-19 modeling literature in resource-constrained settings. We anticipate that our review will appraise spatio-temporal epidemiologic applications and identify knowledge gaps essential for steering key modeling decisions and timely public health measures. In the transparent and reproducible science era, this may help augment sound methodology when quantifying the burden of

diseases in space in time. As more data becomes available, our review will provide practical insights, help clarify complex and multi-component spatial and spatio-temporal methods, and enhance evidence-based practice and decision-making.

Anticipated challenges

We foresee potential challenges relating to our systematic review. First, our search strategy might yield more articles than we might expect. To mitigate this, we will work closely with the Head of Research at William & Mary Libraries to ensure that the scope is manageable. Secondly, categorizing and appraising methods accurately and exhaustively might be a challenge. However, we intend to engage with stakeholders with in-depth subject knowledge of Covid-19 modelling to receive feedback important for the review.

Conclusion

The continuous spread of Covid-19 , particularly in unvaccinated populations in SSA, threatens to choke progress made in fighting the pandemic. As high and upper-middle-income countries ease mandates, the risk of global resurgence remains due to the significant disparity in vaccine distribution, particularly in SSA. There is an urgent need to increase equitable access to vaccination and the pace of vaccination. This can be done if policymakers make inferences based on a robust statistical methodology to mitigate the pandemic. By outlining the main methodological approaches used to quantify progress, the results from this review can expand our current understanding of the etiology of Covid-19 , orient resource allocation, monitor healthcare access, and plan for effective interventions in SSA and other resource-constrained settings. Additionally, the review will provide valuable insight to support future bibliographic queries and serve as a resource for outlining the evolution of modeling tools in a major global pandemic. It potentially will offer helpful information specifically on how countries collect and report data and steer pandemic health policies.

List Of Abbreviations

Covid-19 : Coronavirus disease 2019

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PROSPERO: International Prospective Register of Systematic Reviews

SSA: Sub Saharan Africa

WHO: World Health Organization

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Competing Interests

The authors declare that they have no competing interests.

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Author contributions

Both authors (JNO and CBD) conceptualized the review and developed the review's background. JNO contributed to the development of the methods relating to the review and synthesis of data, and prepared the draft manuscript. Both authors reviewed and approved the final manuscript.

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Figures

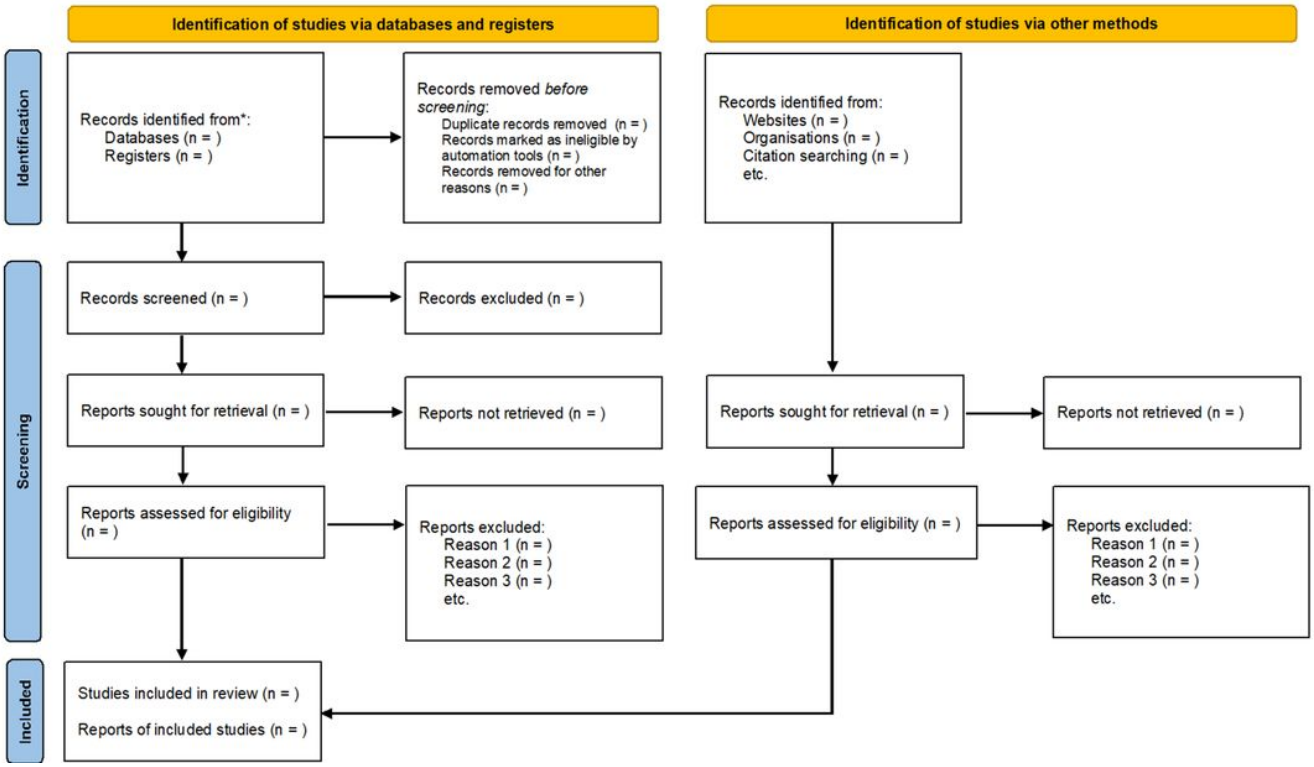

Figure 1

PRISMA 2020 flow diagram

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementarytable1Riskofbias.docx
- Additionalfile1PRISMAP2015checklist.docx
- Additionalfile2Preliminarysearchresults.docx