Preparedness and vulnerability of African countries against importations of COVID-19: a modelling study


Summary

Background The novel coronavirus disease 2019 (COVID-19) epidemic has spread from China to 25 countries. Local cycles of transmission have already occurred in 12 countries after case importation. In Africa, Egypt has so far confirmed one case. The management and control of COVID-19 importations heavily rely on a country’s health capacity. Here we evaluate the preparedness and vulnerability of African countries against their risk of importation of COVID-19.

Methods We used data on the volume of air travel departing from airports in the infected provinces in China and directed to Africa to estimate the risk of importation per country. We determined the country’s capacity to detect and respond to cases with two indicators: preparedness, using the WHO International Health Regulations Monitoring and Evaluation Framework; and vulnerability, using the Infectious Disease Vulnerability Index. Countries were clustered according to the Chinese regions contributing most to their risk.

Findings Countries with the highest importation risk (ie, Egypt, Algeria, and South Africa) have moderate to high capacity to respond to outbreaks. Countries at moderate risk (ie, Nigeria, Ethiopia, Sudan, Angola, Tanzania, Ghana, and Kenya) have variable capacity and high vulnerability. We identified three clusters of countries that share the same exposure to the risk originating from the provinces of Guangdong, Fujian, and the city of Beijing, respectively.

Interpretation Many countries in Africa are stepping up their preparedness to detect and cope with COVID-19 importations. Resources, intensified surveillance, and capacity building should be urgently prioritised in countries with moderate risk that might be ill-prepared to detect imported cases and to limit onward transmission.

Funding EU Framework Programme for Research and Innovation Horizon 2020, Agence Nationale de la Recherche.

Introduction

On Jan 30, 2020, WHO declared the current novel coronavirus disease 2019 (COVID-19) epidemic a Public Health Emergency of International Concern.1 As of Feb 11, 2020, the epidemic registered 42 708 cases in China and spread to 25 countries that reported a total of 395 cases.2 Limited local transmission outside China was reported in Germany, France, Japan, Malaysia, Singapore, South Korea, Spain, Thailand, Vietnam, the United Arab Emirates, the UK, and the USA.

All continents reported confirmed cases of COVID-19. Africa confirmed its first case in Egypt on Feb 14, 2020. China is Africa’s leading commercial partner; thus, there are large travel volumes through which severe acute respiratory syndrome coronavirus 2 could reach the continent. Several measures have already been implemented to prevent and control possible case importations from China;3,4 however, the ability to limit and control local transmission after importation depends on the application and execution of strict measures of detection, prevention, and control. These measures include heightened surveillance and rapid identification of suspected cases, followed by patient transfer and isolation, rapid diagnosis, tracing, and follow-up of potential contacts.5 The application of such a vast technical and operational set of interventions depends on each country’s public health and laboratory infrastructures and resources.

We assessed the risk of importation of cases of COVID-19 to Africa from affected provinces in China, and contextualised this risk with each country’s vulnerability to epidemic emergencies and capacity to respond. Importation risk was determined by the volume of air traffic connections6–8 from areas where the virus currently circulates in China. Each country’s functional capacity to manage health security issues is based on WHO International Health Regulations (IHR) Monitoring and Evaluation Framework (MEF),9 and on an indicator of vulnerability to emerging epidemics.

Methods

The risk of importation of cases of COVID-19 to Africa from China was estimated based on origin–destination air travel flows from January, 2019;3,10,11 number of cases in Chinese provinces; and the population in each of the Chinese provinces that reported transmission. Air travel flows counts the number of origin–destination tickets and account for any connection at intermediate airports.12 Case data included all confirmed cases recorded until Feb 11, 2020.13 Human population data per province14
Evidence before this study

The current outbreak of novel coronavirus disease 2019 (COVID-19) has spread rapidly within China and across many countries. Very few data are available that describe and estimate the risk of international spread beyond Asia and Europe. We searched PubMed for articles in English published on and before Feb 1, 2020, that included “coronavirus”, “CoV”, “2019-nCoV”, and “international spread”. Few studies have investigated the risk of spread based on local incidence of COVID-19 in China at the provincial level, international air travel to countries in Africa, local capacity to detect the outbreak, and capacity to contain the outbreak successfully.

Research in context

For sensitivity, we considered a larger area as the basin of attraction of the airports of Beijing and Shanghai, which included their neighbouring provinces (appendix p 2).

For each African country, the most likely origins of potential case importation were identified by computing a country’s exposure to each Chinese province, measuring the probability of a city in China being the origin of a travelling case to the country. Similarity between exposure profiles of different countries was quantified with entropy-based metrics, and used to group countries with similar importation patterns via agglomerative clustering (appendix p 2).

The WHO IHR MEF is a set of four components developed by WHO to support the evaluation of a country’s functional ability to detect and respond to a health emergency. The IHR MEF is composed of a mandatory self-reporting of capacity (the State Party Self-Assessment Annual Reporting [SPAR]), and three voluntary components, namely the Joint External Evaluation, the after-action reviews, and simulation exercises, which are all collected and disseminated by WHO. SPAR generates data and has indicators for all African countries for 2018. Joint External Evaluation is consolidated through joint internal and external evaluation processes. In Africa, Joint External Evaluation data were only available for 43 countries from 2016 to 2019.

The 2018 SPAR database contains 24 indicator scores, organised and grouped according to the following capacities (bracketed number shows indicators per capacity): legislation (three), IHR Coordination (two), zoonoses (one), food safety (one), laboratory (three), surveillance (two), human resource (one), national health emergency framework (three), health service provision (three), communication (one), points of entry (two), chemical events (one), and radiation emergency (one). The SPAR index was derived to quantify each country’s functional ability to detect and respond to a health emergency. The IHR MEF is composed of four components developed by WHO to support the evaluation of a country’s functional ability to detect and respond to a health emergency.

For sensitivity, we considered a larger area as the basin of attraction of the airports of Beijing and Shanghai, which included their neighbouring provinces (appendix p 2).

For each African country, the most likely origins of potential case importation were identified by computing a country’s exposure to each Chinese province, measuring the probability of a city in China being the origin of a travelling case to the country. Similarity between exposure profiles of different countries was quantified with entropy-based metrics, and used to group countries with similar importation patterns via agglomerative clustering (appendix p 2).

The WHO IHR MEF is a set of four components developed by WHO to support the evaluation of a country’s functional ability to detect and respond to a health emergency. The IHR MEF is composed of a mandatory self-reporting of capacity (the State Party Self-Assessment Annual Reporting [SPAR]), and three voluntary components, namely the Joint External Evaluation, the after-action reviews, and simulation exercises, which are all collected and disseminated by WHO. SPAR generates data and has indicators for all African countries for 2018. Joint External Evaluation is consolidated through joint internal and external evaluation processes. In Africa, Joint External Evaluation data were only available for 43 countries from 2016 to 2019.

The 2018 SPAR database contains 24 indicator scores, organised and grouped according to the following capacities (bracketed number shows indicators per capacity): legislation (three), IHR Coordination (two), zoonoses (one), food safety (one), laboratory (three), surveillance (two), human resource (one), national health emergency framework (three), health service provision (three), communication (one), points of entry (two), chemical events (one), and radiation emergency (one). The SPAR index was derived to quantify each country’s functional ability to detect and respond to a health emergency.

For sensitivity, we considered a larger area as the basin of attraction of the airports of Beijing and Shanghai, which included their neighbouring provinces (appendix p 2).

For each African country, the most likely origins of potential case importation were identified by computing a country’s exposure to each Chinese province, measuring the probability of a city in China being the origin of a travelling case to the country. Similarity between exposure profiles of different countries was quantified with entropy-based metrics, and used to group countries with similar importation patterns via agglomerative clustering (appendix p 2).

The WHO IHR MEF is a set of four components developed by WHO to support the evaluation of a country’s functional ability to detect and respond to a health emergency. The IHR MEF is composed of a mandatory self-reporting of capacity (the State Party Self-Assessment Annual Reporting [SPAR]), and three voluntary components, namely the Joint External Evaluation, the after-action reviews, and simulation exercises, which are all collected and disseminated by WHO. SPAR generates data and has indicators for all African countries for 2018. Joint External Evaluation is consolidated through joint internal and external evaluation processes. In Africa, Joint External Evaluation data were only available for 43 countries from 2016 to 2019.

The 2018 SPAR database contains 24 indicator scores, organised and grouped according to the following capacities (bracketed number shows indicators per capacity): legislation (three), IHR Coordination (two), zoonoses (one), food safety (one), laboratory (three), surveillance (two), human resource (one), national health emergency framework (three), health service provision (three), communication (one), points of entry (two), chemical events (one), and radiation emergency (one). The SPAR index was derived to quantify each country’s functional ability to detect and respond to a health emergency.
country’s capacity to deal with the importation and spread of COVID-19 by averaging indicators from all capacities, except those of the capacities zoonoses, food safety, chemical events, and radiation emergency.

Both SPAR and Joint External Evaluation metrics were designed to quantify each country’s functional capacity, without accounting for other indirect factors that might compromise the control of emerging epidemics, such as demographic, environmental, socioeconomic, and political conditions. The Infectious Disease Vulnerability Index (IDVI) was introduced as a synthetic metric of vulnerability to account for these factors. Another indicator, the INFORM Epidemic Risk Index, was developed by the EU Joint Research Centre in collaboration with WHO, to account for different combined effects of each country’s epidemic transmission risk, infrastructure, vulnerability, and coping capacity.

For African countries where data were available, a multivariate analysis of these indicators showed a high correlation between SPAR and Joint External Evaluation indicators, and between IDVI and INFORM Epidemic Risk Index (appendix p 3). Given their coverage and complementarity, we selected SPAR and IDVI for our analysis. Both SPAR and IDVI indicators range from zero to 100, with increasing levels of capacity and decreasing vulnerability, respectively.

Role of the funding source
The funders had no role in study design, data collection, data analysis, data interpretation, writing of the manuscript, and decision to submit. The first author and the corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results
Egypt, Algeria, and South Africa were the countries at highest importation risk from China, with moderate to high SPAR capacity scores (87, 76, and 62, respectively) and IDVI (53, 49, and 69, respectively; figures 2, 3). Countries with the second highest importation risk ranking included Nigeria and Ethiopia, with moderate capacity (51 and 67, respectively), but high vulnerability (27 and 38, respectively), and substantially larger populations potentially exposed (figure 1). Morocco, Sudan, Angola, Tanzania, Ghana, and Kenya had similar moderate importation risk and population sizes; however, these countries presented variable levels of capacity (ranging from 34 to 75) and an...
overall low IDVI (<46), reflecting a high vulnerability (except Morocco, with an IDVI of 56). All other countries had low to moderate importation risk and low to moderate IDVI, with most having a low SPAR capacity, with the exception of Tunisia and Rwanda. No substantial change was observed when the larger basins of attraction for the airports of Beijing and Shanghai were considered (appendix p 3). For comparison, Organisation for Economic Co-operation and Development countries had a SPAR ranging from 51 to 99, with a mean of 84.2 (SD 12.36), and an IDVI ranging from 78 to 97, with a mean of 88.3 (SD 6.33; figure 3).

Three clusters were identified among the countries with non-negligible risk (figure 4). Each of the clusters corresponded to different Chinese airports as the main source of entry risk. Cluster number 1 was highly exposed to Beijing, and moderately exposed to Guangdong province and Shanghai; cluster number 3 (including Botswana and Lesotho only) was exposed exclusively to the potential risk from airports in the Fujian province; and cluster number 2 was heavily exposed to risk from Guangdong province and weakly to Zhejiang province (figure 4).

**Discussion**

Early detection of COVID-19 importation and prevention of onward transmission are crucial challenges to all countries at risk of importation from areas with active transmission in China. 12 countries in Asia, Europe, and North America have already reported secondary spread following importation. Onward transmission potentially occurring in countries with weaker health systems is a major public health concern.

We show that the risk of importation to African countries is highly heterogeneous, with Egypt, Algeria, South Africa, Ethiopia, and Nigeria estimated to be at highest risk. We also identified that part of this heterogeneity in Africa depended on the distribution of cases within Chinese provinces. Although certain provinces in China are

---

**Figure 3:** Importation risk as a function of the SPAR capacity and IDVI in Africa

**Figure 4:** Cluster of countries sharing similar risk of importation from specific Chinese provinces
Cluster number 1: Algeria, Angola, Chad, Egypt, Ethiopia, Ghana, Guinea, Côte d’Ivoire, Kenya, Mauritius, Morocco, Nigeria, South Africa, Sudan, Tanzania, Uganda, Zambia, and Zimbabwe. Cluster number 2: Cameroon, Democratic Republic of the Congo, Madagascar, Mozambique, Rwanda, Senegal, and Tunisia. Cluster number 3: Botswana and Lesotho. Countries in grey were estimated to have a negligible risk of entry at the time of analysis.
Countries at the highest risk of importation, based on the current epidemic situation in China, had moderate to high capacity scores; however, these scores might correspond to different contributions to the mean SPAR indicators, reflecting different aspects of a country’s functional capacity. For example, South Africa had the maximum score for laboratory capacity (100), but a low score in risk communication (20). Conversely, Nigeria had a low score in the laboratory capacity (27) and the maximum score in the IHR Coordination capacity (100). Conversely, countries with the lowest SPAR capacity score (ie, Kenya, Tanzania, and Ghana) had moderate to low importation risk. The evaluation of additional factors (ie, demographic, socioeconomic, and political factors) included in the IDVI that might influence the overall potential effect of an unfolding epidemic identified several countries that had a significant importation risk with a low to medium IDVI, such as Nigeria, Ethiopia, Egypt, and Algeria. The risk of importation from other points of entry, such as seaports, was not evaluated.

Our results should be interpreted carefully. The overall risk of importation to Africa is lower than that to Europe (1% vs 11%, respectively, according to our estimates on the current situation), but response and reaction capacity are also lower. The overall SPAR score and IDVI of African countries are linked to their overall wealth, and are generally significantly lower than many high-income countries with higher overall resources for detection, prevention, and control. Comparatively, China has a SPAR score of 93 and an IDVI of 63.

African countries have recently strengthened their preparedness against COVID-19 importations. Many countries have improved airport surveillance and implemented temperature screening at ports of entry, thanks to equipment that was readily available following the 2013–16 Ebola epidemic, including high-risk countries according to our analysis—South Africa, Ethiopia, and Nigeria, with the latter also interviewing passengers arriving from China. Overall recommendations to avoid travel to China have been issued (eg, by the Ministry of Health of Nigeria). Communication campaigns have been intensified after the publication of WHO guidelines encouraging the provision of information to health professionals and the general public, often with 24 h dedicated hotlines, as in the case of Senegal.

Some countries remain ill-equipped. Some are without the diagnostic capacity for rapid testing for the virus; thus, if cases are imported, tests will need to be done abroad, which might critically increase the delay from identification of suspected cases to their confirmation and isolation, affecting possible disease transmission. WHO is currently supporting countries to improve their diagnostic capacity. In the African region, this capacity has now expanded from just two referral laboratories to a larger set of countries, and is expected to continue to increase in the upcoming weeks. The capacity of these laboratories is still limited by the shortage of personnel...
trained to run the tests, and inadequate stock of materials needed to do these tests. It is essential to train, equip, and strengthen the diagnostic capacities of hospital laboratories close to infectious disease and emergency departments to reduce the time to deliver results, manage confirmed cases and contacts more rapidly, and preserve strict infection control measures.

In the African region, resources to set up quarantine rooms for suspected cases at airports and hospitals, or to trace contacts of confirmed cases, as recommended by WHO, might be scarce. 74% of countries in Africa have an influenza pandemic preparedness plan; however, most are outdated (prior to the 2009 influenza A H1N1 pandemic) and considered inadequate to deal with a global pandemic. 26 Countries might not have the same capacity to manage repatriations of nationals (eg, African students) from the province of Hubei in China, as done by high-income countries, because of a scarcity of resources, including personnel, centres, and equipment for quarantine and isolation. The epidemic in China highlights the rapid saturation of the hospital capacity if the outbreak is not contained. Increasing the number of available beds and supplies in resource-limited countries is crucial in preparation for possible local transmission following importation.

The aftermath of recent epidemics and pandemics (eg, severe acute respiratory syndrome, H1N1 pandemic, Middle East respiratory syndrome, and Ebola) have highlighted the need to reinforce national public health capabilities and infrastructures, including disease-surveillance systems and laboratory networks, as well as human capacity (eg, training in surveillance, epidemic response, and diagnostic testing). 27,28 National public health capabilities and infrastructures remain at the core of global health security, because they are the first line of defence in infectious disease emergencies. 22 Crisis management plans should be ready in each African country; involvement of the international community should catalyse such preparedness. Our findings should help to inform urgent prioritisation for intensified support for preparedness and response in specific African countries found to be at moderate to high risk of importation of COVID-19 and with relatively low capacity to manage the health emergency.

Contributors
MG, MUGK, EV, and VC conceived of and designed the study. MG, GP, MUGK, FP, EV, and BG collected and analyzed the data, and did the analysis. MG, CP, P-YB, ED’O, YY, SPE, MA, MUGK, and VC interpreted the results. MG and VC drafted the Article. All authors contributed to the writing of the final version of the Article.

Declaration of interests
We declare no competing interests.

Data sharing
All data used are publicly available, and sources are cited throughout.

Acknowledgments
We thank WHO for input on the use of the SPAR and Joint External Evaluation data, Laura Di Domenico and Ernesto Ortega for help with data collection, Sally Blower for useful input on the study, and REACTing (https://reacting.insERM.fr/) for useful discussions. This study was partially supported by the ANR project DATAREDUX (ANR-19-CESA-0008-03) to VC; the EU grant MOOD (112020-874850) to MG, CP, MUGK, P-YB, and VC; and the Municipality of Paris through the programme Emergence(s) to CP and FF; the Branco Weiss Fellowship to MUGK; and the African coalition for Epidemic Research, Response and Training (ALERRT), EDCTP2, EU (RIA2016-E-1612) to SPE and MA.

Editorial note: the Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

References
24 Nkengasong J. China’s response to a novel coronavirus stands in stark contrast to the 2002 SARS outbreak response. Nat Med 2020; published online Jan 27. h t t p://doi.org/10.1038/s41591-020-0771-1.