Chapter

International Health Security: A Summative Assessment by ACAIM Consensus Group

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Abstract

International health security (IHS) encompasses any natural or anthropogenic occurrence that can threaten the safety of human health and well-being. The American College of Academic International Medicine IHS Consensus Group (ACAIM-CG) developed a summative assessment highlighting the main issues that can impact IHS including emerging infectious diseases; chronic health conditions; bioterrorism; planetary changes (volcanic eruptions, earthquakes, wildfires, and climate change); nuclear incidents; information and cyber health; industrialization; globalization; pharmaceutical production; and communication platforms (social media). These concerns can directly and indirectly impact IHS both in the long and short term. When considering IHS, we aim to emphasize the utility of applying a predefined framework to effectively approach health security threats. This framework comprises of prevention, detection, assessment, reporting, response, addressing needs, and the perpetual repetition of the above cycle (inclusive of appropriate mitigation measures). It is hoped that this collective work will provide a foundation for further research within the redefined, expanded scope of IHS.

Keywords: global health security, international health security, consensus statement, redefined scope, expanded definition, summative assessment

1. Introduction

International health security (IHS), also referred to as "global health security" or "public health security," consists of topics that are directly or indirectly tied to the well-being of humankind and broadly understood "safety from harm" [1]. First outlined by the United Nations in 1994, the definition of "health security" continues to be nebulous, with somewhat of an incomplete overlap between the primary domains of "health" and "security" [2]. Thus, some controversy exists regarding both the degree of overlap and its precise context. In general, more recent IHS applications pertain to emerging infectious diseases (EIDs) and the threat of bioterrorism (BT) [3, 4]; however, the primary domain can be defined much more broadly when one considers the potential impact of various human-made and non-human-made events or factors on "health security" from the global health (GH) governance perspective [5–8]. Within the latter subset, a number of important topics emerge, including climate change, nuclear incidents, and misuse of global media platforms (both traditional and nontraditional) to disseminate medical (and public health-related) misinformation [9–11]. This summative assessment provides a high-level overview of issues that have the potential to directly or indirectly impact IHS. It was compiled specifically to reflect and highlight the perspective of Academic International Medicine (AIM) as previously defined by the American College of Academic International Medicine (ACAIM) [12].

2. International health security: the mechanism for sustainable development

To streamline the Consensus Group's (CG) effort, the discussion will focus on the most relevant topics within the overall scope of IHS, with the following general operational outline:

1. **Overarching structure of discussion**: *P*revent ➔ *D*etect ➔ *A*ssess & *M*itigate ➔ *R*eport ➔ *R*espond ➔ *A*ddress needs ➔ Cycle repetition (see **Figure 1**)

2. **Key areas of discussion**: Emerging infectious diseases (including antimicrobial resistance); chronic conditions and access to medical treatment (e.g., diabetes, heart disease, and respiratory and renal insufficiency); social determinants of health; bioterrorism (biological weapons); chemical exposures (industrial and nonindustrial); Earth changes and their relationship to IHS (e.g., natural disasters: volcanic events and natural fires, coastal changes [not mentioned as a subsection in body of text]) and emergence of invasive species (not mentioned as a subsection in body of text); nuclear accidents; cyber health security (including personal data theft, social media misuse, and news disinformation); and various risks associated with human activity (e.g., industrial pollution, pharmaceutical manufacturing and distribution, global travel, and armed conflict).

At this juncture, a brief outline of the summative assessment (SA) discussion structure will be provided, focusing on the IHS improvement cycle that starts and ends with prevention (**Figure 1**):

1. **Prevention**: The foundation of a sustainable IHS framework is a focus on prevention; previously identified IHS threats should be subject to appropriate preventive strategies, including continuous effort within communities to ensure that an optimal environment exists for the avoidance of factors (or circumstances) conducive to the emergence or re-emergence of IHS threats

2. **Detection**: An organized, system-based methodology for collecting key information that facilitates the discovery of a broad range of potential IHS threats;

strict definitions and expectation of timeliness should be built into the reporting system to avoid potentially harmful delays

3. **Assessment**: An organized, system-based approach toward evaluating potential IHS threats and categorizing such potential threats into a reportable database. An important part of the assessment process is the estimation of item-specific risk(s) and urgency

4. **Reporting**: A structured communication procedure consisting of categorized items that are grouped according to IHS threat type and are assigned corresponding levels of priority/urgency

5. **Response**: An organized and highly coordinated series of steps designed to proactively address any potential IHS threats while setting up the stage to address any associated population health needs; mitigation efforts are put into place in case of prevention failures

6. **Addressing needs**: A structured process that features its own assessment cycle, designed to catalog, prioritize, and provide resources (financial and nonfinancial) required to effectively deal with the IHS threat aftermath; embedded within this phase is also the early stage of short-term and long-term preventive efforts

7. **Cycle repeats**: Once completed, the process returns to the preventive focus, with detection of new IHS threats triggering new/additional operational cycles.

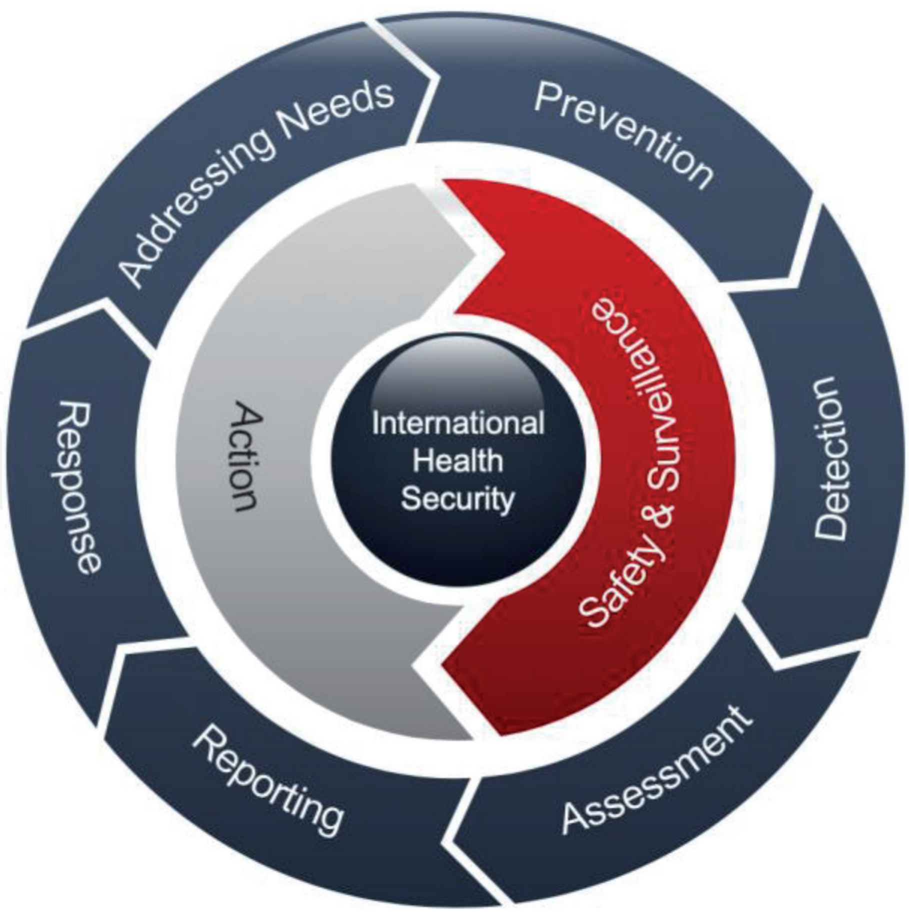

Figure 1.
The international health security improvement cycle: safety & surveillance through prevention, detection and assessment; action through reporting, response, and addressing needs.

At this point, our attention will turn to a list of specific IHS threats, beginning with emerging infectious diseases and ending with the emerging risk of weaponizing social media to disseminate potentially harmful medical/health-related information.

3. Emerging infectious diseases

The emergence (and re-emergence) of pathogens represents a significant threat to public health, including both high-income regions (HIRs) and low/middle-income regions (LMIRs) [13–17]. Detection of new IHS threats in this domain is challenging, primarily due to the nonspecific and often insidious nature of the emergence of a particular infection or pathogen [18–20]. Potential EIDs can arise from epidemic-prone, vaccine-preventable, vector-borne, food-borne, zoonotic, and/or antibiotic-resistant pathogens, or from a lack of access to safe water and sanitation [21–23]. In addition to lost lives, these diseases can lead to significant economic strain and may overburden local health system(s) capacity [24]. The lessons learned from prior outbreaks can help to improve future responses to emerging infectious diseases [24, 25].

For example, the well-documented response to the 2014 Ebola outbreak not only revealed a vulnerability to this important IHS threat, but also exposed significant inefficiencies of the current global public health infrastructure [26]. The initial response was disorganized and uncoordinated. The tracking of cases was also inadequate as the case trajectory deceptively appeared to decline before the true transmission spanned internationally [27]. Moreover, transmission was able to increase at an accelerating rate due to an overburdening of local health-care systems, lack of communication timeliness within the existing surveillance system, rapid urbanization, and widespread poverty where people lacked access to adequate water and waste management infrastructure [28–32]. Finally, even when there are ample resources available to address EID threats, local conflicts may effectively render any public health initiatives and medical efforts either highly dangerous or potentially impossible [33, 34].

To prevent the emergence or re-emergence of potentially life-threatening diseases, necessary measures must be initiated. Such measures include, but are not limited to, active surveillance for (timely response to) outbreaks. Emphasis must be placed on education and dissemination of key information to all stakeholders, antibiotic stewardship, vector control, and increased efforts toward combatting poverty and improving water and waste management [15, 35–37]. One important factor to consider when combatting EIDs is the need to coordinate all efforts as a unified, global front [16]. In a world characterized by continual globalization, phenomena such as mass migration and increasing ease of travel take on extreme importance to IHS [38, 39]. Collectively, the above factors may lead to accelerated spread of certain diseases and when coupled with inadequate response, lack of recognition, and limited awareness of various associated risks, local outbreaks can easily escalate into pandemics [20, 40, 41]. Finally, as the global community begins to expand the collective focus to include some of the more prevalent chronic, communicable and noncommunicable diseases, necessary assurances will be required that any corresponding public health initiatives will receive ample funding across all domains and services. Moreover, systemic mechanisms will need to be established to ensure continuous reassessment, training, and readiness to prevent the emergence of international complacency.

4. Chronic health conditions and access to care

With the aging of the world population, the increasing prevalence of chronic health conditions (CHCs), from diabetes to depression, is becoming an urgent public health issue [42–44]. This is especially true in the context of access to care across LMIR. The aging world population (ages ≥60 years) is increasing and expected to triple in size from 962 million in 2017 to 3.1 billion in 2100 [45]. A significant proportion of this growing population segment will come from today's LMIR [46], and much of this growth has been attributed to improved medical care, resulting in longer life expectancy [47, 48]. In addition, the world population is aging in association with decreased fertility rates [49, 50]. Along with an aging population come CHCs that collectively must be viewed as an international security threat, especially as resource-to-patient ratios begin to decline. Dementia, heart disease, diabetes, obesity, mental health disorders, stroke, human immunodeficiency virus (HIV), sexually transmitted diseases (STDs), malnutrition, sensory impairments, substance abuse, polypharmacy, bladder irregularities, and mobility issues are a few of the most common CHCs facing this emerging elderly population, with LMIRs challenged the hardest [48, 51–53].

These barriers may become further compounded by external factors. Competing forces such as rising health-care costs and physician/provider shortages will require creative solutions. Strategies aiming for long-term sustainability can utilize technology, focus on innovation, and create global economies of scale [43, 54]. Specific examples include at-home primary care, telemedicine, preventative initiatives, and community/family engagement [43, 54–56]. As access to care in many LMIRs is difficult, home health and telemedicine programs will need to replace less efficient models where transportation to and from health-care facilities was the norm [57, 58]. Community educational programs can aid in informing patients and family members about in-home care for the aging.

Thanks to rapid advances in telecommunication, most of the world has access to "smart phone" technology, and telemedicine options based on this technology can provide portable care in places where traditional health-care information infrastructure is inadequate or outdated [59, 60]. Improved preventative measures such as diabetes/cardiovascular screening may be initiated with point-of-care (POC) technology, including behavioral modifications that result in improved health, wellness, and continuity of care [61, 62]. Community engagement, with dedicated non-health care degree personnel trained in specific interventions, will be valuable when expanding the existing health-care workforce. Similarly, providing employment or volunteering opportunities for the elderly can keep the aging population engaged, active, and reinvested in their own communities [63, 64].

In addition to the operational solutions described above, CHCs in the aging LMIR populations can benefit from patient-centered care. To ensure sustainability, decreasing overall disability in the geriatric population will become imperative. Providing proper dental care, hearing aids, glasses, devices to assist in mobility, and relevant group activities can promote personal independence, socialization, and mobility [53]. Nutrition support from local farming connected to food banks, meal delivery from food programs, or food sharing mechanisms involving group meals can ensure that patients are achieving a proper diet while remaining invested within the community [65, 66].

Important from a variety of perspectives and dimensions, early discussions of end-of-life (EOL) care can help reconcile patient and community goals while decreasing unnecessary, costly EOL interventions [67]. Home hospice, ethical EOL policy measures, and better community education can improve patient experiences [68]. CHCs in the aging population of LMIRs must be addressed in a proactive and systematic manner. Highlighting goals of care to maximize the quality of life, enhancing independence while decreasing disability, and creating safe, secure access to health-care in an innovative, technological manner will be imperative for health systems to effectively address the emerging elderly population in LMIRs [68, 69].

5. Social determinants of health

An important component of IHS is the development and continued focus on social determinants of health (SDH). This broad umbrella term encompasses the economic and societal conditions that affect an individual's health and underlines the interconnectedness of development and health. Although there is no predefined set of SDH parameters, commonly accepted components include: access to health-care, education, employment, socioeconomic status, and safe physical environment—for example, neighborhood and social support networks [70]. These factors are the outcome of public policy and not traditionally considered under the auspices of healthcare but are increasingly recognized as important factors in a society's well-being.

The WHO Commission on Social Determinants of Health (CDSH) recommended a multifaceted approach to address inequity in SDH, which included housing options; employment options; educational opportunities; universal healthcare; gender equality; fiscal responsibility and opportunity; and social programs as well as monitoring, assessment, and evaluation of interventions for effectiveness [71]. In 2011, 125 member states signed the Rio Political Declaration on Social Determinants of Health and this was subsequently adopted as World Health Assembly resolution 65.8 in 2012. The document focuses on equitable policy toward development and healthcare, SDH-focused policy-making, and global collaboration and accountability for SDH policy [72].

Social determinants of health do not constitute a fixed idea and should therefore be considered a dynamic and evolving concept (and process). The inclusion of gender identity among SDH highlights the importance of continued vigilance to identify and address health inequities [73]. The interlinked nature of these factors makes it clearly evident that SDH and health security can be impacted by nearly every aspect of policy and is not limited by national borders. Let us consider the case of climate change and its impact on numerous health determinants, including employment, air quality, food security, invasive species, agriculture, and housing options. Within this broader context, LMIRs will be disproportionally affected and without sufficient resources, the optimization of SDH for best health outcomes across potentially affected populations becomes increasingly difficult. The unpredictable nature of change may manifest in numerous ways, from supply chain interruptions to health-care infrastructure damage [74, 75]. Recognizing the need for continued advocacy, the WHO created a Department of Social Determinants of Health to lead the SDH effort for the WHO 13th General Programme of Work 2019–2023.

The final recommendation from the CSDH was for assessment, monitoring, and evaluation of interventions. There has been some work to determine feasibility and accuracy of monitoring for specific SDH indicators; however, future national and international programs should consider building intrinsic capability of SDH assessment [76].

6. Biological and chemical terrorism

In 2016, there were more than 13,000 terrorist attacks around the world resulting in over 34,000 deaths [77]. The IHS expert community has never faced this level of complexity and such diverse array of biological and chemical agents that can cause death, morbidity, disability, social disruption, and economic loss [78, 79]. Humans have engaged in biological and chemical warfare for centuries, with some of the historical applications including deliberate use of manure, plague victims, and dead animals; the delivery of smallpox-infected blankets to Native American tribes; poisoning of wells with shigella and cholera; and the dispersing of plague-infested fleas by the Japanese in Manchuria during World War II [80–82]. Beyond biological warfare, the use of chemical agents to hurt other humans goes back over 10,000 years, from application of poison to spear tips, to the poisoning of Athenian wells by Sparta, the use of battlefield chemical weapons in World War I, and the Nazi development of the most lethal nerve agents [83–93].

The Centers for Disease Control and Prevention (CDC) have defined biological terrorism, or bioterrorism, as the use of biological agents (microbes, toxins, viruses) as weapons to further personal, religious, or political agendas [94, 95]. Acts of bioterrorism range from a single exposure directed at an individual by another individual, to wider scale biological warfare resulting in mass casualties. This definition may also be extended to include the infliction of harm that involves animals and plants/crops (a.k.a., econo-bioterrorism) [96–100]. Bioterrorism is often considered jointly with chemical terrorism, which is the release of nerve agents (organophosphorus compounds—e.g., sarin gas); vesicants, which damage skin and mucous membranes (i.e., mustard gas and Lewisite); agents affecting the airway and lungs (i.e., choking agents, phosgene gas); and/or cyanide agents affecting cellular respiration (e.g., hydrogen cyanide and cyanic chloride) [101–103].

Today's risk of biological or chemical terrorism is high because of a normative erosion of the social anathema regarding the use of biological and chemical weapons [104]. Specifically, such erosion has occurred because of the modern-day contempt for the 1925 Geneva Protocol, the 1972 Biological Weapons Convention, and the 1993 Chemical Weapons Convention, which collectively outlaw "the development, production, stockpiling, acquisition, and use of chemical and biological weapons [104]." Additionally, the rise of affordable small-scale science and technology capacity linked with the emergence of asymmetrical warfare (i.e., the interplay between smaller international actors versus traditional monolithic nation-states) is a serious threat to populations and resources [105, 106].

Specific recommendations by the CDC include five focus areas, with each area encompassing pertinent training and research: (a) preparedness and prevention; (b) detection and surveillance; (c) diagnosis and characterization of biological and chemical agents; (d) response; and (e) communication [107]. In addition, the authors of this report advocate strongly for the incorporation of mitigation efforts as critical to optimizing the effectiveness of the above-outlined incident response paradigm. To successfully address IHS threats, national and international institutions must provide measures aimed at augmenting public health diagnostics, including microbial recognition and typing, surveillance, enhanced pharmacological therapeutics (e.g., antimicrobials that can overcome resistance), vaccines, chemical sniffers, training, and education [96]. Where applicable, fast-tracking of innovations through various governmental and nongovernmental organizations (NGOs) will accelerate the work and delivery of new therapies and biological agent-specific vaccines to the field. Furthermore, implementation of clinical and field trials during a public health emergency (PHE) while at the same time respecting cultural differences between societies should be considered. Ensuring the provision of an ethical and just framework for such actions can accelerate the work and delivery of new therapies and vaccines to remedy the potential devastation of biological and chemical terrorism [40, 108].

7. Health security in the context of natural disasters

The planet Earth is our home within the indifferent emptiness of the known universe. Always changing and evolving, the Earth is not a static environment. And while planetary changes (PCs) actively influence human activity and well-being, human civilization increasingly impacts the finely balanced planetary ecological and biophysical system [109]. The World Health Organization (WHO) 2006 Report on the estimate of the environmental contribution to disease mentions that about one-quarter of the global disease burden and more than one-third of the burden of disease among children may be attributable to PCs. Earth's environmental disequilibrium has been evidenced in the contamination of drinking water supplies, pollution of its atmosphere, and increasing number of natural fires that significantly affect human health [110]. Moreover, the 1990–2016 Burden of Disease study mentions environmental factors such as climate change, food scarcity, unsafe sanitation, occupational exposure to chemical substances, population displacements, and conflicts as having significant impact on human health [111, 112].

Based on the above developments, a new definition of "health" has emerged as an extension of the health concept established in the 1946 Constitution of the World Health Organization: "Health is a state of complete physical, mental, and social wellbeing and not merely the absence of disease or infirmity" [113]. This updated definition includes not only the complete well-being of human civilization, but also the well-being of the environmental systems on which humans depend for sustainability [114]. Consequently, economic policies should balance economic development, social progress, human health, and environmental sustainability. Health professionals have an essential role in advocating for the preservation of Earth's socioeconomic and natural environments in order to protect the health of current and future generations [112, 115]. The following sections will describe some of the more important topics within this general theme.

Volcanic events: Volcanic eruptions and associated earthquakes pose significant health security risk(s). Destructive aspects of eruptions include explosions, hot ash release, melted ice, lava, and gas emissions [116]. These events inherently affect human activity and health as more than 500 million people live in close proximity to volcanoes [117]. Volcanic explosions can cause burns, death, and traumatic injuries, often in an unpredictable fashion [118]. Between 1900 and 2009, approximately 100,000 deaths and nearly 5 million people were affected by volcanic events, with primary causes of mortality being ash asphyxiation, thermal injuries from pyroclastic flow, and trauma [117, 119]. Lava flows can cause burns, death, destruction of critical health infrastructure, and loss of property/land. Volcanic ash exposure can lead to pulmonary complications (including acute respiratory distress, suffocation, and chronic lung disease), ocular injuries/infections, and cutaneous reactions [120–125]. At higher elevations, ice melting can lead to flooding and mud slides. Moreover, volcanoes can emit harmful gases, which include carbon monoxide, sulfur dioxide, hydrogen fluoride, and CO_2H_2S (carbon dioxide and hydrogen sulfide). These gases accumulate in low areas and are easily inhaled [116]. Several are colorless and odorless and can lead to respiratory distress, asphyxiation, and death. Volcanic ash containing crystalline silica can lead to pneumonoultramicroscopicsilicovolcanoconiosis and chronic lung disease. Volcano-associated earthquakes may cause structural damage and displacement [116]. Finally, there may be significant mental health sequelae (e.g., post-traumatic stress disorder or PTSD, and anxiety) [120–125].

Volcanic events have led to significant socioeconomic disruptions, affecting basic survival by negatively altering crops, livestock, water, heavy metal concentrations in the soil, and preventing access to healthcare [116, 126]. For example, the largest air transportation freeze since World War II occurred during the 2010 Icelandic Eyjafjallajökull eruption, where an estimated 107,000 flights were canceled during an 8-day period [127–129]. This single event affected nearly half of global air traffic, including 10.5 million stranded passengers and a staggering cost of $1.7 billion [128, 129].

Volcanic event readiness requires a comprehensive approach, which involves preparation, an emergency action plan, and a post-disaster plan. In an event of an eruption, communities should have an emergency kit ready in their homes [130]. Flashlights with extra batteries, first aid supplies, emergency food and water along with a manual can opener, essential medicines, shoes, breathing protection, and eye protection are all recommended by the CDC [131]. During an eruption, affected communities should adhere to evacuation instructions by local authorities. Understanding local culture and customs aids in evacuation strategies, keeps emergency team members prepared, and allows for clear communication. Oftentimes, survivors of volcanic eruptions prefer to stay in their communities despite any future risk [132]. Consequently, avoiding harmful exposure is the most important strategy. Protective masks can prevent inhalation of ash particles and minimize respiratory symptoms if exposure is unavoidable. Although N-95 type masks are most effective, they can be poorly tolerated [133, 134]. Protecting eyes, removing contact lenses, and wearing clothing to cover open skin are among recommended measures [116]. Of importance, appropriate mitigation procedures should also be considered in case primary prevention measures fail. Post-disaster assistance and restoration will require internal and external cooperative efforts, and community involvement is critical. Teaching local community members how to treat burns, administer inhalers, provide oxygen, and give oral fluids for dehydration can greatly assist local health centers. Health-care providers in LMIRs will need to be adept at treating severe burns, preventing infection, and providing respiratory assistance to those in distress.

Earthquakes: Whether associated with volcanic events or isolated tectonic activity, earthquakes have a significant potential to impact local health-care capacity and health security, including the potential damage to hospitals, clinics, as well as possible disruptions to various political and social structures. When limited to smaller geographic areas or regions, the need for post-earthquake emergency surge capacity can be provided by nearby facilities that were not affected by the event. However, in cases of more widespread earthquake damage, or severe structural destruction that occurs within a geographically isolated area (e.g., as seen during the massive 2010 Haiti event), the damage to health-care infrastructure may reach sufficient magnitude to result in simultaneous threats to both public health (e.g., the ability to provide essential emergency medical services) and IHS (e.g., through secondary effects such as the possibility of population displacement, migration, and/or exacerbation of a preexisting conflict). Coordinated international relief action is indicated under such conditions.

7.1 Increased risk and impact of natural fires

The fires in the Amazon rainforest of Brazil have been a source of great concern among the environmentalists and climate scientists [135]. However, the response of health-care professionals has been surprisingly muted despite the consensus that extensive Amazon fires may have far-reaching effects on human health and IHS. In fact, the current response is a far cry from our response to other health-care emergencies or epidemics. The reasons include reluctance to engage in a multi-stakeholder model of mitigating health-care concerns, the general acceptance of national health systems "existing in silos," and more generally the failure to appreciate the health-care implications of climate change taking place around us.

The major portion (~60%) of the Amazon, covering more than 2 million square miles in Brazil, is often called "the planet's lungs" and the carbon "sink" [136, 137]. In fact, it has been estimated that the Amazon is responsible for processing vast quantities of carbon dioxide and providing about 20% of the world's oxygen [138, 139]. Of importance, it is estimated that about 20% of the rainforest has already been lost, with the tipping point or "danger zone" for human well-being being not too far, at approximately 25% total rainforest capacity lost [140, 141]. While a nontrivial proportion of the Amazon fires may have been set intentionally (e.g., to clear the land for various forms of local economic endeavors), we must remember that this activity only deepens the current climate crisis by destroying CO_2-absorbing capacity while actively releasing vast quantities of CO_2 into the atmosphere [141]. The current wave of Amazon fires represents the highest number of such events in nearly a decade, with a clear relationship to deforestation activity [142, 143].

Human effects attributable to tropical forest fires may be more pronounced than we think. In a more direct fashion, the respiratory system is exposed to various levels of smoke, with an associated presence of various volatile chemical agents [144]. This may contribute to both short-term and long-term pulmonary sequelae, including acute respiratory infections, chronic obstructive pulmonary disease exacerbations, and bronchial asthma [144, 145]. Emergency visits due to ocular exposures with resultant eye irritations have also been reported [145]. In another report, smoke exposures were associated with increased incidence of self-reported symptoms, medication use, outpatient and emergency room visits, hospital admissions, and mortality [146]. The strongest associations were noted between forest fire smoke exposure and asthma [146].

More indirectly, forest fires and the associated gradual climate change may also be affecting non-pulmonary organ systems. A recently published commentary proposes a potential link between chronic kidney disease of unknown origin (CKDu)—also known in Central America as Mesoamerican nephropathy—and greenhouse gas emissions [147]. The report is based on experiences with CKDu in El Salvador in the 1990s, when unusually large numbers of agricultural workers began dying from irreversible renal failure. The report finds the phenomenon to be pervasive among agricultural communities in hot, humid regions of Central America, suggesting an important contributory role of local climate characteristics [148, 149]. This may be further corroborated by reports of CKDu among sugarcane workers in Central America, who work, heavily clothed, in temperatures that frequently surpass 40°C (104°F) [148]. It has been proposed that CKDu may represent a form of heat-stress nephropathy that is associated with rapidly evolving environmental conditions [148, 150].

This important area of clinical investigation requires significantly more investment and resources so that we can better prepare for the consequences of environmental changes due to forest fires and global warming in general. Significant increases in severity and frequency of fires have been noted across the globe [151–155]. As health-care providers, we must venture beyond our traditional focus of medicine and therapeutics, and begin taking a more active role in advocacy, prevention, and mitigation. This will require multidisciplinary approaches that integrate elements of environmental science into clinical practice and public health [156, 157]. High-quality early warning systems should be developed to help protect vulnerable populations using "an epidemic prevention model strategy" employed in other areas of public health [158, 159]. Ample support must be provided for research into "climate-sensitive diseases" [160]. Appropriate rapid response capability should be integrated into public health systems around the globe.

8. Nuclear incidents and health security

Nuclear incidents can be broadly divided into military and civilian occurrences. Although military events (e.g., nuclear war, nuclear terrorism, and nuclear weapons testing) are of great importance in the overall contexts of potential modulation of planetary change, such scenarios are beyond the scope of the current chapter. For completeness, we are directing the reader to other sources referenced herein [10, 161–165].

The focus of this section will be on civilian nuclear occurrences. Within this subdomain, radioactive exposures can be broadly classified as either medical (e.g., health-care equipment used for radiation therapy, reagents used in nuclear medicine) [10, 166] or industrial (e.g., power generation, by-products of medical or military production, long-term storage of nuclear waste) [10, 167]. We will briefly discuss each of these—in fairly general terms—focusing on potential implications to various aspects of IHS.

Health-care related exposures tend to be contained to the immediate environment surrounding the area of radioactive contamination. One historical event of significance took place in Goiania, Brazil [166]. Another incident occurred in Indiana, Pennsylvania [166]. In both cases, injuries and mortalities were limited to a small number of directly affected individuals. Of importance, the Goiania incident involved negligent removal and disposal of 50.9 TBq of Cesium 137 from a radiotherapy unit [168]. Environmental contamination requires high-intensity cleanup efforts, with generally acceptable results despite some degree of persistent residual radiation exposure risk [169]. Of note, post-event psychological and behavioral effects (termed "radiophobia" and similar to PTSD) were noted among survivors [170, 171].

In terms of industrial exposures, some of the most significant incidents involve the nuclear power plant explosion in Chernobyl, Ukraine (Former Soviet Union) [172] and the more recent nuclear reactor meltdowns at the Fukushima Daiichi Nuclear electric plant [173]. Both incidents exemplify the potential for long-term adverse effects of radioactive isotope releases on the immediate surroundings [174, 175], as well as the more remote, much subtler downstream exposures secondary to radioisotope concentration within the food chain [176–178]. In terms of the associated impact on IHS, various studies estimated long-term and long-distance effects of resultant radioactive releases [178–181]. Similar to medical radiation incidents, both social and mental health consequences have been noted among those exposed [182, 183]. Associations with medical conditions, including malignancies, appear to be less specific and weaker [184–186]. Appropriately administered food and contamination control programs are effective in minimizing the risk of internal radiation exposure [178, 187]. Of importance, governmental agencies such as the United States Nuclear Regulatory Commission are tasked with the oversight, nuclear safety framework, emergency planning, and appropriate protective actions as it relates to civilian nuclear incidents.

9. Information and cyber health security

Health-care institutions have been increasingly aware of cyber health security (CHS) threats to our population and have taken measures to protect patients, visitors, and staff from such threats [188, 189]. Yet, despite this, the academic health-care community has been relatively slow to recognize and mitigate various cybersecurity threats [190]. Within this broad area of IHS, three aspects have been identified as most important:

- *Software supply chain attacks*: Attempts to infiltrate the information-technology (IT) infrastructure via a third-party vendor (e.g., EHR add-ons) or partner (e.g., HVAC) systems [191–193]. Symantec's 2018 Internet Security Threat Report found a 200% increase in supply chain attacks across all industry sectors [193].

- *Internet of things (IOT) attacks:* The second area is the IOT attacks. More and more nontraditional devices are connected to the internet, which means devices that do not have the highest levels of security may become integrated into hospital networks [194–196].

- *Ransomware attacks:* Ransomware, one of the most common types of malware, utilizes malicious software to infiltrate computer systems or connected devices in order to encrypt a user's files [197]. Most commonly, servers for web and email applications, databases, end-user computers and removable media are involved [198]. Once encrypted, the information is indecipherable and inaccessible. The user receives a pop-up notification demanding payment of a ransom (usually in untraceable or difficult-to-trace digital currency) in exchange for the decryption key [199]. But ransomware does not destroy information; rather, it locks-up the data until a ransom is paid. Even if the ransomware infection is removed, the data remain encrypted [200]. Of note, the mere infection of a machine with ransomware is not sufficient, as the ransomware must communicate with a server to get an encryption key and report its results. This, in turn, requires a server hosted by a third-party company that will ignore the illegal activity and guarantee the attackers anonymity (called Bulletproof Hosting) [200]. Attackers also use a proxy or virtual private network (VPN) services to further disguise their own internet protocol (IP) addresses [200].

In February 2013, President Obama issued an Executive Order on Improving Critical Infrastructure Cybersecurity, with the goal of improving cybersecurity and reducing cyber threats to the nation's "critical infrastructure sectors," including the Healthcare and Public Health Sector [201]. The Executive Order defines "critical infrastructure" as "systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters" [201]. In other words, the executive order and other governmental policies collectively identify health-care systems and assets as so vital to the U.S. that their impairment would severely threaten public health and safety.

Many medical devices and other hospital assets now have direct access to the Internet—both in an encrypted (e.g., secured) and unencrypted (e.g., unsecured) fashion [202, 203]. Billing systems use electronic financial transfers, medical devices upload vital statistics in real time to EHRs, hospitals allow patients and visitors access to hospital WiFi as a courtesy, and patients are being provided access to protected health information (PHI) via authentication on the Internet—all of these are important and vital aspects of a modern hospital ecosystem [204–207]. As hospitals benefit from networked technology and greater connectivity, they also must ensure that they evaluate and manage these new risks. The American Hospital Association has identified the following priorities [208, 209]:

1. Establish procedures and a core cybersecurity (CS) team to identify and mitigate risks, including board involvement as appropriate.

2. Develop a CS investigation and incident response plan that is mindful of the CS Framework being drafted by the National Institute of Standards and Technology.

3. Investigate the medical devices used by the hospital in accordance with the June 2013 FDA guidance to ensure that the devices include intrusion detection and prevention assistance and are not currently infected with malware.

4. Review, test, evaluate, and modify, as appropriate, the hospital's incident response and data breach plans to ensure that the plans remain as current as possible in the changing cyber threat environment.

5. Consider engaging in regional or national information-sharing organizations to learn more about the CS risks faced by hospitals.

6. Review the hospital's insurance coverage to determine whether the current coverage is adequate and appropriate given CS risks.

10. Global communication platforms and social media: balancing benefits and threats

The role of social media platforms in IHS is substantial, and is likely to continue to grow [210]. There are certainly many positive aspects of social media (SM), such as the ability to quickly conduct population-level education, surveillance, and even preventive interventions [210]. At the same, there is the "dark side" potential of subverting these powerful platforms to both passively and actively facilitate harm and to disseminate misinformation [9]. Among the most challenging aspects of SM platform use in public health and IHS is the need for real-time verification and interception of potentially harmful messaging while at the same time promoting (and certainly not impeding) helpful content [9, 211].

The role of SM as a potential agent for dissemination of harmful medical misinformation tends to be underappreciated and/or intentionally minimized. Yet this health security threat is not only global but also represents a more pervasive form of harm, where incorrect, erroneous, or outright dangerous information becomes "entrenched" within the population's collective mind. A hypothetical example of medical misinformation may appear as follows, "all those who wash hands with alcohol solution expose themselves to deadly mutations and cancers." When disseminated widely, through a combination of "likes" and "upvotes," this dishonest and extremely harmful information may reach the status of "accepted reality" where people blindly believe in the validity of the damaging claim without critically evaluating its merits. In addition to potential harm and elevated risk to individuals, misuse of SM platforms can lead to population-level manifestations such as public anger and civil unrest [212].

In one real-life example where cultural norms, religious beliefs, and SM reinforcement played an important role in adversely influencing health security, the reluctance to comply with modified burial practices may have contributed to ongoing spread of Ebola virus during the 2014–2015 outbreak [24, 213]. In another instance, support for SM-based conspiracy theories around the Ebola pandemic abounded, while changes in infection prevention practices appeared to be lagging the dissemination of correct health information [25]. Finally, the unethical opportunism of false promises and exploitation of the naïve was highlighted by the emergence of unsubstantiated and harmful claims of "disease-modifying behaviors" that may actually lead to significant morbidity and/or mortality [213, 214], whether intentionally or not. One such example is the public health harm created by the anti-vaccination movement, which was greatly aided by the misinformed adoption of SM platforms as "trusted sources" [9]. At the governmental level, various organizations and agencies actively work on responses and countermeasures to disinformation present across various media platforms, including the National Security Communications Team in the United Kingdom, the National Cyber Directorate in Israel, the National Cybersecurity Agency in France, and the Australian Security Intelligence Organization, among others.

11. Health security in the context of human activity and sustainability

11.1 Human activity

Above and beyond previously discussed topics, modern human activity has had a tremendous impact on both individual and population health and well-being [215]. Key etiological and inherently interrelated concepts include industrialization, globalization, information transfers, and social interactions. Each of these areas will now be discussed in greater detail.

- *Industrialization:* Industrialization is a key contributor to the contemporary health epidemics of obesity and cardiovascular disease—a phenomenon deeply rooted in a gradual human transition from agricultural production to service economies. Industrialization has led to increased energy demands, dependence on fossil fuels, and the resultant global warming [216, 217]. Planetary-level effects include extreme weather events, rising sea levels, dangerous heat waves, decreased crop yields and nutritional density, worsening air quality, and unpredictable patterns of vector-borne diseases [20, 150, 218–221]. Extreme weather events lead to greater devastation and consequently exacerbate disproportionate hardships faced by LMIRs, leading to downstream sequelae including mass hunger, migrations, and armed conflict [75, 150, 220, 222].

- *Globalization*: Globalization and an increase in human mobility have not only augmented global warming-induced risk of vector-borne diseases, but have promoted their rapid transmission [223, 224]. Increasing human interactions and interconnectedness, while having a positive effect on intercultural relatability and collaboration, have at the same time facilitated the globalization of violence through terrorism and destabilization of vulnerable governments [225–227].

- *Information transfers and social interactions*: The ease of information sharing is unprecedented in human history. While generally accepted to be positive, a downside of false information becoming amplified and leading to harmful downstream consequences has been increasingly noted with the advent of internet and SM [228]. Empowering untrained and self-professed experts to discredit established peer-reviewed medical literature is proving to be more destructive than previously believed [9, 229]. The current pervasiveness of SM gives the appearance of positivity and health promotion as it enables interconnectivity and maintenance of relationships. Unfortunately bullying and psychological trauma are quickly becoming a reality facilitated by this still emerging technology [230, 231].

When considering the above entities, a worrisome negative synergism becomes apparent. Moreover, the velocity and intensity of negative developments make compensation and adaptation difficult, and, too frequently, existing governing bodies are unable to effectively address any enduring impacts [232, 233]. Consequently, calls for a global coalition committed to preventing adverse health effects from human activity are imperative.

12. Planetary climate change: a health security threat

Our planet is changing and evolving constantly, with continued climate transitions throughout the Earth's history becoming the scientifically accepted norm [234–236]. For the purposes of this discussion, we will refer to this complex set of phenomena simply as "planetary climate change" or PCC. Key areas affected by PCC include agriculture [237], forestry [238, 239], species migrations [240], vector-borne infectious diseases [241], urban air pollution [241], wind activity [75, 242], as well as changes in water availability [243]. Of importance, all of the above elements are closely interrelated, and it will be extremely difficult to elucidate any binary cause-and-effect relationships, making any debates around the topic of PCC both circumstantial and highly controversial. Beyond various direct and indirect effects of climate change on human health [244], it has been suggested that among the manifestations of the observed human response to PCC are armed conflict and widespread migration [245, 246].

Perhaps one of the most impactful aspects of the current PCC trends is the emergence of increasing temperature variability [247], which can, in turn, create local weather conditions that regions of the planet may simply not be prepared to handle effectively [248, 249]. One of the proposed models suggests the emergence of "severe and widespread droughts in the next 30-90 years" [235, 250], with clear implications to other topics discussed in this review such as food security, emerging infectious diseases, and human migrations [251].

Another important aspect of the overall management of PCC is the need to better understand any effects of solar (and even beyond that, cosmic) energetic inputs, with special focus on the relationship on such activity on the observed patterns of climate behavior [252, 253]. This includes the potential interplay between the Earth's magnetic field, solar output, and cosmic rays as climate modulators, including key determinants of various phenomena such as cloud formation [254–256]. Although far too vast—and inadequately understood—the topic of "planetary health" is by default the overarching determinant of human well-being and sustainability. In the United States, multiple organizations and agencies are involved in activities and actions revolving around PCC, including the Department of Agriculture, the US Agency for International Development, the National Science Foundation, the National Aeronautics and Space Administration, the Environmental Protection Agency, the Department of Transportation, and the Department of State, among others.

13. Pharmaceutical manufacturing and distribution: a clear health security concern

In 1982, seven people died in the greater Chicago, Illinois metropolitan area after consuming acetaminophen that had been intentionally laced with potassium cyanide [257]. While the response by the drug manufacturers has since been widely recognized and praised as a textbook case in corporate crisis and public relations management, the greater concern was the recognition of how vulnerable pharmaceuticals are to potential tampering and bioterrorism [258, 259]. As a result, the United States Food and Drug Administration (US FDA) and Federal Government—working jointly with pharmaceutical manufacturers—established harsh anti-tampering laws and guidelines to limit the risk of further contamination of the drug supply [260, 261].

However, it became clear that such "tampering" events—especially if intentional—can occur on a global scale [258, 259]. This is particularly true when one considers the extensive worldwide supply-chain manufacturing process that is involved in the production of consumer pharmaceuticals. Even slight changes in a drug's production—be it the initial recipes, mixing with drug stabilizers, buffers, or binders, all the way to packaging and distribution—can have catastrophic, if not fatal, consequences. The complexity of pharmaceutical development and distribution illustrates that there are numerous opportunities for sabotage, bioterrorism, neglect, or various forms of human error [262, 263]. Even local events can spark worldwide concerns and public fear. Any breakdown, intentional or otherwise, can compromise the safety of medications that millions depend on for their daily health. Potential observed effects may include avoidance of long-term maintenance medications, clinically significant manifestations of fear, and tremendous economic damage related to combined supply chain disruptions, in addition to increased downstream health-care costs.

While there are safeguards built into the entire process to assure pharmaceutical purity—including oversight by government agencies, such as the US FDA and European Union (EU) European Medicines Agency (EMA)—the system is not without potential risk. Many LMIR areas are challenged by the lack of appropriate regulatory oversight, government penalties, and even public (i.e., public company shareholders) accountability. In addition, pharmaceuticals that are no longer protected by intellectual property laws may be manufactured and distributed worldwide with lower regulatory or quality oversight [264, 265]. In fact, many well-established pharmaceuticals can vary significantly in their drug bio-availabilities and potencies depending on how and where they are manufactured [266, 267].

14. Conclusions

International health security is a complex and highly heterogeneous area of expertise. The American College of Academic International Medicine IHS Consensus Group (ACAIM-CG) developed a summative assessment highlighting the main issues that can impact IHS including emerging infectious diseases; chronic health conditions; bioterrorism; planetary changes (volcanic eruptions, earthquakes, wildfires, and climate change); nuclear incidents; information and cyber health; industrialization; globalization; pharmaceutical production; and communication platforms (social media). These concerns can directly and indirectly impact IHS both in the long and short term. When considering each IHS component, we aim to emphasize the utility of applying a predefined framework to effectively approach health security threats. This framework comprises of prevention, detection, assessment, reporting, response, addressing needs, and the ongoing repetition of this cycle (inclusive of appropriate mitigation measures). It is hoped that this collective work will provide a foundation for further research within the redefined, expanded scope of IHS.

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Glossary

BT	bioterrorism
CG	consensus Group
CHC	chronic health condition
CHS	cyber health security
EID	emerging infectious diseases
EOL	end-of-life
GH	global health
HIR	high-income regions
IHS	international health security
LMIR	low- and middle-income regions
NGO	nongovernmental organization
PC	planetary changes
PCC	planetary climate change
PHE	public health emergency
PHI	protected health information
POC	point-of-care
PTSD	post-traumatic stress disorder
SA	summative assessment
SDH	social determinants of health
SM	social media

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