ECDC **PHE Technical Document**

Infection prevention and control measures for Ebola virus disease
Entry and exit body temperature screening measures
12 October 2014, Stockholm

Main conclusions

As the epidemic of Ebola virus disease continues to rise in West Africa, there is an increasing possibility of infected individuals travelling to the European Union. The primary mitigation strategy to reduce this risk, as recommended by the WHO following its declaration of a Public Health Event of International Concern (PHEIC) on 8 August 2014, is for affected countries to conduct exit screening of all persons at international airports, seaports and major land crossings for unexplained febrile illness consistent with potential Ebola infection. WHO also recommended that there should be no international travel of known Ebola cases or contacts of cases, unless the travel is part of an appropriate medical evacuation.

Exit screening focuses efforts on those at highest risk, thereby minimising the resources required and maximising the positive predictive value of screening. All affected countries have implemented exit screening, supported by the US Centers for Disease Control and Prevention (CDC). Based on current estimates of prevalence of infection (2 per 10 000 population in the affected countries) and what was observed during the first two months of exit screening in the three affected countries, the predictive positive value of the detection of one individual through screening is extremely low, as no EVD was confirmed in the 77 who were detected out of 36 000 travellers screened.

Entry screening is also being considered, or has been adopted, by a small number of countries, in addition to the ongoing exit screening. Based on the evidence of the validity of methods currently available for entry screening at major points of entry, and the likely prevalence of screening-detectable cases among those who have undergone exit screening, the added value of entry screening, if exit screening is being conducted effectively, is likely to be very small, and the resource implications considerable.

Complementing exit screening with entry screening may, however, be considered:

- In particular when there are doubts about the efficiency of exit screening;

- To detect the few who may develop fever between the time of departure and the time of arrival. This could be considered in particular for long haul flights with multiple connexions, extending beyond 12 hours.

The following points need to be considered in order to support decision making by EU public health authorities:

- The use of screening for infectious diseases has not proven to be effective to prevent or delay transmission in past epidemics such as SARS.

- Temperature screening of passengers is able to detect travellers presenting with high fever with an appropriate level of performance when using appropriate equipment operated by trained staff.

- Temperature screening requires protocols and resources to further investigate possibly febrile passengers detected in order to perform appropriately.
- Screening will result in a significant increase in the request for Ebola testing;
- Even the best temperature screening scheme will
    - miss up to 20% of the febrile symptomatic EVD cases (sensitivity of the measurement);
    - miss travellers concealing their fever;
    - miss two-third of infected cases, still incubating and not yet presenting with symptoms;
    - detect cases of fever related to many different infectious diseases such as malaria or influenza. It is likely that EVD cases will represent an extremely small proportion of febrile passengers, if any.
- Complementing temperature screening with visual review and health questionnaire may be considered:
    - To increase the performance of screening relying only on temperature screening;
    - To identify possibly contagious travellers missed by temperature screening;
    - To identify travellers having had high risk exposure and enrol them in monitoring schemes or quarantine.

Overall, screening for EVD among travellers may detect a few contagious EVD cases over time. In the face of exit screening in the affected countries, however, screening for EVD is likely to have an exceedingly low yield, given the poor intrinsic performance of the methods available, and represents a high investment, which may only contribute to a limited extent, to the prevention of importation of the disease.

Background

The unprecedented magnitude and geographic extent of the Ebola Virus Disease (EVD) outbreak in West Africa has overwhelmed the local response capacity, posing an extreme challenge for outbreak containment.

As the number of new cases continues to rise in Guinea, Liberia and Sierra Leone [1], there is an increasing possibility of infected persons travelling to the European Union. Persons infected with EVD may arrive in the EU by direct or indirect flights from affected countries or on board of freighters or passenger ships.

Following the declaration of the Public Health Event of International Concern (PHEIC) on 8 August 2014, WHO recommended affected countries to conduct exit screening of all persons at international airports, seaports and major land crossings for unexplained febrile illness consistent with potential Ebola infection. WHO also recommended that there should be no international travel of known Ebola cases or contacts of cases, unless the travel is part of an appropriate medical evacuation.

All affected countries have implemented exit screening, supported by the US Centers for Disease Control and Prevention (CDC). CDC have also produced guidelines on screening at points of departure in Ebola affected countries. Following the importation of a first case of Ebola, the US has decided to implement, in a layered approach, entry screening in five airports through which 94% of travellers from affected countries enter into the US. At the same time, and in the absence of an evaluation of the effectiveness of the implementation of exit screening in West African affected countries, a number of European countries are considering entry screening as an additional measure to reduce the likelihood of importation of cases.

This document reviews the existing evidence on entry and exit screening in order to support decision making by EU public health authorities.

Screening approaches

Screening of travellers can be done at the point of departure (exit screening), or at the point of arrival (entry screening). It aims at detecting passengers possibly infected with a communicable disease in order to

prevent transmission during flight and in the country of destination. During epidemics, it has been implemented during large epidemics (SARS) and pandemics (influenza A/H1N1) in an attempt to prevent spread of the disease or delay its introduction.

Travellers' screening approaches generally include a measurement of body temperature. It can be complemented by a questionnaire enquiring about symptoms and exposure, a visual review or an interview with health personnel. In case of suspicion, additional investigations are performed, including laboratory testing.

Temperature screening

Body temperature scanning measures for exit or entry screening have not previously been applied for detection of Ebola virus infection. However, it has been used for the detection of passengers infected with SARS, influenza A(H1N1)pdm09 and dengue virus across the world. Two types of devices are used: non-contact infrared thermometers (NCIT) and thermal scanner cameras (TSC).

Non-contact infrared thermometers

Temperature screening relies on the use of non-contact infrared thermometers, allowing measurement of the temperature without touching a passenger and therefore eliminating the risk of transmission of an infection from one passenger to another. NCIT are as accurate as contact thermometers and are low cost. Training is easy and the thermometers are easy to use and do not need much work to set them correctly [2]. NCIT are devices measuring skin temperature and not the core body temperature [3]. NCIT have been assessed to perform moderately well in detecting fever [4-7]

Some NCITs are approved for use as thermometers and do not need to have a confirmation measurement of temperature. For others, a confirmation measurement of temperature may be required to increase accuracy, using other more accurate types of devices.

NCIT are simple to use, cheap and more accurate than TSC. However, they require more personnel for screening and are slower for screening large numbers of passengers.

Different products are commercialised. Performance of devices is difficult to compare because of different targets and modes of operation. In addition, performance of the devices is affected by the choice of the cut-off value set for screening. Very few studies have been conducted to compare them. From these, US-CDC reports their overall performance as follows:

- Sensitivity: 80% - 99%, meaning that between 1 and 20% of the febrile passengers will not be detected (false negative);
- Specificity: 75% - 99%, meaning that between 1 and 25% of non-febrile passengers will be reported as febrile (false positive).

Some reports suggest that taking the average of several readings improves accuracy.

Thermal scanner cameras

According to the US-CDC [22], "thermal scanner cameras can measure temperature from a greater distance although they have not been evaluated for use as a primary diagnostic tool or for screening multiple individuals in an uncontrolled environment, such as an airport. They are not as accurate as NCIT's and may be more difficult to use effectively."

In addition, none of the TSC are approved to be used alone to measure temperature. Their measurement can only be interpreted along with an approved thermometer measurement. They can be used to screen large numbers of passengers at once and therefore result in faster operations. However, they are significantly more expensive, require more advanced training for their use and more frequent calibration, being affected by changes in environmental conditions.

TSC tend to be used with higher thresholds for fever to avoid detecting too many false positive febrile passengers [23]. However, while this increases the specificity of the detection, it tends to detect only higher-grade fevers. TSC require very strict application of standards in order to perform accurately. These standards have been published [24].

Experience of using temperature screening in epidemics

Dengue

Infrared thermal camera fever screening was found to be effective in identifying imported acute viraemic cases of dengue fever. However there appeared to be no significant impact on community transmission when comparing the presence and absence of airport fever screening [9-11].

SARS

During the SARS outbreak WHO recommended exit screening [12]. In addition, Canada, New Zealand, Hong Kong and Australia implemented entry screening with extremely low detection rates of SARS:

- In Australia, 1.84 million arriving passengers were checked. Four suspected cases were detected but not confirmed later. Five probable cases and 20 suspected cases were missed [13];

- Canada screened 6.5 million people, detected 9 100 febrile travellers (0.001% of all arrivals) and did not identify any case [14];

- Hong Kong screened 35.6 million people and identified two persons with SARS [15];

- Singapore screened 0.4 million people without detecting SARS cases [15].

Influenza

Border controls using thermal scanners for the identification of febrile passengers have been used during the 2009-2010 pandemic. The identification of passengers infected with pandemic influenza based on the criteria "measured fever of 37.8 °C or greater" showed very low sensitivity (2.6-6.6%) [6,7,16].

The effectiveness decreases further when fever is not a particularly common symptom among infected travellers [6]. Border entry screening detected between 22-37% of travel-related influenza cases in studies in China; the main symptom among these persons was fever at time of entry [16,17]. Overall, fever was identified in 0.06-0.002% of the arriving passengers [8,18].

Ebola

The current epidemic of Ebola affecting West African countries is the first Ebola epidemic where temperature screening has been used. According to the CDC, the Ebola exit screening in West Africa has identified 77 febrile travellers out of 36 000 people screened. These were denied boarding although none were later diagnosed with Ebola [16].

Current screening implemented

Affected countries

According to the US-CDC providing support to Guinea, Liberia and Sierra Leone, exit screening is implemented in these countries [31]. Outbound passengers are filling a questionnaire enquiring about their health and potential exposure to Ebola virus, visually inspected for illness and their temperature checked using a NICT. Exit screening began two month ago. During this period, 36 000 passengers were screened and as a result from the screening, 77 were denied boarding a flight. None of the 77 passengers tested positive for Ebola and malaria was confirmed for many [25]. However, informal information received from the EU delegation in some affected counties indicate that exit screening is not consistently applied at all time. No evaluation is currently available.

US

The US have decided to implement entry screening at five airports receiving 94% of passengers arriving from Guinea, Liberia and Sierra Leone. The US-CDC is providing staff to support the process in the five airports.

The process consists of identifying at immigration control passengers arriving from the three affected countries and direct them to an area set for screening where trained custom and border officers enquire about health status and exposure and verify their temperature using a NICT. Passengers presenting symptoms or fever, or indicating an exposure to Ebola are ascertained by a CDC quarantine officer who may refer them to the appropriate public health authority. Other passengers receive information on Ebola and are reminded to monitor symptoms.

Canada

On 8 October 2014, the Minister of Health of Canada announced an additional measure to screen travellers to Canada from Ebola-affected regions for signs of illness by confirming the Government's approach to targeted temperature screening at Canadian borders. Ill travellers or travellers reporting having been in contact with an ill person will be referred to a Public Health Agency of Canada Quarantine Officer to conduct a health assessment and determine whether additional health measures are required [29].

UK

On 9 October, the UK published A statement on the introduction of screening at UK travel destinations following advice from the Chief Medical Officer. Enhanced screening will initially be implemented at London's Heathrow and Gatwick airports and Eurostar terminals and will involve assessing passengers' recent travel history, who they have been in contact with and onward travel arrangements as well as a possible medical assessment, conducted by trained medical personnel rather than Border Force staff. Passengers will also be given advice on what to do should they develop symptoms later [30].

Effectiveness and limitations of screening

Skin temperature as a proxy of body temperature

Skin temperature tends to under-estimate the body temperature. NCIT and TSC are therefore using various algorithms for estimating body temperature more accurately. The relation between the skin and body temperature is affected by environmental conditions. A 10°C difference in air temperature may induce a 2°C difference in face temperature despite a constant internal body temperature [8].

Fever as a criteria for EVD screening

Infection with Ebola viruses causes severe disease in humans. The onset of symptoms is sudden and generally includes fever. A recent review of cases indicates that 83% of the more than 4 000 patients enrolled in the survey presented with fever in the course of the disease. Therefore, fever is a relatively sensitive symptom for the detection of EVD despite the fact that 13% of symptomatic patients may not present initially with fever [19]. In addition, fever is one of the most common symptoms of infectious disease. In the context of West African countries, several frequent infectious or parasitic diseases may affect travellers and in particular malaria. Taking unspecific symptoms like fever into account, the positive predictive value of a positive screening result for a rare disease is very low, particularly when the prevalence of other febrile infectious diseases among travellers is higher than that of Ebola (e.g. influenza, malaria).

Fever is a symptom that can be temporarily concealed by using antipyretic drugs. Passengers aware of presenting with fever may be tempted to conceal it for fear of being prevented boarding a flight (exit screening) or entering the country (entry screening).

Non-detection of incubating passengers

Using temperature measurement allows the detection of febrile passengers.

The duration of the incubation period affects the likelihood of infected persons developing symptoms during flights. When the incubation period is short as for Influenza (0.7–2.8 days, [20,21]), the likelihood of disease progression during a flight is higher [22]. For SARS, with a longer incubation period, (2-7, max 14 days [25]), only a small proportion of infected individuals will progress to symptomatic disease during the flight. In case of Ebola with an incubation period up to 21 days, the likelihood of disease progression during the flight is likely to be even lower.

EVD is a disease with a relatively long incubation period. Patients infected with Ebola virus develop symptoms including fever on average 11 days after infection, ranging from 2 to 21 days. Assuming that a patient developing symptoms could travel in the five days following the rise in temperature, we can estimate that for one febrile case of Ebola infection entering the temperature screening, another two patients could be non-febrile incubating travellers. This allows a rough estimation that a temperature-screening programme able to detect all febrile travellers may at best not detect more than one third of infected travellers.

Added value of entry screening in addition to exit screening

When exit screening at the airports in the affected western African countries is performed following the CDC guidelines[31], the likelihood of disease progression during the flight to Europe (minimum 6 hours) and presenting with high fever at border entry is likely to be low. The purpose of entry screening when exit screening is appropriately implemented is to detect people that develop symptoms in flight or who have been missed by the initial assessment at exit screening. It is therefore unlikely to be effective in preventing additional cases to those prevented by exit screening, considering the long incubation period of Ebola of up to 21 days coupled with the low sensitivity of entry screening. For longer durations of travel (e.g. from West Africa to the US or for longer itineraries to the EU), the assessment could differ.

Even the combined use of entry and exit screening as performed in Canada during SARS screening when 763,082 persons were screened (467 870 inbound and 295 212 outbound) did not prevent infected persons either leaving or entering the country [23].

Screening protocol

Thermal scanner cameras allow for a rapid temperature screening of large amount of travellers. To compensate for their relative low specificity, TSCs' can be used as a first line screening tool, complemented by a more accurate measurement of temperature. This allows improving the performance of the screening, but results in more resources mobilised. Screening of temperature alone will only identify at most 25% of all infected travellers.

In order to increase this proportion, asking travellers about symptoms and a visual inspection may allow detecting sick passengers not presenting with fever or having concealed their fever by the use of antipyretic drugs. Travellers aware of having experienced an exposure to the Ebola virus are more likely to be infected than other travellers, but their probability of being infected is very low. Therefore, asking travellers about exposure to Ebola may identify persons at risk of being infected who can be actively monitored for the appearance of symptoms or quarantined. Such exposure would include having been in contact with a friend or relative having had Ebola, being a healthcare worker, having participated unprotected in burial ceremonies.

However, the value of asking travellers about symptoms and exposure is limited by the fact that travellers may conceal their status from fear of being denied entry in the country of being quarantined.

Cost

Screening measures are an expensive and potentially are highly intrusive measures when used in combination with visual or clinical screening of travellers by medical personnel, health declaration cards that documented travel history, symptoms and history of contact with potential cases. During the SARS outbreak, for example, Canada estimated a Can$7.55 million investment for airport screening measures over 4 months [23].

Public health resources, particularly trained staff, are limited, and the considerable effort required for border screening may reduce staff available for other aspects of crisis or preparedness management. The resources required for implementation of such measures should be balanced against the expected benefits of entry screening [24].

Travel routes

Entry screening can be performed on direct flights from affected areas, but to be effective, would require that passengers arriving through connecting flights are screened as well. The US CDC has implemented a layered process for entry screening taking the origin of travel as a basis for decision of screening instead of applying a general temperature screening to all passengers entering the country [25]. Such an approach aiming at maximising the cost-effectiveness of entry screening requires that detailed information on passengers arriving is available to authorities in order to identify timely passengers arriving on indirect flights from affected areas.

Investigation of febrile passengers detected

Febrile passengers detected through the screening should be investigated. A portion of them will require to be tested for Ebola virus, resulting in a significant increase in the requests for testing. While being investigated, it may (or should that be "will") be necessary to isolate such passengers until the result is available.

Performance of screening

The performance of a screening programme is estimated by its sensitivity, specificity and predictive positive and negative values. These performance indicators are defined as follows:

- The sensitivity of an Ebola screening programme is the proportion of Ebola infected cases detected. It reflects the capacity of the programme at identifying all Ebola infected cases;
- The specificity of an Ebola screening programme is defined as the proportion of non-infected travellers that are rightly not detected by the screening. It reflects the capacity of the programme to identify correctly Ebola infections;
- The predictive positive value (PPV) of an Ebola infection screening programme is the likelihood that someone testing positive in the screening programme is an Ebola infected case;
- The predictive negative value (PNV) of an Ebola infection screening programme is the likelihood that someone testing negative in the screening programme is not an Ebola infected case.

The sensitivity and specificity an Ebola screening programme is determined by the protocol used. The more accurate the measurement of temperature, the more effective the interview, the better the sensitivity and specificity. The PPV and PNV are dependent of the prevalence of the infection in the population.

To estimate these screening performance indicators, we can use the figures published by the US CDC regarding the first two months of implementation of exit screening in the affected countries. Of 36 000 passengers screened, 77 were detected as possible cases of Ebola infection, and none were confirmed. The prevalence of infection with Ebola virus in the population can be derived from the surveillance data. With around one thousand new cases of disease reported through the surveillance system every week, considering around two weeks for incubation and around one week for the duration of disease that would allow a case to travel, we can roughly estimate that three thousands people are infected at any given day in the region comprising 16 million inhabitant. This allows calculating a crude estimate of the point prevalence of 2 per 10 000 population.

Assuming that the prevalence of infection among travellers is not higher than in the general population in the affected countries, we could have expected up to 7 infected cases among the 36 000 travellers tested in the three airports. None were identified by the screening, but we know that one infected case was not (the case who developed symptoms in Dallas, Texas). This confirms that the sensitivity and the predictive positive value are probably extremely low, being in fact 0 on this limited sample using crude estimates.

Figure 1. Performance indicators of exit screening using CDC screening information

	Infected	Not infected	Total			
					Sensitivity	0,00%
Screened +	0	77	77		Specificity	99,79%
Screened -	1	35922	35923		PPV	0,00%
Total	1	35999	36000		PVN	100,00%

Conclusions

- The use of screening for infectious diseases has not proven to be effective to prevent or delay transmission in past epidemics such as SARS.

- Temperature screening of passengers is able to detect travellers presenting with high fever with an appropriate level of performance when using appropriate equipment operated by trained staff.

- Even the best temperature screening scheme will
    - miss up to 20% of the febrile symptomatic EVD cases (sensitivity of the measurement);
    - miss travellers concealing their fever;
    - miss two-third of infected cases, still incubating and not yet presenting with symptoms;
    - detect cases of fever related to many different infectious diseases such as malaria or influenza. It is likely that EVD cases will represent an extremely small proportion of febrile passengers, if any.

- Complementing temperature screening with visual review and health questionnaire may be considered:
    - To increase the performance of screening relying only on temperature screening;
    - To identify possibly contagious travellers missed by temperature screening;
    - To identify travellers having had high risk exposure and enrol them in monitoring schemes or quarantine.

- Complementing exit screening with entry screening may be considered:
    - In particular when there are doubts about the efficiency of exit screening;
    - To detect the few who may develop fever between the time of departure and the time of arrival. This could be considered in particular for long haul flights with multiple connexions, extending beyond 12 hours.

- Temperature screening requires protocols and resources to further investigate possibly febrile passengers detected in order to perform appropriately;

- Screening will result in a significant increase in the request for Ebola testing;

- Overall, screening for EVD among travellers may detect a few contagious EVD cases over time. However, screening for EVD has a poor intrinsic performance and therefore represents a high investment, with may only contribute to a limited extent, to the prevention of importation of the disease and facilitate the contact tracing of exposed passengers.

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