A rapid review of the effectiveness of screening practices at airports, land borders and ports to reduce the transmission of respiratory infectious diseases such as COVID-19

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Background. Travel screening for infectious diseases is often implemented to delay or prevent the entry of infected persons to a country/area.
Objectives. To evaluate the effectiveness of different point-of-entry screening strategies in achieving a reduction in imported COVID-19 transmission.
Methods. A rapid evidence review was conducted, systematically searching PubMed and Google Scholar and grey literature on 27 March 2020.
Results. We screened 1 194 records. Nine potential full-text articles were assessed for eligibility and included. Three articles investigated the effectiveness of entry-based thermal and body temperature scanning. Entry-based infrared thermal or body temperature scanning for COVID-19 was unlikely to be effective. Two systematic reviews found no additional benefit of travel restrictions/screening. In a COVID-19 modelling study, airport screening was not effective, with exit and entry thermal scanning identifying half and missing almost half of infected travellers. Two other modelling studies found that entry-based travel screening would achieve only modest delays in community transmission, while international travel quarantine could reduce case importations by 80%.
Conclusions. There is insufficient evidence to support entry and exit screening at points of entry, as these strategies detect just over half of the infected cases, missing almost half at entry points. The benefits of airport screening therefore need to be context specific and weighed against the resources and cost of implementation, the contribution of imported cases to total cases, and the benefits of identifying 50% of cases in the South African context with the country's high HIV and tuberculosis prevalence and limited resources to deal with a pandemic of this nature.

S Afr Med J. Published online 13 October 2020. https://doi.org/10.7196/SAMJ.2020.v110i11.14959

Coronaviruses are emerging respiratory viruses known to cause illnesses ranging from the common cold to severe acute respiratory syndrome (SARS).[1] They are zoonotic pathogens that can be transmitted via animal-to-human and human-to-human interaction[2] through air, droplet, faeco-oral and direct contact (incubation period 2 - 14 days).[3] Multiple epidemic outbreaks occurred during 2002 (SARS), with ~800 deaths, and 2012 (Middle East respiratory syndrome (MERS-CoV)), with 860 deaths.[2,4] Approximately 8 years after the MERS-CoV epidemic, the current outbreak of novel coronavirus disease (COVID-19) caused by SARS-CoV-2, which started in Wuhan City, Hubei Province, China, has emerged as a significant public health issue globally.[5] On 30 January 2020, the World Health Organization declared COVID-19 a public health emergency of international concern.[6] In the first week of March, a devastating number of new cases were reported globally, and COVID-19 emerged as a pandemic. As of 20 July 2020, more than 14 million confirmed cases across 118 countries and 609 531 deaths had been reported.[3] On 20 July 2020, South Africa (SA) reported 364 328 confirmed COVID-19 cases with 5 033 deaths.[3]

In response to the pandemic, there have been global restrictions on travel, with several countries implementing screening measures at airports, land border crossings and ports to prevent international COVID-19 transmission by detecting exposed or ill travellers from affected areas and prohibiting their further travel.[7,8] While such screening appears politically correct and reassuring, and may deter sick infectious individuals from travelling, it is exceedingly rare for screeners to detect infected passengers. The long incubation period and high proportion of asymptomatic infections make it difficult to identify cases.[9,10] There is concern that even if an occasional case is detected, it will have almost no impact on the course of an epidemic.

The following exit and entry airport screening procedures have been implemented to detect possible COVID-19 cases, and are being applied in a universal (all passengers) or targeted (passengers from specific countries) manner: (*i*) symptom screening (including Venice, Bosnia, Serbia, Croatia, Moldovia, Albania, Malaysia) by observation (Prague) or a questionnaire (Slovakia, USA, Canada, SA); (*ii*) on-site doctors checking the health of all passengers (Italy); (*iii*) infrared thermal scanners (Thailand, SA, India, Dubai, Abu Dhabi, Trinidad and Tobago, Turkey) or body temperature screen (Italy, Singapore, USA, Canada); (*iv*) visual observation of travellers; and (*v*) establishing testing sites at airports for travellers who screen positive by the first four measures (targeted COVID-19 testing at ports of entry). Galway Airport (Ireland) currently has a testing tent on site, open to the public by appointment, not only to travellers.[11]

However, screening at the point of entry into and exit from countries is labour intensive, and the protective benefits associated with this type of preventive measure are contradictory, with limited public health impact, or evidence of success and benefits, of such measures.[12] In assessing the benefits of a screening measure as a public health intervention, the criteria for effective screening should be considered. Most importantly, screening should target diseases with serious consequences in terms of mortality and morbidity.[13] Currently, global mortality associated with COVID-19 is 3.8%, warranting screening.[14] The screening test should also detect the

disease before the critical point, and should be affordable and readily available. The critical point is the point where detection of the disease could potentially result in a different disease outcome, either drastically reducing the disease spreading to other people in the case of a viral disease, or enabling early treatment to drastically alter prognosis; it will differ for different diseases. An added benefit of early screening is the increased efficacy of treatment when it is applied before symptoms begin, depending on treatment availability.[13] Entry and exit screening at airports, ports and land crossings is aimed at blocking the importation of cases before local transmission can occur, and has particular significance in the case of COVID-19, for which no antiviral treatment or vaccine has been explicitly recommended. Applying preventive measures to control COVID-19 infection is therefore the most critical intervention to prevent importation or spread. Other modalities such as the Cepheid Xpert Xpress SARS-CoV-2 test, a 45-minute rapid polymerase chain reaction (PCR) test that uses the GeneXpert platform to test for SARS-CoV-2, may be beneficial. It is the only new antigen test currently approved. This test may be useful for symptomatic travellers and will allow the laboratory-based PCR test to be reserved for asymptomatic screening.

Objectives

The objective of this rapid review was to provide guidance to the SA Ministry of Health on the available evidence to determine whether screening at airports, land borders and ports was sufficiently beneficial to public health to justify continued use of this measure to curb the pandemic.

Methods

Search strategy

The authors searched two electronic databases (PubMed and Google Scholar) restricted to publications in English. The past 5 years were considered to be most relevant in terms of reviewing evidence and informing guidelines and policy on travel screening in SA. The search terms were as follows: (exit screening OR entry screening OR border measure) AND (patient OR ill OR sick OR infected OR affected OR exposed OR symptomatic) AND (human OR passenger OR travellers OR travellers OR crew) AND (airport OR aerodrome OR airdrome OR seaport OR port OR point of entry OR port of entry).

The research topic assessed the public health impact, practices and experiences of conducting entry or exit screening for infectious diseases among travellers at ports, airports and land crossings, using several screening methods. The search strategy was as broad as possible for the question on travel screening across all infectious diseases and encompassed SARS, influenza and Ebola virus disease (EVD). At the time of the review in early March, evidence on COVID-19 or SARS-CoV-2 was scarce and including these search terms did not yield any studies that were not modelling COVID-19 transmission scenarios.

Inclusion and exclusion criteria

Inclusion criteria were articles or reports or other documents published in peer-reviewed journals or national and international organisations' publications (including conference abstracts) referenced in the two abovementioned electronic databases, from 2015 until March 2020, reporting practices, implementation of guidelines, experiences, structures, processes and evaluation results with regard to national routine or *ad hoc* entry or exit screening activities for travellers at ports or airports or land crossings, during serious cross-border global health events. Articles were excluded if they referred to: (*i*) migrants, refugees and asylum seekers, except when related to response to a global health emergency; (*ii*) screening

for diseases that were not part of a global health emergency response; and (*iii*) entry or exit screening measures that were part of the response to a specific outbreak on board an aeroplane or a ship and not part of a country's response to a global health threat.

All records were uploaded into Mendeley version 1.19.4 (Elsevier, UK).

Data extraction

TC developed and conducted the search strategy and independently screened records to identify eligible studies, and all authors agreed on the final eligible studies. All records that met the eligibility criteria were subject to data extraction (Supplementary File 1, http://samj.org.za/public/sup/14959-1.pdf). TC, NN and BD reviewed and summarised the eligible studies, which were checked by AG.

Meta-analysis

A meta-analysis was not conducted for this rapid review owing to heterogeneity between studies.

Results

Most available publications included modelling data and entry screening measures at airports. Little evidence is available about the implementation and effectiveness of entry and exit screening measures at ports and land crossings. Of the 1 194 citations found, 592 were excluded because they were published more than 5 years ago; of 602 screened, only 9 full-text articles met the inclusion criteria and were reviewed (Fig. 1). A full summary of the included studies is provided in Supplementary File 2 (http://samj.org.za/public/sup/14959-2.pdf).

Characteristics of the included studies

Three articles investigated the effectiveness of thermal scanning and body temperature screening for the identification of infectious diseases at the point of entry.[15-17] All three suggested that infrared thermal
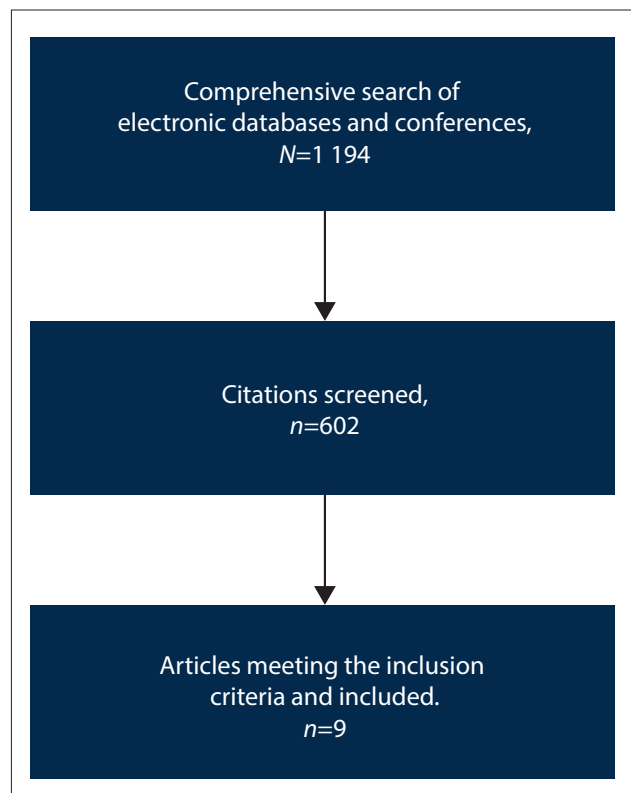

Comprehensive search of electronic databases and conferences, *N*=1 194

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Citations screened, *n*=602

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Articles meeting the inclusion criteria and included. *n*=9

Fig. 1. Flowchart of the screening process.

scanning or body temperature screening was unlikely to be effective for entry screening of travellers to detect either influenza or similar infections such as COVID-19 infection to prevent the entry of the virus into a country.

Two systematic reviews (for influenza and EVD) found no additional benefit of travel restrictions/screening.[18,19]

In the systematic review of travel restrictions to curb influenza transmission,[18] international travel restrictions:

- Delayed the spread and peak of epidemics by periods varying between a few days and 4 months
- Reduced the incidence of new cases by >3%
- Had reduced impact when restrictions were implemented >6 weeks after the notification of epidemics, or when the level of transmissibility was high
- Had minimal impact in urban centres with dense populations and travel networks
- Did not contain influenza within a defined geographical area.

In the systematic review of exit and entry screening measures for EVD between 2003 and 2018 in the three most affected West African countries:[19]

- Screening measures did not identify any cases and showed zero sensitivity and very low specificity
- The percentages of confirmed cases identified out of the total numbers of travellers who passed through entry screening measures in various countries globally for pandemic influenza (H1N1) and EVD in West Africa were also zero or extremely low
- Additionally, entry screening measures for SARS did not detect any confirmed SARS cases in Australia, Canada and Singapore.

Of the four modelling studies included, two used stochastic models, one used a compartmental model, and one used a combination of both stochastic and probabilistic methods. The focus of the included studies was the effectiveness of internal or international travel restrictions or combined internal and international travel restrictions (Table 1).

In a modelling study that specifically focused on COVID-19, Gostic et al.[20] concluded that even in the best-case assumptions, airport screening would not be effective:

- Screening using thermal scanners at exit points would miss almost half of the infected travellers
- Most infected cases missed by screening were fundamentally undetectable because they had not yet developed symptoms and were unaware they were exposed.

Table 1. Characteristics of included modelling studies

Study	Type of restrictions and setting	Study design	Viral strain involved	Strain transmissibility (R0)	Scenario and duration of intervention	Effect estimate
Quilty et al., 2020[15]	Effectiveness of exit and entry screening for detecting travellers entering Europe with COVID-19 infection	Mathematical stochastic model	SARS-CoV-2	Not reported	Assume 100 infected air travellers who in the absence of screening would arrive at their destination infected. Of 100 travellers, how many are likely to: • be detected via exit screening on departure • present with severe disease during travel • be detected via entry screening on arrival • not be detected	44% (95% CI 33 - 56) 0% (95% CI 0 - 3) 9% (95% CI 2 - 16) 46% (95% CI 36 - 58)
Mandal et al., 2020[21]	Port-of-entry symptom screening of travellers with clinical features and from COVID-19-affected countries; India	Deterministic model and stochastic models	SARS-CoV-2	R0=1.5 / R0=4	Infectiousness of asymptomatic cases relative to symptomatic cases = 0 / Infectiousness of asymptomatic cases relative to symptomatic cases = 0.5	Cumulative incidence reduction of COVID-19 infection = 62% / Cumulative incidence reduction of COVID-19 infection = 2%
Gostic et al., 2020[20]	Travel screening (exit screening only, entry screening only or a combination of both)	Probabilistic model	SARS-CoV-2	R0=1.5 - 3.5	Exit screening only (5% subclinical) / Entry screening only (5% subclinical) / Combination of exit and entry screening (5% subclinical)	Fraction detected = 0.21 / Fraction detected = 0.27 / Fraction detected = 0.34
Chinazzi et al., 2020[22]	Domestic and international travel restrictions from China	Individual-based stochastic and spatial epidemiological models (meta-population approach)	SARS-CoV-2	R0=2.4 / R0=2.4	Local travel quarantine within China / International travel quarantine	Local epidemic in China: travel quarantine reduces the overall epidemic progression by only 3 - 5 days / International scale: travel quarantine reduces the number of case importations by 80%

CI = confidence interval.

Similarly, a modelling study of port-of-entry screening in India of travellers with suggestive clinical features and arriving from COVID-19-affected countries used two scenarios: an optimistic scenario where the basic reproduction number (R0)=1.5, and asymptomatic infections lacking any infectiousness.[21] In the optimistic scenario, screening would reduce the cumulative incidence by 62%. In the pessimistic scenario of R0=4, and asymptomatic infections being half as infectious as symptomatic, this projected impact falls to 2% (Table 1). The authors concluded that port-of-entry-based entry screening of travellers with suggestive clinical features and from COVID-19-affected countries would achieve modest delays in the introduction of the virus into the community. These screening measures alone would be insufficient to delay the epidemic by weeks or longer.

Quilty et al.[15] focused their modelling analysis on the effectiveness of airport screening to detect 100 COVID-19-infected travellers. They concluded that 46% of infected travelers (95% confidence interval (CI) 36 - 58) would not be detected, depending on the sensitivity of exit and entry screening and the travellers' incubation period.[15]

Chinazzi et al.[22] modelled the impact of both global and international travel limitations on the national and international spread of the COVID-19 epidemic using a global metapopulation disease transmission model based on the evidence of internationally imported cases before implementation of the travel quarantine of Wuhan. By assuming a generation time of 7.5 days, the reproduction number was estimated to be 2.4 (90% CI 2.2 - 2.6). The median estimate for the number of cases before the travel ban implementation on 23 January 2020 was 58 956 (90% CI 40 759 - 87 471) in Wuhan and 3 491 (90% CI 1 924 - 7 360) in other locations in Mainland China. The model showed that as of 23 January, most Chinese cities had already received a considerable number of infected cases, and the travel quarantine delayed the overall epidemic progression by only 3 - 5 days. The travel quarantine has a more marked effect on the international scale, where the authors estimated the number of case importations to be reduced by 80% until the end of February. Modelling results also indicated that sustained 90% travel restrictions to and from Mainland China only modestly affected the epidemic trajectory unless combined with a 50% or higher reduction of transmission in the community.

In their article, Selvey et al.[23] discussed border screening experiences with SARS and influenza, and by reviewing several articles discussing modelling and observational studies, proposed an approach to decision-making for future pandemics. They concluded that outbreak-associated communications for travellers at border entry points, together with effective communication with clinicians and more effective disease control measures in the community, would be a more effective approach to the international control of communicable diseases.

Risk of bias within studies

Of the four studies based on mathematical modelling, all were found to be at low risk of bias. Methodological issues that may have led to bias included a lack of transmission variation during epidemic progression, seasonality, heterogeneous mixing, and varying population susceptibility. Two of the included studies were editorials or commentaries on prior evidence and cannot be assessed for risk of bias. The two systematic reviews were found to be low risk in terms of bias.

Discussion

Of the possible 602 citations that met the inclusion criteria, 9 full-text articles on entry and exit screening for infectious diseases at the point of entry were reviewed. Five of the 9 identified studies assessed or modelled the effectiveness of travel screening at the point of entry on COVID-19 transmission.

Quilty et al.[15] assessed the effectiveness of thermal scanning for exit screening for international flights departing from China's major airports.[15] Thermal scanning screens travellers for fever and allows for passengers exhibiting COVID-19 symptoms to be tested for infection before boarding a plane. Assuming sensitivity of entry and exit screening of 86%, duration of travel of 12 hours and 17% of asymptomatic cases being undetectable by screening procedures, the authors estimated in their baseline scenario that 44 of 100 infected travellers would be detected by exit screening, no cases would develop severe symptoms, and 9 cases would be detected by entry screening; 46 of 100 cases would not be detected. While the authors concluded that exit or entry screening via thermal scanning or similar was unlikely to prevent the passage of infected travellers into new countries or regions where they may seed local transmission, 53 of 100 cases would be detected if only entry screening was used under their baseline assumptions. Notably, Quilty et al. focused on infected travellers only[15] and not screening for the general population.

Similarly, modelled data reported by Gostic et al.[20] indicated that more than half of cases would be missed under the best-case assumptions imputed in their model.[20] Moreover, most cases missed by screening in their model were fundamentally undetectable, because they had not yet developed symptoms and were unaware they had been exposed.[20] Mandal et al.[21] modelled data on quarantine of symptomatic individuals, showing that such measures would reduce cumulative COVID-19 incidence by 62%, assuming a reproductive rate of 1.5. However, when the reproductive rate was assumed to be 4 and included asymptomatic individuals, the projected reduction in cumulative incidence fell to 2%.[21] Chinazzi et al.[22] modelled the effect of travel quarantine in Chinese cities on curbing the epidemic. Overall, the model showed that there were a considerable number of infected cases in Chinese cities outside Wuhan and the travel quarantine delayed the epidemic by 3 - 5 days. However, the travel quarantine had a more marked effect on international transmission, where the authors estimated that travel quarantine would curb transmission by 80% until the end of February.

In their communication, Bwire and Paulo[16] reported that asymptomatic contact COVID-19 transmission and travellers who had passed the symptoms-based screening tests and subsequently tested CoV-positive using reverse transcriptase-PCR testing challenge the effect of temperature monitoring in detecting those incubating the disease or those deliberately concealing infection symptoms.[16]

In assessing the evidence from studies of screening for COVID-19 and other infectious diseases at the point of entry, studies included in this review concluded that the effectiveness of screening at the point of entry or exit would need to be considered in relation to other measures such as travel restrictions and quarantine of travellers from high-risk countries. In their systematic review of evidence from 2003 to 2018, Mouchtouri et al.[19] reported that entry and exit screening measures for other infectious diseases such as EVD, pandemic influenza (H1N1) and SARS were not effective in detecting cases of infection.[19] However, the authors noted the positive effect of these screening procedures of discouraging travel of ill persons, raising awareness, and educating the travelling public on measures to reduce infection risk.

The lack of available data from observational or experimental studies precluded meta-analysis and sensitivity analysis. Most of the studies included in this review used stochastic or probabilistic models that appeared to have adequate levels of complexity to simulate disease spread and the impact of interventions. The reviewed studies

may have been limited by a lack of consideration of heterogeneous mixing, socioeconomic status and the relationship between age and immunity. Furthermore, simulations may not have considered that transmissibility can vary over time because of seasonal climactic conditions, changes in host susceptibility, and the effects of interventions such as social distancing and quarantine. There was a general paucity of data on land and sea travel.

In considering the policy implications of screening at the point of entry, the question then becomes how many general travellers would need to be screened before one COVID-19 case can be detected? The risk of infected travellers and the number needed to screen would have to be weighed against the risk of local transmission of not screening and other urgent competing priorities. Moreover, as COVID-19 is rapidly evolving in SA and globally, the proportion of cases with local transmission v. international is unknown. In this scenario with unknown data on imported v. local spread, detecting 53 of 100 COVID-19 cases as reported by Quilty *et al.*[15] and over half of the infected cases (Gostic *et al.*[20]) would mean that screening measures at the point of entry had a positive effect on partially blocking the importation of COVID-19 infection. Moreover, additional data would be required on the reproductive rate of a particular case who is under quarantine or practising social distancing.

Current data show that 3% of those tested for COVID-19 are positive given the current case definition.[3] If imported cases are the main source of infection and we are able to contact, trace and isolate these cases, targeted airport screening may be an effective and cost-effective measure to halt transmission of COVID-19, a disease that has a high reproductive rate. Once the nature of the epidemic evolves, with local transmission or asymptomatic cases among adults or children fuelling it, COVID-19 screening at the point of entry may need to be re-evaluated. However, these assumptions need to be validated by current data as the pandemic evolves. Moreover, recommendations on point-of-entry screening need to be contextualised by the high HIV and tuberculosis (TB) burden in SA, with the majority of the country lacking access to adequate healthcare.[24]

Conclusions

While the studies included in this rapid review did not find sufficient evidence to support entry and exit screening measures at points of entry, they indicate that over half of the infected cases may be detected at the point of entry. The benefits of airport screening therefore need to be context specific and weighed against the resources and cost of implementation, the contribution of imported cases to total cases, and the benefits of identifying 50% of imported cases in the SA context, with the country's high HIV and TB prevalence and limited resources to deal with a pandemic of this nature. As COVID-19 is a novel emerging infectious disease, more data are required to fully evaluate this question, and we propose testing potentially effective screening models to identify the most efficient and effective one before mass international travel resumes.

Author contributions. TC developed and conducted the search strategy, and independently screened records to identify eligible studies. TC, BBD and NKN assessed the eligible studies for inclusion. All authors checked and approved the final report.

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