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Detecting Infectious Communicable Biothreats Using Biosensor Systems at Airports and other Critical State Infrastructures

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Abstract

This article encompasses a review of the limitations of the current methods used for the detection of SARS CoV-2 (the virus responsible for COVID-19) at airports across the globe. These methods involve the screening for vital signs and symptoms, including thermal scanning, heart rate and breathing capabilities. From the impact of COVID-19, other pathogens could be exploited as potential weapons (bioweapons) against civil aviation. Bioagents such as viruses, bacteria, fungi, and toxins, have been used by the military and terrorists in conflicts to cause mass casualties, death, panic, and disruptions. In this review, focus is on the development of biosensor detection system that will address the limitations of the current measures being employed to detect pathogens. Biosensor detection system offers real-time, specific, sensitive, and a cost-effective means of detection of bioweapons at airports.

Keywords: Bioagents; Biodefense; Biosensors; Biothreats

Introduction

Civil aviation has been plagued with several threats, and the outbreak and spread of the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS CoV-2), the virus responsible for the Coronavirus Disease-2019 (COVID-19) has brought to fore yet another potential threat, not only to civil aviation operations, but also to national security. The impact of this threat to a nation, both in human and economic terms, is very monumental, thus presents a potentially attractive means of attack that could be exploited against an airport, aircraft, or nation. This is further compounded with the general accessibility to the knowledge of culturing microorganisms and ease of transmission or dissemination from an individual to another [1].

Threats to civil aviation have been mitigated using security screening equipment that prevents concealed weapons, articles or other items which could be used to commit acts of unlawful Interference from being introduced into Security Restricted Areas (SRAs) of airport or aircraft. Walk Through Metal Detectors (WTMDs) and Hand Held Metal Detectors (HHMDs) are primarily deployed to detect metal-based weapons such as guns, knives and other prohibited items of metallic nature that could be concealed on persons, or in their belongings, with intent for use as means of attacking airports, aircraft or other critical aviation infrastructures capable of disrupting operations [2]. X-ray screening machines have also been deployed to detect metallic, organic, and inorganic materials, including guns, explosives, and other such prohibited items that could be concealed in cabin or hold baggage with intent for use to commit acts of unlawful interference against civil aviation. Like X-ray screening machines, body scanners are also used to detect both concealed metallic, explosive, and other prohibited items on persons. Explosive Detection Systems (EDSs) to detect concealed explosives on persons and their belongings (cabin and hold baggage), cargo consignments or vehicles. Through these systems, persons and their belongings or vehicles that may contain concealed items or may have come in contact with prohibited materials, can be detected to enable further investigation as to the nature and circumstance of such contact.

Like with other threats to civil aviation, threats of bioagents as weapons of attack against civil aviation are emerging and thus require to be detected to prevent them from being introduced into the SRAs with the intention of committing acts of unlawful interference. However, bioweapon threats posed a different challenge of concealments; besides contaminating personal belongings as means of transmission, there are the possibilities that perpetrators themselves can be also weaponized as a means of transmission to their targets, using principles of biotechnology and genetic engineering. Since these bioagents cannot be detected in real-time using conventional security screening equipment, or through the current methods that were deployed to detect and prevent the spread of pathogens, this poses serious vulnerability to civil aviation security due to the limitations attributed to existing methods. Thus, to tackle the limitation, security screening systems that can sense and specifically detect the presence of biothreat, in real time, have to be developed and deployed.

It is without doubt that civil air transportation is a determining factor in the transmission and spread of communicable pathogens, many countries have had to introduce several measures to check their spread, including the use of thermal detection systems to monitor vital signs as a preventive safety measure against the spread, as used during the Ebola and other flu viral outbreaks.

Temperature checks have been employed at airport for departing and arriving passengers and aircraft crew, to detect signs of COVID-19-related fever. The objective was to detect persons with elevated body temperature and expression of other vital signs as an indicator of the presence of a possible infectious disease. This objective has not been achieved based on the limitations reported from application of these measures. The various measures shall be examined to elucidate their limitations and proffer alternative that will not only produce specific and accurate results but can be done in real time.

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Examination of the Current Measures Applied To Screen Persons for Covid-19

Since the COVID-19 pandemic broke out, several methods have been employed at airports to curb the spread of the virus. This article seeks to examine these measures from the perspective of aviation security to ascertain the vulnerabilities, if any, that could be exploited by terrorists to commit acts of unlawful interference against civil aviation and national security in general, and to proffer the most appropriate detection system that will ensure the safeguard of civil aviation against biothreats and bioterrorism.

ICAO/IATA/ACI Recommended Measures to the Industry to Check COVID-19

The International Civil Aviation Organization (ICAO), International Air Transport Association (IATA) and Airport Council International (ACI), the apex bodies for international civil aviation have issued similar measures to combat the spread of SARS CoV-2 and other pathogens at airports. These methods included temperature screening, hand sanitization, face mask use and social distancing. Member States of ICAO have also adopted these measures at their respective airports, as means of minimizing the transmission of SARS CoV-2. These measures were largely adopted as part of the post-COVID-19 restart plans to open the international and domestic airspace for commercial air transportation.

ICAO's measures were more of public health intervention bordering on the reduction of risks related to the virus in air transport [3]. Thus, it provides guidance to Member States on their approach to dealing with the pandemic, while adhering to their obligations under the Convention of International Civil Aviation. To respond to communicable diseases, ICAO required member state to put in place a National Aviation Plan and a National Air Transport Facilitation Programme to deal with such outbreaks, in line with World Health Organization (WHO) preparedness guide and the ICAO Doc. 10042 Model National Air Transport Facilitation Programme. All these were geared towards protecting public health.

In its Advisory Bulletin on security screening, the ACI proposed several best practices, to help protect passengers, screeners and other airport staff while preserving the objectives of aviation security [4]. These practices bothered on checkpoint management, screening of passengers and staff, screening of cabin baggage and other items carried, the protection of screening agents, as well as information signages for passengers.

In addition to social distancing, the use of face masks and disinfection of surfaces, temperature screening was also a key screening measure proposed by IATA in the bid to minimize the transmission of SARS CoV-2 [5]. Non-contact thermometers and thermal imaging cameras were also recommended for use at screening checkpoints to check vital signs of persons requiring access to SRAs to identify person who are potentially ill for further examination.

Etihad Triage and Contactless Check-in at Abu Dhabi Airport

As a measure to minimize the potential of any viral or bacterial transmission at its Abu Dhabi airport, Etihad airlines introduced the testing of a touchless self-service and automated system for health screening and identify travelers with medical conditions [6]. The health screening was deployed at airport kiosks and bag drops meant to estimate a passenger's vital signs. The service developed by Elenium, was a technology that could detect a passenger's heart rate, temperature and breathing rate, thus enabling the system to act as a screening station for potential symptoms of illnesses, including COVID-19.

The intent of this technology was to potentially limit the spread of any communicable disease, including viruses and bacteria, on board their aircraft.

The Challenges with the Current Measures for Security Screening For Potential Communicable Diseases at Airports

While emphasis has been on preventive measures including the use of thermal measurement system (both non-contact thermometers and thermal imaging cameras) [4,7], social distancing and sanitation, more remains desired in the effort to stem the spread of communicable disease pathogens through civil aviation. From aviation security perspective, these measures are ineffective and can be easily exploited by perpetrators of acts of unlawful interference to carry out a successful bioattack at airports, with far-reaching implications.

The use of thermal scanning and symptom screening that monitor the body temperature and other vital signs of individuals to ascertain that if a person is infected or otherwise, is not only ineffective method in the detection of pathogens but are also not foolproof. Because these systems are non- specific, there are risks of flagging up persons with a different type of illness, while missing those that are incubating the pathogen but have not started showing symptoms. Thermal scanning, which were widely implemented during the Severe Acute Respiratory Syndrome (SARS) and bird flu epidemics of 2003 and 2009 respectively, have remained controversial as a means of detecting individuals with elevated body temperature and thus a likely infectious disease.

In a study on the effectiveness of screening at airports to detect passengers infected with COVID- 19 reported that an estimated 46% of travelers found to be infected were not detected based on the sensitivity of the available screening techniques or the incubation time of the virus [8]. Quilty and others noted that most cases were asymptomatic during incubation, thus limiting the effectiveness of existing screening measures. Their position was further buttressed by the fact that during the 2009 influenza A (H1N1) pandemic and the SARS epidemic of 2003, there was limited evidence of the effectiveness of the screening measures implemented at airports. Furthermore, during the Ebola Virus Disease (EVD) in 2014, a study of the entry and exit screening in Freetown International Airport in Sierra Leone showed that five (5) of the persons referred to the Ebola Treatment Centre (ETC) for further examination were refused travel through the airport after testing positive during the primary and secondary screenings [9]. However, the laboratory test revealed that none of the travelers were positive for EVD. Interestingly, the screening steps involved thermal scanning using a non-contact infrared thermometer and symptoms of physical illness as part of the primary screening to determine the risk of EVD exposure or infection. More so, during the period under review, no case of EVD was detected during the entry screening. Despite the limitations of employing vital signs and symptoms to determining risk of infectious diseases, these methods are also being used across the globe to test for SARS CoV-2 as a means of curbing its spread.

Unfortunately, thermal scanning has not proven to be entirely accurate, as those who are infected but incubating pathogens are usually without obvious symptoms. As an example, during the SARS epidemic, while Canada recorded 251 cases, not a single case was flagged from the country's intensive border screening [7]. Similarly, the Millar's report also noted that an investigation by Cable News Network (CNN) revealed that well over 30,000 passengers screened for COVID-19 by mid-February failed to detect any person. This was largely due to the incubation period of the virus, which ranged from between 7 to 14 days, while some cases were mild and may show no symptoms even at their peak.

It will probably be naïve to assume that some people did not try to trick the system to avoid been held up outside their own country or even from their homes. For fear of being prevented from travelling, passengers were reported to have attempted to use antipyretic medications to mask their feverish conditions [8,9]. For instance, during the 2009 bird flu, some sick persons flying into Vietnam's Ho Chi Minh City were reported to have taken antipyretic drugs (fever reducers) such as Tylenol and Aspirin several hours before arrival to beat the thermal scanners at the airport [10,11]. Perpetrators of bioterrorism can also employ these tactics to beat the current screening measures proposed by aviation bodies across the globe to commit a successfully bioattack against civil aviation.

As with thermal scanning, the vulnerability of scanning for symptoms and vital signs employed by Etihad and others could also be exploited to mask symptoms and vital signs. Vital signs such as heart rate and breathing capacity can also be masked using certain medications, as the case reported by [10]. This can be exploited by potential terrorist prior to arrival at airports to beat the current measures used to detect infected persons. Elevated heartbeats due to lung infection can be controlled using calcium channel blockers or beta-blockers such as propafenone and flecainide which are able to slow heart rate and improve blood flow [12]. Several other medications exist, and are readily available, that can be taken to mask heartrates associated with health concerns of interest with the aim of evading detection.

In the same vein, breathing problems resulting from complication with respiratory infections can be concealed using some quick-relief control medications which could mask a person's inability to breathe normally [13]. Quick-relief medications to control breathing include inhaled steroids, short-acting beta-agonists, steroid syrups, and pills, as well as anticholinergic agents. These medications could provide perpetrators an opportunity to beat the current screening measures designed to monitor such vital signs of travelers and airport users.

From aviation security viewpoint, relying on these measures cannot only have a negative impact on facilitation, but also pose serious vulnerabilities to civil aviation security. Considering the multiplicity of measures of thermal scanning and screening of vital signs and symptoms, and the requirements for secondary screening to confirm results from initial vital signs and symptoms checks, security and facilitation will be greatly impaired. Furthermore, implementation of these measures could result in litigations, when an uninfected passenger made to miss flights for being wrongfully flagged and made to undergo rigors involved the secondary screening to verify the initial result. Therefore, to achieve the objective of facilitation while implementing aviation security measures, a more robust system of screening for pathogens is required that will not only be specific, but it should also be cost effective and done in a way that saves time.

Biosensor Detection Systems for Biodefense and Biothreat Application

As with the measures to mitigate other threats to civil aviation, a specific, sensitive, rapid, real- time, and low-cost approach to detect such threats and prevent them from being introduced into SRAs is required [14-16]. This can be achieved using biosensing systems that are able to detect potential pathogens and prevent their spread in the airport terminals, aircraft, or other critical infrastructures. As with the use of explosive trace detectors, biosensors can be programmed to detect the existence of contagions carried by persons or which may have contacted their personal belongings. Biosensor detection techniques provides a novel approach for the detection of pathogens that is specific and real-time to control of the spread of potential biothreats that could be transmitted through aerosols, surfaces, or body fluids [15,17]. Bioagents used in bioweapon application are usually exogenous agents (commonly airborne pathogens), weaponized and intentionally dispersed in the environments which humans interact. The detection of pathogen- based airborne biothreats is therefore critical for biowarfare defense as they may be introduced in the civil aviation environment as aerosols.

The basis of biosensors allows the detection of biomolecules in a real-time, specific, label-free, highly sensitive and efficient format for diagnostic of pathogenic diseases. The detection capability occurs through the integration of selective biorecognition elements and sensitive physiological transducer elements [16,17].

The concept of biosensing employs the application of the elements of analytes, biorecognition elements, transducers, and on an immobilized layer [14]. Pathogens (analytes) are recognized through their characteristic biomarkers, immobilized bioreceptors or biorecognition elements [14, 18]. The biorecognition elements are crucial elements of the biosensor system as their biochemical properties enables high specificity and sensitivity of the biomarker which prevents interference from other microorganisms that may be present in the sample being tested. The transducer, a device that produces magnetic, optical, acoustic, electrochemical, or calorimetric signals of interactions between specific interacting partners such as target analyte and bioreceptor, enabling signals to be amplified and read via an output device [14]. The immobilized layer, once in contact with a specific analyte, a physiological change is produced that is converted to measurable signals by the transducer. The transducers yield digital electronic signals that are proportionate to the concentration of the specific analytes.

Electrochemical biosensors utilize conducting and semiconducting electrodes as transducers that enables the conversion of chemical information into analytically useful information [19]. The chemical energy associated with the binding of the target biothreats and the electrode-immobilized biorecognition receptors are converted to electrical signals and displayed in an output device [17]. Electrochemical biosensors applying the use of electrochemical transducers will enable sample preparation-free detection of pathogens in several formats, including surfaces, aerosols, and body fluids. It can also offer rapid detection using cheaper platforms, with capacity to detect multiple pathogens in those matrices. The biosensor system could involve programming of biosensors receptors to highly contagious and pathogenic analytes such as SARS CoV-2, Anthrax (Bacillus anthracis), West Nile Virus, Severe Acute Respiratory Syndrome Coronavirus (SARS CoV), Middle East Respiratory Syndrome Coronavirus (MERS CoV), H1N1 influenza A, H5N1 avian influenza, Ebola, botulinum toxin, staphylococcal enterotoxin B, Francisella tularensis, Brucella sp., Yersinia pestis, etc. required to design the biorecognition electrodes.

The concept of a biosensor detection system, like the explosive detection system (EDS), can be deployed at airports to analyse persons and their properties for presence of any infectious communicable pathogens at entry or exit points. As with EDS, the outcome of the test will identify persons who pose security and health risk to others from gaining access to SRAs. Biosensors are self-contained and integrated systems that eliminate the need for sample preparation and are compatible with label-free procedures.

Biosensors have been applied in various fields, including agriculture, water and food quality, clinical and diagnostic medical applications, environmental and industrial analysis, and in the military and offer beneficial potentials in combatting bioterrorism in civil aviation [14].

Application of this technology in the civil aviation security system and other State's critical infrastructures will eliminate the need for thermal scanning and screening for symptoms and vital signs. Due to the specific and real-time nature of detection, the non-specificity of thermal scanning is address, as the exact threat will be detected in real time, without the need for secondary screening. Furthermore, the advantage of the concept favors facilitation of operations, as the delay time will be drastically reduced applying this technology at screening checkpoints and ensure facilitation is not hindered.

Conclusion

In this article, the current measures for the detection of SARS-CoV-2 have been elaborated, including thermal scanning and screening of vital signs and symptoms of the virus. These measures have been shown to have numerous limitations that include non-specificity of detection and time consuming. The use of biosensors has been employed over the years for detection of pathogens in environment, water quality checks and agriculture.

Biosensors application hold the promise for rapid, sensitive, selective, and cost-effective means for the detection of potential bioagents of threats nature that could be deployed to commit acts of unlawful interference against civil aviation. Furthermore, deployment of biosensor detection system at airports will ensure facilitation is not adversely affected by the introduction of additional aviation security screening measures to detect and prevent the introduction of virulent pathogen into the SRAs of airports. Thus, further work is required on the development of biothreat detection systems based on the principles of explosive detection systems using biosensors.

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