Strategic modeling of medical intelligence as a countermeasure for future pandemics

MENIZIBEYA O. WELCOME
Department of Physiology,
Faculty of Basic Medical Sciences,
College of Health Sciences,
Nile University of Nigeria, Abuja, NIGERIA

DILEEP KUMAR M.
Faculty of Management Sciences,
Nile University of Nigeria
Abuja (FCT), NIGERIA. 900001

Abstract: The coronavirus disease 2019 (COVID-19) evidently caused untold suffering and disruption of activities worldwide. Several hundreds of millions of individuals were infected, resulting in millions of deaths and socioeconomic losses in all regions of the world. It is possible that availability of information required to make a quick decision would have prevented the consequences of the disease, suggesting that the COVID-19 pandemic was an indication of a global medical intelligence failure. Indeed, medical intelligence is a critical aspect of intelligence gathering, responsible for collection, analysis, interpretation and characterization of the data to effectively monitor the outbreak of diseases and activate the required modalities and strategic planning to provide prompt preparedness and response countermeasures (including nonmedical and medical such as rehabilitation) to manage the public health risk or mitigate the incident. In this context, the role of technology, especially AI, ML and DL applications to support the medical intelligence is explored into this paper. The study followed systematic literature review to gather the information and arrive at strategic model. The study extends practical implications by suggesting the role of AI, ML and DL in medical intelligence, that should be considered as a fundamental arm of the national security architecture of a nation. With tremendous progress in technologies, further enhancement of medical intelligence can help to mitigate potential public health risks and future pandemics. There is an urgent demand for a better knowledge of what tasks information structures and technology scientists can play in this global pandemic related to medical intelligence. Current paper thus details the critical components of medical intelligence systems and networks required as countermeasures for future pandemics.

Keywords: Strategic modeling; medical intelligence; surveillance system; countermeasure; artificial intelligence, deep learning, machine learning, pandemics.

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1. Introduction

THE coronavirus disease 2019 (COVID-19) started in China in December 2019 and rapidly spread to other parts of the world within a few weeks, causing untold suffering and disruption of global activities. So far, more than 609 million of people have been infected with over 6.5 million deaths, resulting in serious socioeconomic consequences in all regions of the world [1], [2].

The trends in the incidence of the disease and associated deaths (Figures 1 & 2) suggest unavailability of information to make a quick decision, which evidently would have prevented the consequences of the illness, suggesting that the COVID-19 pandemic was an indication of a global failure of medical intelligence. Medical intelligence is a critical aspect of intelligence gathering that is responsible for the active and ongoing manual and automatic collection of data from classified and unclassified sources (which may include but not limited to local and national medical, scientific and environmental data), analysis, interpretation and characterization of the data to effectively monitor the outbreak of infectious diseases, pattern of behavioral disorders, chemical, radiological and biological attacks, and activate the required modalities and strategic planning to provide prompt preparedness and response countermeasures (including nonmedical and medical such as rehabilitation) to manage the public health risk or mitigate the incident [3], [4]. Medical intelligence arrangements were responsible for determining how to expect the infection to spread, what such a pattern of spread would appear to be like, what the associated strategic risks would be, and what an appropriate response should be. Security and global health are distinct topics that frequently intersect, especially as the movement toward a global health security program gains traction [3] – [5]. Thus, medical intelligence should be considered as a fundamental arm of the national security architecture of a nation.

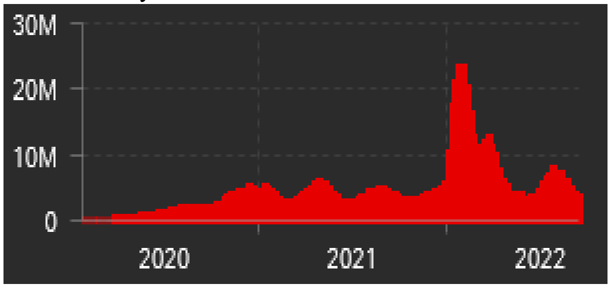

Fig. 1. Incidence of COVID-19 from December 2020 to September 2022 [1]. Available from: https://coronavirus.jhu.edu/map.html].

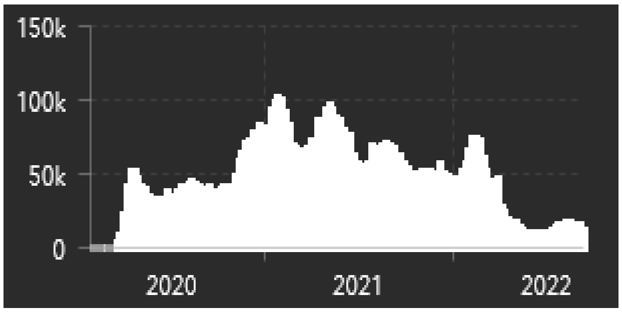

Fig. 2. Incidence of Deaths from December 2020 to September 2022 [1]. Available from: https://coronavirus.jhu.edu/map.html]

Medical intelligence can provide a quick forecast of event trends and ensure the readiness to efficiently manage future events. Therefore, development of effective medical intelligence network could translate to an efficient global security network that will promptly manage future events. Indeed, the tremendous progress in technologies and the recent global medical intelligence failure of CVOID-19 indicate the need to enhance medical intelligence and surveillance systems to help mitigate potential public health risks and future pandemics. In this paper, we dissect the critical components of medical intelligence systems and networks required as countermeasures for future pandemics. Potential models that will account for effective medical intelligence as a countermeasure for future pandemics are also discussed.

2. Medical Intelligence, Diplomacy And Safety

It is estimated that medical intelligence is at least six millennia old (beginning from ancestral technique of detection of illness to the modern automated systems) [4], [6]. Medical intelligence has unquestionably been useful in influencing global diplomacy, safety measures since the beginning of the twentieth century. However, despite critical growth in the technological world, diplomatic ties and health surveillance, reappearance of previously eradicated infectious diseases and emergence of new diseases that caused substantial global havoc have apparently led to a growing lack of confidence in the global efficiency of medical intelligence. Therefore, it is crucial to strengthen the existing medical intelligence and surveillance systems worldwide and establish control measures and response to biological weapons or disease outbreak for prevention of avoidable loss of lives and property [3], [7] – [9]. A methodical application of medical intelligence can deliver initial alert to the leaders and medical practitioners about the possibility for disruption in certain administrations where organizers are critically handicapped with modern tools required for swift decision-making.

Global diplomacy is required for efficient medical intelligence, which guarantees national security or safety. Indeed, medical intelligence, diplomacy and national security are inextricably linked because they ensure that events are closely monitored in order to protect the lives and properties of people. National security is concerned with the preservation of security and peace in all aspects of human life and the state as a whole through the application of military, diplomatic, and governmental power. Effective medical intelligence is critical to improving national security and diplomatic ties between nations [3], [7] – [11]. Truly, indeed, diplomatic ties help nations not only to build a stronger security network, but also socio-economic relationship to foster national growth and development. Consequently, therefore, effective medical intelligence must include investments in vital state infrastructure. Unfortunately, however, political ideology and national interests have substantially and negatively affected the efficiency of medical intelligence. Thus, strong international ties and professionalism should constitute crucial characteristics of a solid intelligence network [3], [7] – [9]. It is also important to promote specific global treaties to regulate the behavior of individual nations in relation to global medical intelligence. This will, to a large extent, prevent local political ideologies from significantly hindering the effectiveness of medical intelligence [3], [6].

3. Components Of Medical Intelligence And Their Operational Mechanisms: An Overview

In addition to the components outlined in the previous section, an established medical intelligence network for countering biological threats or disease outbreak should include fundamental components as outlined in Figure 3. However, depending on the type and generation, medical intelligence and surveillance system can be grouped into the following. A monomodal medical intelligence and surveillance system is designed to protect against only one category of threat. A bimodal system is designed to protect against two categories of threats. A multimodal system is designed to defend multiple categories of threats [3] – [5]. However, existence of numerous types of biological threats, emerging and re-emerging infectious diseases suggest that multimodal systems that might be able to learn to detect new and potential outbreaks are particularly required.

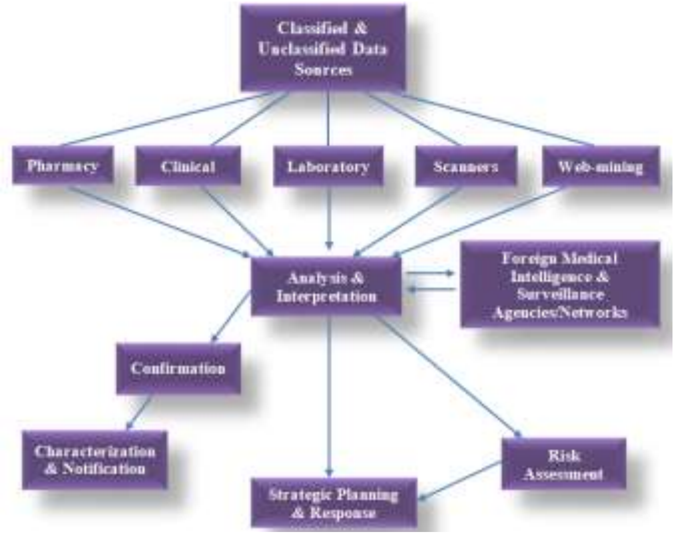

Fig. 3. A typical design system of medical intelligence and surveillance for prompt and appropriate response to potential threats. Data from different sources (such as web, internet search trends, specialized automated scanners, drug sales in the pharmacy, laboratory tests or orders, clinics, signs and symptoms of illnesses etc.) are fed to a central station of analysis and interpretation. The central analysis and interpretation station contribute to efficient response and tactics by continually shaping the response through risk assessment and recommendations on the most appropriate method of mitigating or reducing the threat. Where appropriate, the relevant event or biological agent maybe comprehensively studied by the respective experts-scientists to offer an important contribution to strategic planning and response to mitigate the event or outbreak. Following analysis, interpretation and confirmation, the information may be characterized before notification, while also activating other components of the surveillance network.

4. Modeling Of Medical Intelligence For Future Pandemics

Data indicate that medical intelligence systems have grown dramatically in Europe and United States [3], [7] – [13]. Examples of medical intelligence systems include MedISys, Emergency Communications System (ECS), BioWatch, PulseNet (U.S. national laboratory network), Laboratory Response Network (LRN), Health Alert Network (HAN), Morbidity and Mortality Weekly Report (MMWR), World Health Organization's Global Outbreak Alert and Response Network, Global Public Health Intelligence Network, and HealthMap. These medical intelligence and surveillance systems collect information from sources, including clinics, laboratory, news media, internet, and other sources to identify and notify the population about potential outbreak of infectious diseases. However, the BioWatch is the leading medical intelligence and surveillance system due to its unique method of automation and identification of multiple biological threats. Several generations of BioWatch system have been developed [3], [7] – [11]. Unfortunately, these systems have failed to effectively address and meet the current demands of biological threats, emerging and re-emerging diseases. Furthermore, no single strategy or system currently covers all public health threats completely. An efficient medical intelligence and surveillance system must be able to compare the data collected to the taxonomy of named entities such as infectious disease names, states, cities, villages, health organizations, or use other algorithms to identify novel agents. The system must be trained generate reports, send requests, alerts or warning, automatically execute result processing and perform other activities related to the effectiveness of medical intelligence, including but not limited to selective processing, conduction of professionalized and deeper analysis of results of critical importance [3] – [5].

The recent COVID-19 pandemic and pattern of events during the preceding century clearly highlight the need to develop an advanced technological intelligence unit for medical intelligence to address possible future pandemics that might harm the lives and property and potentially throw our world into a chaotic situation [14] – [18]. Research evidence from the past clearly shows that the advancement of efficient medical intelligence and reconnaissance could have immense significance for a useful worldwide security system that will swiftly manage future events [3] – [5], [19].

4.1 Contemporary models of medical intelligence

Medical intelligence and surveillance approaches such as syndromic that includes not only the monitoring of signs and symptoms of infectious diseases, but also behavioral and psychopathological indicators are used in biological surveillance [20], [21]. This enables proper monitoring, tracking, and forecasting of future events. Suspicious trends are exported for professional analysis and trigger the activation of the decision-support system. The system must be capable of properly identifying and monitoring hazards early enough and providing forecast for future trends or events to meet contemporary reality [3], [22].

In addition to efficient solar intelligence network system, molecular rays and registers, AI, ML, DL powered model of medical intelligence can efficiently mitigate future incidents of public health concern.

4.2 Molecular rays and registers for medical intelligence

To meet the needs of current global realities, medical intelligence and surveillance systems may use molecular "floating" registers or rays to detect the substrate of interest or learn to identify novel materials not previously known and generate an automated signal for recognition by the central station as well as generate an alert response. The polymorphism of microbial particles (including viral) and species diversity should be considered in the design of molecular based automated intelligence systems [4], [5].

4.3 Artificial Intelligence-, machine learning-, and deep learning- driven model of medical intelligence

Artificial intelligence (AI) is a technology that applies specified algorithms to produce intelligent systems with human-like behavior [23]. Machine learning (ML) is a subfield of AI that builds AI-based applications using data-trained algorithms [23]. Deep learning (DL) is a type of ML, created from the knowledge of the human brain structure and function that learn complex data or algorithms to improve recognition from raw data, thereby bypassing any need for human expertise [23], [24]. DL offers a predictive analysis to make automatic decision on raw data [24]. AI system applies neural networks, cognitive computing or computer vision to produce intelligent applications [23], [24].

The first reported use of intelligence in disease surveillance is mentioned in the 2004 report of the National Intelligence Council [25]. The recent COVID-19 pandemic obviously required AI, ML, and DL automated devices for early detection, diagnosis and treatment [26]. Though applied late to forecast different aspects of COVID-19, the IHME (Institute of Health Metrics and Evaluation at the University of Washington) model reportedly produced some benefits, but the model could not predict the transmission of the causative agent and disease [27]. (IHME model is a statistical model that uses ML for short duration forecasting [27]). Thus, AI, ML, and DL applications were effective only to some extent in the COVID-19 pandemic [27]. AI and DL were applied for interpretation of medical images, viral testing, and drug discovery in COVID-19 [27]. However, results from accurate prediction of spread of the disease, therapeutic options, treatment outcomes and deaths had substantial drawbacks when compared with the actual trends in the reported incidence of the disease and deaths.

5. Strategic Planning And Response

All types of institutions, including healthcare and therapeutic organizations, can be managed rationally and effectively through strategic planning. A long-term strategy for security and public health that incorporates the use of contemporary technology for intelligence collection needs to be considered. Adequate planning of disease response modalities and strategies unavoidably constitute part of every medical intelligence system [28] – [30]. To achieve an efficient medical intelligence, planning and response approaches must be closely incorporated into the model. The following should be considered as part of the response and planning strategies in case of an outbreak. Precise, adequate and timely information management is required to help mitigate the consequences of an outbreak. Long-duration AI-driven modeling with integrated update capabilities and laboratory surveillance systems to detect threats and make prolonged forecasting even at the earliest period of the disease outbreak is needed as a countermeasure for disease outbreak. Alongside ongoing response strategy, border surveillance is required to successfully battle, contain or manage the outbreak (Figure 4). Finally, AI-driven modeling of intelligent drugs, treatment, first aid approaches, vaccines, as well as population-based education are essential as part of the strategic planning and response against disease outbreak.

The whole realization of AI is contingent on the accessibility of a considerable volume of information for the reason that this information is utilized for the following guidance delivered to the system. The availability and the right to use information from several database suppliers means experiencing additional expenses to a setting, and the information must also be consistent and superior in value to guarantee an exact outcome forecast.

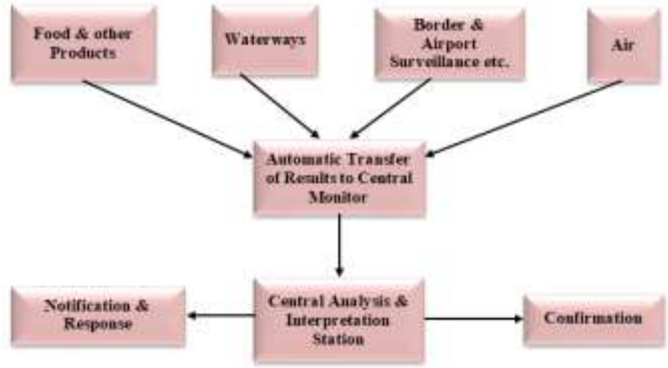

Fig. 4. Identification and response model in biological surveillance

6. Practical Implications Of Medical Intelligence

Healthcare is a multifaceted arrangement with diverse participants: patients, physicians, clinics, drug companies, and healthcare decision-makers. This particular sector, however, is further restricted by stringent guidelines and laws. Nevertheless, globally, it is observed that a radical change from the conventional doctor-patient style, where the clinical practitioners turn out to be partners and the patient is actively participating in the curative procedure, has occurred. Medical interactions and interventions are no longer concentrated on the medication of patients. The purpose of therapeutic interventions is thus required to encourage appropriate health mindsets and avert illnesses. In addition to the identification of illness symptoms, patients’ sentiments and behavior also need to be well evaluated. This turned out to be obvious and significant, particularly throughout the COVID-19 pandemic. Solutions have to be derived through IoT and AI-driven platforms to engage in medical and therapeutic treatments [3], [19], [25], [27].

Big Data is usually denoted as a huge quantity of digital information, large data collections, devices, technology, or experience. Data volume in numerous structures requires processing for any health care purpose, and information type, information size, and additional attributes are important in data processing and management. Because of its significance, there is a demand to create useful and well-working algorithms, methods, and devices to evaluate multi-modal therapeutic big data at the gene level to the medical stage. Nevertheless, the conventional ways of applying data with the assistance of individual observations and statistical applications are not efficient enough to analyze such complicated information. Here, the role of ML applications and the use of machine-based algorithms are increasing, which enables doctors to arrive at better medical intelligence for clinical and therapeutic interventions. Big data analytical instruments gather information from patients as well as allied institutional sources and supply those for analyzed data to give advanced healthcare facilities to patients to conserve their lives and to advance novel approaches for diagnosing and treating various ailments. Precise evaluation of therapeutic information has the advantages of preliminary illness recognition and enhanced patient treatment services, especially in biomedical and healthcare populations [19], [25], [27].

Evidence-oriented medical treatments and designs are getting better input from AI applications for clinical decision-making. Moving away from the classical manual statistical applications with limited data to arrive at clinical predictions, AI facilitates arriving at optimum patterns from millions of medical and clinical data that enable practitioners to make better clinical predictions. Advancement of AI applications, for example, supporting practitioners to evaluate the interconnected neurons in the human brain and enabling clinicians to monitor, assess, and evaluate the neural networks. The empirical observations are made with the machine-based learning parameters, which encourage assessing evidence to achieve coherent decisions. A great advantage of ML applications includes the possibilities of limitless inputs that a clinical practitioner could see in many lifetimes. As it is pointed out, the intelligent application of AI in healthcare clinical image processing has been frequently embraced by the majority of units that employ snapshots in fields such as ophthalmology, anatomy, gastroenterology, dermatology, and cardiology, in addition to radiology. AI uses, nevertheless, are determined by establishing an immediate relation to information value administration and the technology consciousness of health staffs [19], [25], [27]. In terms of practical implications, present paper intends to generate a productive debate with health care specialists and managerial work force on exactly how AI will be able to extend their service to increase better medical intelligence and its application.

7. Conclusion

The purpose of this review paper is to explore and describe the significance of medical intelligence with the support of AI, ML, and DL-driven devices in medical and allied settings. Medical intelligence must be developed to efficiently meet current and future crises. Strong leadership principles and diplomacy can enhance the efficiency of medical intelligence. Medical intelligence approaches should also focus on multisystem integration in order to ensure early warning and manage future pandemics. Potential areas in the advancement of medical intelligence should include development of AI-, ML-, DL-driven devices for earliest detection of causative agents, disease spread, diagnosis, treatment, and deaths. The current paper is entirely focused on systematic literature related to AI platforms for better control over the strategic governance of pandemic scenarios. The current paper thus clearly suggests a concentrated attention to health diplomacy, technology, and its prominent role in gathering medical intelligence for better security and curbing pandemic-like scenarios. The paper envisages a technology-driven medical intelligence and its deeper assimilation of global health into foreign policy agendas. However, future research should concentrate on specific fields of medicine and surgery to explain the data-driven medical treatments supported by AI, ML, and DL.

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