Accident & Emergency Informatics and One Digital Health

Mostafa Haghi[1], Arriel Benis[2,3], Thomas M. Deserno[1]

[1] Peter L. Reichertz Institute for Medical Informatics, TU Braunschweig and Hannover Medical School, Braunschweig, Germany

[2] Faculty of Industrial Engineering and Technology Management, Holon Institute of Technology, Holon, Israel

[3] Faculty of Digital Technologies in Medicine, Holon Institute of Technology, Holon, Israel

Summary

Objectives: Climate changes are the major challenge in public and individual health, as they modify the ecosystem and yield contagious diseases from animal to human. Furthermore, we notice the rapid development of elderly, changing the population demographic. These critical measures have imposed economical costs, require trained personnel, and reduce the healthcare systems' performances.

Methods: COVID-19 pandemic showed that digital health paradigms such as m-health, telemedicine, and Internet of medical things (IoMT) should be further developed for such disasters. Quarantine was experienced frequently at different levels, which indicates the urgent need to develop smart medical homes for continuous monitoring of the patients. Human health, environment, and animals are the three interwoven aspects of public health that should be formulated under a conceptual and unified framework. Accident and Emergency Informatics (A&EI) considers the prediction and prevention of an individual's health in the long term and detects instant accidents and emergencies for further processes linking to hospital and rescue services for lowering the impact. One Digital Health (ODH) considers the health of the human, the animal, and the environment as a whole.

Results & Conclusion: In this position paper, we discuss the mutual benefits of A&EI and ODH in disaster management. We outline the mission, current status of A&EI in healthcare, and summarize the most important development of A&EI-related scope in the other fields of science. We discuss developing smart environments to monitor environmental and animal aspects. Then we examine the use of the ODH framework for enhancing the A&EI capacities to deal with complex disasters. Moreover, we discuss the further development of the international standard accident number (ISAN) to include and link environmental and animal event related data. Besides, ODH will cope with the A&EI protocols and technical specifications to be part of A&EI in the application layer.

Keywords

Accident, disaster, digital health, ecosystem, pandemic

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1 Accident and Emergency Informatics

1.1 Definition and Background

An accident is "an event, independent of the will of man, caused by a quickly acting extraneous force, and manifesting itself by an injury to body or mind" [1]. Half a century after the accident definition by the World Health Organization (WHO), the field of "accident and emergency informatics" (A&EI) was defined to enrich the knowledge of on-site accidents/events by accomplishing the requirements. A&EI is a novel discipline in medical informatics, aiming at integrating data recorded at the accident sites with health records of subjects being involved in such accidents for better support and curation and to lower the impact of accidents and emergencies [2]. It is a trans-disciplinary science of systematic collecting and managing medical data (e.g., electronic health records) as well as sensor data (e.g., flight and other event data recorders) from the human environment, their syntactic and semantic integration, and their analytics.

To ensure safe environments and healthy life, the health and safety (H&S) sectors work hard to prevent accidents and emergencies, which can occur at any scale for anyone, anywhere, and anytime. Each year, German rescue services receive over one million emergency reports, and this number is still increasing [3].

On a worldwide scale, WHO attempts to give opportune and definitive circumstance examination, hazard assessment, and response observing for all significant wellbeing dangers and events. This requires effective surveillance frameworks to distinguish dangers, the ability to research and examine cautions, and a reasonable announcing framework that guarantees a fast and composed reaction. Thus, WHO gives a reconnaissance framework to detect and evaluate public health events for providing emergency funds, field teams, and materials [4]. On a local scale, accidents and emergencies are still detected and reported to emergency centers manually by witnesses or semi-automatically by, for example, the European eCall system or wearables such as the Apple Watch (Series 4, Apple, Los Altos, CA, USA) [5–7].

Usually, a human detects an event/accident and reports it to the emergency center. The rescue team receives selective information by asking the witness prepared questions in a structured interview. Accordingly, the authorities dispatch appropriate personnel (e.g., firefighters, medics, or both) to the scene of an event [8]. This manual method lacks the structured, unified, and automated system to link medical and non-medical data silos. Following a standardized protocol, an automated data linker system would improve the reaction time, reduce human errors, and facilitate the data flow between various correspondences (e.g., accident site, rescue team, and hospital).

1.2 Objectives and Contributions

A&EI focuses on the conception (syntactic and semantic interoperability), implementation (prototype level), and operation functionality (field experiment) of sensor-enriched medical information systems.

Hence, in order to accomplish these three, we address four major and several subtasks:

a *Data collection* aims at real-time sensor-based acquisition of data corresponding to the same event. Relevant data is recorded by off the shelf and state-of-the-art sensors deployed in the living environment (e.g., smart homes), the vehicle (e.g., smart cars), the human body (e.g., smart wearables), or even inside the body (e.g., smart implants);

b *Data management* aims at providing syntactic and semantic interoperability of the collected data. It requires appropriate storage in repositories or registries, centralized or decentralized, and should meet the privacy and security requirements;

c *Data integration* aims at linking event-related data to medical data to gain knowledge of accidents and emergencies. Information such as location, timestamp, and automated unique identifiers bridge the different registries for a particular subject and event;

d *Data analytics* aims at predicting accidents and emergencies, taking specific actions to prevent such events, or to lower their impact on humans. Therefore, the merged data has to be analyzed comprehensively.

Therefore, the core mission of A&EI is saving lives, from one side, by combining and jointly analyzing medical and non-medical data silos from various distributed data sources, and from the other side, by involving decision-makers, actors, and stakeholders from politics, infrastructure and health management, and industry.

2 Application of A&EI in Different Fields

In this section, we summarize some of the latest perspectives, development, and applications of the A&EI field in the other areas, including life sciences, robotics, social media, telemedicine, and emergency departments (EDs).

2.1 Social Media, IoMT, and Robots for Emergency and Disaster Management

Social media networks (SMNs), objects from IoMT, and small robots are taking a dominant part in daily life [9,10]. Being available all the time, they support communication and productivity tasks. During disruptive events such as natural [11] or human-made disasters [12, 13], people are spreading first reports in near real-time over SMNs. SMNs companies and official institutions developed tools and published up-to-date directives [14] to allow SMNs users to flag their profiles as safe for reassuring loved ones [15]. IoT is critical for managing these mass-casualties events. Sensors and robots are involved in the emergency response to assist the rescue teams in survival discovery, extraction, and transportation [15, 16].

For supporting A&E events, SMNs, IoMT, and robots are useful for both, the persons to be assisted and the professionals involved. In the last years, instant messengers, which are part of the SMNs, have demonstrated their efficiency by facilitating the interactions between rescue services and the individual requesting assistance [17, 18]. Moreover, IoMT gives advanced opportunities for monitoring individuals with some health risks in real-time and detecting different levels of anomalies that might lead to critical medical and/or emergency events [19,20]. Emergency and disaster medicine deals with broad and complex environmental, physical, psychological, social, epidemiological, managerial, and communicational issues. SMNs [21], the IoMT [22], and robots [23], alone or as a whole, increase and enhance the cyber-physical interactions between individuals, machines, and their environment. Over time, all these technologies generate an enormous volume of data that can be used for mitigation processes and building predictive models to anticipate or detect the need for rescue or intensive care teams.

2.2 Integrated Sensing for Disease Prevention and Automated Health Alerts

Telemedicine is a potential solution supporting the real-time and remote monitoring of subjects and bidirectional communication with medical personnel for care delivery at the point of perception. Smart homes and smart cars are private spaces where subjects (elderly or young, disabled or not, disease-suffering or healthy) spend most of their time [24]. Hence, turning such private spaces into diagnostic environments for continuous, real-time, and unobtrusive health monitoring allows disease prediction and prevention before the subject perceives any symptoms [25]. According to WHO, health, well-being, and quality of life (QoL) assessment require the monitoring of interwoven domains such as environmental, behavioral, physiological, and psychological domains. Sensing devices and technologies utilized in smart homes and smart cars can record parameters of multiple domains. Integrating sensing devices from all four WHO domains, joint data processing, transmission, and synchronization is important to develop sensor-enriched diagnostic spaces. This enables short-time event detection and long-time monitoring for prediction and prevention [26].

2.3 Virtual Emergency Departments

Our aging population yields overcrowded EDs. In addition to chronic diseases, Covid-19 became a serious issue for ED staff and health care providers [27]. We might consider virtual EDs as a faster and affordable medical service to maintain social distance. Thus, the role of information technology (IT) in the healthcare system and its contributions in managing the situation in an emergency should be investigated. An integrated virtual ED can be built combining existing telemedicine, e-health, and machine learning algorithms [28]. We suggest designing, modeling, implementing, and further investigating a virtual ED to explore the possibility of success in each step, including admission, triage, diagnoses, and clinical advice.

2.4 Innovative Sensor Technology for Emergency Detection

Many of the compounds used in chemical and biological laboratories are harmful or even toxic to laboratory personnel, and permanent monitoring of air quality is important for occupational safety. The demand for small, portable, and convenient gas sensing devices that enable continuous, flexible, and reliable personal monitoring increases. Off-the-shelf, smart, and integrated multi- sensors are available increasingly. Depending on their scope, the sensors require a distinct effort and methods of integration. Therefore, using available sensors, their integration options, and ready-to-use sensor systems for personal monitoring in life science laboratories is essential to reduce the probability of exposure in an emergency [29–31].

2.5 Medical Emergency Data and Network

A critical number of issues in emergency care result from the lack of access to prior patient data, information, and knowledge. Upon the occurrence of an emergency, fast access to such knowledge in terms of medication, allergies, and medical history is vital. Medical emergency datasets (MEDs) are the brief informative summary of an individual's medical history, supporting emergency medical providers with vital patient information. Implementing tele-emergency services should deal with technical challenges, special education, and training for physicians [32]. In managing an event as a tele-emergency, communication is the key point for physicians. The MED and real-time virtual support systems (VSSs) are now being presented as a component of the telematic infrastructure [33]. VSSs support team-based healthcare delivery independent of the actual location. Such systems have been implemented for intensive care, emergency medicine, primary care, and several other medical specialties [34]. Since tele-emergency is a new developing approach in healthcare, further research and examination are required to determine the essential skills and knowledge for the successful delivery of tele-emergency care [35].

2.6 Patients Safety Event Recording

In order to highlight the importance of patient safety and also to encourage people to show their commitment to safer healthcare, WHO announced the first-ever World Patient Safety Day on September 17, 2019, which commemorates a global campaign [36]. To detect incidents' patterns, discover the underlying factors, and explore the solutions, reporting medical incidents or patient safety events (PSE) is effective [37]. PSE reporting systems (e-reporting) are an enriched resource for sharing and learning information if the event data are collected in an appropriately structured format. Additionally, under-reporting and low quality of the reports are crucial barriers to prevent medical incidents. Review of PSE taxonomies, a deeper look into the conceptual frameworks, studies on medication events, patient falls, and PSE involved in health information technologies indicate extensive efforts to improve e-reporting through informatics approaches. However, future e-reporting systems are required, i.e., designed and implemented [38].

2.7 Methodologies in Fusing Accident and Health Record Data

In the era of digitization, A&EI has become a novel approach to accident research that integrates data recorded at accident sites with data from electronic health records of patients. To appropriately address the application of A&EI, we need to deal with the question on whether the existing and well-established evaluation methodologies used in accident- and patient-centered research within clinical medicine are sufficient and should also be used for such integrated data or whether they have to be modified or extended. Thus, based on the Gaus-Muche-Nomenclature on studies in clinical medicine, it is also important to outline which types of studies are appropriate [39]. Besides observational studies and registers, we regard controlled randomized trials as important approaches for gaining knowledge. In order to appropriately access data from health records and from accidents, standards are needed [40]. Another criterion is referential integrity. Here and regarding accidents, the International Standard Accident Number (ISAN) would be helpful.

3 International Standard Accident Number

One of the major roles of A&EI is to link medical and non-medical data silos automatically upon the occurrence of an accident or emergency. The data linkage, depending on the aim of acquisition, may take place at any level of data abstraction. Thus, we have suggested the International Standard Accident Number (ISAN) to uniquely and securely link the corresponding data from different data sources [41].

3.1 ISAN: Concept and Application

IoMT and smart environments are developing. Consequently, smart living, connected health, and smart cities have improved. In the near future, accidents, emergencies, or adverse health events will be reported automatically by smart environments. For instance, smart homes, smart vehicles, and smart wearables such as mobility trackers, or smart robots will request for rescue without any humans in the loop [26, 42, 43]. Several parties are involved in such an event: the smart environments (alerting system), the rescue services on land, water, and air (responding system), and the emergency departments in the hospital (curing system). They aim to detect and report, dispatch, and complete the rescue mission, respectively. In most parts of our world, these parties still use isolated information and communication technology (ICT) systems. We have proposed the ISAN, which is composed of the time and location of an event and a unique identifier (ID). Therefore, it represents a unique identifier that can be used to securely link the data in alerting, responding, and curing systems [41].

3.2 ISAN: Universal Application Platform

We also proposed an ISAN-based communication platform that allows semantically interoperable and secure information exchange. Our aims are threefold: (i) to enable data exchange between the isolated systems, (ii) to avoid data misinterpretation, and (iii) to integrate additional data sources. Our concept meets the requirements for scalability, error handling, and information security [44].

We consider the ISAN token and its interchange as an international standard and public health system, which is complementary to the human-in-the-loop emergency systems. ISAN contributes to public health when it is integrated into software systems of the emergency centers and commercial emergency service providers. In our demonstrator, we apply the responding system (Cobra 4, iSE, Aachen, Germany and rescue track, rescuetrack Gmbh, Reutlingen, Germany). Furthermore, we have already started to work with local companies and emergency service providers to integrate ISAN in their platforms such that received alerts on the ISAN system can be reflected on their systems, too. Currently, we are integrating the ISAN system into the municipal rescue service of the City of Brunswick.

3.3 ISAN: Future Perspectives

Our implementation of the ISAN platform boosts intercommunication, the exchange of information, and services. We expect the healthcare sectors, stakeholders, emergency centers, and policymakers to accept the concept [41, 44]. ISAN will contribute to public health in three stages:

a Short-term: we integrate, test, and use the ISAN in the city of Brunswick. Meanwhile, we will assess the public usage of the system, and evaluate its contribution;
b Mid-term: we integrate the ISAN system at the national level in negotiation with health sectors, policymakers, and stakeholders. In this stage, we expect to closely collaborate with commercial companies and emergency centers in technical specifications and implementations;
c Long-term: the output of our national evaluation will help to integrate ISAN into international systems. However, this third step will require intensive collaboration between various health sectors on an international level.

4 One Digital Health

One digital health (ODH) is a unified structure defined over a conceptual framework build around two keys (i.e., one health and digital health), three perspectives (i.e., individual health and well-being, population and society, and the ecosystem), and five dimensions (i.e., citizens' engagement, education, environment, human and veterinary health care, and healthcare industry 4.0) [45]. ODH aims to implement a systemic approach of health and life sciences broadly combined with digital technologies for looking at humans, animals, and environmental health in a unified way. ODH allows addressing the intrinsic complexity of future health and care scenarios in digitally transformed healthy ecosystems. Citizens and their health data will play a critical position in this new context by enhancing the development of disaster prevention, management, and control systems.

4.1 ODH and A&EI: Viewpoints

Accordingly, ODH and A&EI shake hands by looking from two different but convergent viewpoints to the complex disruptive events :

a ODH looks at a "population to individual" funnel for the global prevention, response, recovery, and mitigation of health and environment-related events ;
b A&EI looks at the disruptive events from the casualty perspective by providing a short-, mid-, and long-term follow-up to each case by identifying in a unique and specific way via ISAN anywhere, anytime, and for anyone or anything (A4) [46]. A&EI uses a complementary funnel to ODH, looking from "individual to population".

4.2 ODH and A&EI: The Role of ISAN

The ISAN is currently focusing on accidents, emergencies, or adverse health events that will be reported automatically by a smart environment and this fits with the ODH integration perspective. In fact, the disruptive events listed before can relate to humans, to animals, to plants, an event, or more globally to a complex living environment. Thus, using ISAN can help to integrate an event from the different ODH perspectives and dimensions for allowing, for example, making a follow-up of the consequence of an accident on the casualties and the collaterals health (i.e., individual and population health) for mitigating and learning from said accident (i.e., education, improving medical practice, providing to manufacturers inputs for improving the safety of the products that they are developing, e.g., cars).

However, to bring both concepts into a mutual and bidirectional ground, A&EI should extend its ISAN concept such that it includes and considers the environment and animal health as the main factors in ODH. Contrary, ODH is required to cope with the standardized data linkage protocols used in ISAN to be part of the so-called ISAN system. The operational-scientific next step is to extend the terminologies of A&EI considering ODH and to develop alerting systems for animals. Having ODH as a unified structure and A&EI with ISAN at the core as the data linker will lead to big data. We will develop the concept of the minimal set of data (MSD) [47] towards smart data--rather than big data--using data analytics to ease data management and improve the system's functionality and performance.

4.3 ODH and A&EI: Perspectives in Pandemics

Developing alerting systems (smart private spaces: e.g., smart medical homes and smart cars) that cover ODH aspects, e.g., measuring the WHO physiological domain continuously, may result in early disaster management. For example, in the current COVID-19 pandemic, increased body temperature is recognized as a symptom. If such symptoms occur in large numbers in certain areas, and at the same time, it might trigger the warning.

4.4 ODH and A&EI: Requirement for Standardized Terminologies

Shifting from the in-use method of accident detection and reporting to the emergency center towards the new automatic approaches needs coping with the requirements. Today, the rescue team receives selective information about an event such as location, number of victims, and type of event by asking the questions. Further details are collected by contextual questions from the witness. This is the basis for decision making and disposing of personnel and equipment. However, in an automatic event reporting there are no humans in the loop to ask or answer such questions. Therefore, all details and information must be communicated automatically. Additionally, among other countries, the German rescue chain is organized at the municipal level and uses many terminologies to classify events [2].

This leads to inconsistency between different emergency centers in various states and may increase the process and decision time and slow down the operation. The International Classification of Diseases (ICD 11) [2] already includes entities that can be linked to events. Although, it is based on the type of event but not on the source of data. In automatic event detection, the emergency status is generated according to the source of data that is a measuring sensor or sensing device (medical or non-medical sensors). To classify an event in detail, further entities are required, like the prior speed of a car regarding a traffic accident. Based on the ISAN [3], we aim at outlining this essential information automatically by developing an appropriate terminology to classify, unify, and standardize reporting an event that suits both human and automatic reporting. Therefore, collaboration with WHO, who is the responsible entity for ICD, has been initiated already [48]. The standardized terminology that is developed for automatic alerting must meet all the requirements on an international level.

4.5 ODH and A&EI: Community Building

In 2018, A&EI was established as a working group of the International Medical Informatics Association (IMIA). It has 32 scientific members affiliated to various universities and institutions all over the world working on a wide range of science correlated with different aspects of the field. Of which eight are core founding members and 24 are active regular members worldwide. Medical informatics, biomedical engineering, life science automation, robotics, network and data security, and artificial intelligence in healthcare are highly tied up with A&EI in the application layer.

From this community, a first book will be published shortly to further spread the concepts, share the knowledge, and strengthen the collaboration within the scientific community [2]. Twenty-two authors have composed ten chapters covering three perspectives: technology and engineering (e.g., developing smart cities, smart living spaces, smart environments), computer and data science (AI and data analytics), and the clinical perspective (e.g., emergency and virtual departments).

We continue tying up with our collaborators by sharing and exploring the latest findings, challenges, and solutions to overcome the current obstacles and construct the future vision. Inviting scientists to the presentations, taking part in internal, and external exchange programs, offering internship programs, offering conceptual and methodological training programs, and writing joint proposals with academia and commercial partners are part of our plan to improve the visibility and highlight the collaboration and roles of ODH and A&EI in healthcare. We have launched a website (https://aei.plri.de) to facilitate the information flow between all collaborators. It describes the field, its concept, contributions, and mission. In addition, the latest projects, publications, society news, and international programs are frequently posted. All our academic and commercial partners freely use it to share, post and establish new connections.

In mid-2021, ODH was established as a working group in the European Federation in Medical Informatics (EFMI). ODH is currently spreading the concept over the medical informatics community.

5 Conclusion

A&EI is growing fast to find its role in public health services. It aims at serving public health by contributing to individuals' health from the perspectives of long-term monitoring and instant event detection. The field increases the correspondence knowledge of on-site accident data by automatic data linkage from distributed sources. A&EI with the ISAN framework as the core, focuses not only on automatic data linkage, data management, and analytics but developing smart environments as the fundamentals. It is expected that in addition to smart mobility monitoring by wearables, in the near future, smart robots also will be part of the ISAN for developing alerting systems. We work towards developing ISAN as an international standard, unified platform, and structured mechanism in healthcare.

Thus, ODH as a unified and comprehensive concept in healthcare that considers public health by tying up human, animal, and environment will be the future playground of A&EI for development. However, A&EI remains in line with the WHO as the health policymaker and prior standards and protocols. As A&EI is developing new frameworks such as ISAN, according to its concept, it also defines the requirements and continues to develop, extend, and refine approaches, such as terminologies in the field. It would remain faithful to its mission of saving life for everyone at anytime and anywhere by developing low-cost and applicable approaches which give equal opportunities to everyone from any working and living group to use.

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Correspondence to:
Mostafa Haghi
Peter L. Reichertz Institute for Medical Informatics
TU Braunschweig and Hannover Medical School
38106 Braunschweig
Germany
E-mail: mostafa.haghi@plri.de