Adopting Integrated Health Information Systems in Intensive Care Units

Christina-Athanasia Alexandropoulou[a], Ilias Panagiotopoulos[b] and George Dimitrakopoulos[c]
Department of Informatics and Telematics, Harokopio University, Athens, Greece

Keywords: Criticalities, Integrated Health Monitoring, Health Information Technology, Intensive Care Units.

Abstract: Although today's advanced biomedical technology provides unsurpassed power in diagnosis, monitoring, and treatment, interpretation of vast streams of information generated by this technology often poses excessive demands on the cognitive skills of health-care personnel (nurses, doctors, etc). In addition, storage, reduction, retrieval, processing, and presentation of information are significant challenges. These problems are most severe in critical care environments such as Intensive Care Units (ICUs) where many events are life-threatening and thus require immediate attention and the implementation of definitive corrective actions. As such, the modern ICU environment provides fertile soil for the development of more accurate predictive models, better decision support tools, and greater personalization of care. In this respect, the use of Health Information Technology (HIT) and clinical informatics can rapidly analyse many variables to predict outcomes of interest and face heavy uncertainties whose solution may require computing intensive tasks. Therefore, the development of HIT-enabled specific applications or services to alleviate common information management problems encountered in ICU environments is of fundamental importance. This paper discusses the mixed-criticality characteristics of HIT-based systems in ICU environments, as a first requirement to effectively manage them. To do so, the present study describes one principal use case, namely the Integrated Intensive Care Clinical Information System (I-ICCIS), which stems from the combination of health information technologies with classic health care practices in ICU environments. The main criticalities anticipated in such a system are described, whereas open areas for future research activities are also identified.

1 INTRODUCTION

There is a broad consensus that health care in the 21st century will require the intensive use of Health Information Technology (HIT) and clinical informatics to acquire and manage data, transform the data to actionable information, and then disseminate this information so that it can be effectively used by the health-care personnel to improve patients' care (Gulavani and Kulkarni, 2010; Qi et al., 2017). Such technology trends aim to help doctors and nurses to keep up with the rapidly changing state of medical knowledge, as well as to understand what these changes mean for the treatment of specific patients.

In this respect, data from patient monitors and medical devices, although available visually at the bedside, is challenging to acquire and store in digital format. There is limited medical device interoperability and integration with the electronic medical record (EMR) remains incomplete at best and cumbersome. Moreover, standard analytical approaches provide little insight into a patient's actual pathophysiologic state (Islam et al., 2015). Understanding the dynamics of critical illness requires precisely time-stamped physiologic data integrated with clinical context and processed with a wide array of linear and nonlinear analytical tools. This is well beyond the capability of typical commercial monitoring systems. Such an understanding derived from advanced data analytics can aid health-care personnel in making timely and informed decisions and improving patient outcomes (Mieronkoski et al., 2017).

[a] https://orcid.org/0000-0001-5233-0579
[b] https://orcid.org/0000-0003-4366-6470
[c] https://orcid.org/0000-0002-7424-8557

Alexandropoulou, C., Panagiotopoulos, I. and Dimitrakopoulos, G.
Adopting Integrated Health Information Systems in Intensive Care Units.
DOI: 10.5220/0009325302190225
In *Proceedings of the 6th International Conference on Information and Communication Technologies for Ageing Well and e-Health (ICT4AWE 2020)*, pages 219-225
ISBN: 978-989-758-420-6

The above problems are most severe in Intensive Care Units (ICUs), which are hectic, chaotic, and stressful work environments. Clinicians need to be up to date on patient status at all times, coordinate and follow plans for each patient, and closely communicate critical information (Jacobs et al., 2015). They need to continually observe, obtain, and evaluate a vast array of information and collaborate within a multidisciplinary team. They are required to make diffıcult decisions about critically ill patients under the pressure of time. Since team members change with every shift, information can be lost in multiple handovers. In addition, quick patient turnover adds to the list of new issues that need to be resolved on a daily or hourly basis. The combined high cognitive workload and limited number of staff available at any given time leads to an overall decrease in situational awareness (Kurahashi et al., 2016).

Furthermore, critical care involves highly complex decision making. It is by nature data-intense. Large volumes of data are collected from disparate sources and reviewed usually retrospectively; and even that is difficulty. Health care providers must navigate through a jungle of monitors, screens, software applications, and often paper charts that provide supplemental patient data inherent in today's cacophony of information management systems (De Georgia M. et al, 2015). In addition the amount of information in critical care environments can be overwhelming and difficult to process (Lighthall et al., 2015). Accessing and integrating the required data for decision-making can be time-consuming and made difıcult by multiple logins, the need to use different computers for certain tasks, or the information sources being occupied or otherwise unavailable. Furthermore, depending on local resources and structure of an ICU, a large amount of crucial information is still documented on paper by multiple team members, often redundantly. This can lead to missing or misplaced charts and a delay inflow of information (James et al., 2018).

With the vision to build on the aforementioned statements, modern ICU environments provide fertile soil for the development of HIT-based systems, in introducing data management supported tools and greater personalization of care. In this manner, HIT-based systems are expected to introduce many benefits to the operation of ICUs; decrease of hospital death, decrease of length of stay, decrease of cost and increase of care quality (Heidari et al., 2013). In addition, the complex information and communication technology involved in HIT-based systems may also include mission-critical components (Ciccozzi et al., 2017). Identifying the criticalities of the specific components, applications or services in complex HIT-based systems is of significant importance for their effective implementation in ICU environments.

In the light of the above, digital management systems and remote monitoring are on the corner, aiming to prevent dangerous events and improve patients' outcome, considering high incidence of adverse events, medical errors and shortage of specialist nurse numbers in ICU. In that framework, the present study aims to identify and model criticalities of HIT-based systems in ICU, as a first step to effectively manage them in system implementation and deployment. Furthermore, one principal use case that stems from the combination of health information technologies with classic health care practices in ICU is explored, by identifying and explaining the mixed-criticality characteristics of the associated system. In this respect, the present paper proposes a hybrid data clinic management framework, namely 'I-ICCIS' (Integrated Intensive Care Clinical Information System) to pave the way towards incorporating critical care informatics in dynamically monitoring the patient's status in ICU. Such a framework aims to include acquisition, synchronization, integration, and storage of all relevant patient data generated from stand-alone devices and disparate sources, that do not easily integrate with one another, into a central information platform, to extract clinically relevant features and translate them into actionable information, parallel with the assistance of health-care personnel.

The structure of this paper is as follows. Section 2 presents the background for this work, whereas health information systems and technical challenges are briefly discussed in section 3. 'I-ICCIS' framework and its main criticalities are identified in section 4, whereas concluding remarks and perspectives for future work are drawn in section 5.

2 RELATED WORK AND BACKGROUND

Healthcare is becoming one of the most attractive applications fields, where the Information and Communication Technologies (ICTs) can offer improved access to care, increased quality and efficiency and reduced costs. Such systems comprise medical sensors, wireless networks and software applications for patient and remote healthcare monitoring.

In that framework, Milenkovic et al. (2006) described the Terva monitoring system, which had been introduced to collect data related to health condition like blood pressure, temperature, sleep conditions, weight, etc., over quite a long time. The whole system has been housed in a suitcase that includes a laptop, blood pressure monitor and several other monitoring devices. Moreover, Shahriyar et al. (2009) presented the Intelligent Mobile Health Monitoring System (IMHMS), which provides medical feedback to the patients through mobile devices, based on the biomedical and environmental data collected by deployed sensors. In addition, Lin et al. (2018) developed a smart clothing–based intelligent health monitoring system, which was used for electrocardiography (ECG) signal collection and heart rate monitoring, including eight kinds of services, such as surveillance of signs of life, tracking of physiological functions, monitoring of the activity field, anti-lost, fall detection, emergency call for help, device wearing detection, and device low battery warning. Moreover, Watson for Oncology (IBM, 2016) assesses information from a patient's medical record and displays potential cancer treatment options by combining the latest data of the international bibliography with the analytical speed of IBM Watson, in order to improve patient outcome.

Additionally, in the recent study of Lee et al. (2019), an efficient, robust, and customizable information extraction and pre-processing pipeline for electronic health records has been addressed by organizing data into a structured, machine-readable format which can be effectively applied in clinical research studies to optimize processes, personalize care, and improve quality, and outcomes. Moreover, Hammed and Owis (2015) have designed and developed a real-time Integrated Health Monitoring (IHM) system including biological sensors, integrated networking, electronic patient records, and web technology to allow remote monitoring of patient status. This system aims to process, monitor and store the vital signs of the patients starting from home until reaching the hospital.

Following the above works, it should be stated that storage, reduction, retrieval, processing, and presentation of patient information are significant challenges. These problems are most severe in critical care environments such as Intensive Care Units (ICUs) where many events are life-threatening and thus require immediate attention and the implementation of definitive corrective actions. A review of the relevant literature reveals the ongoing and increased interest in the HIT-based systems and solutions for ICUs. In this manner, Hayes-Roth B. et al (1992) presented the function of Guardian, an intelligent system for intensive care monitoring. Guardian's system interprets perceived information from the environment, performs all knowledge-based reasoning and problem solving (e.g. problem detection, diagnosis, prediction, planning, and explanation) and decides what actions to perform. It also constructs and modifies dynamic global control plans to coordinate its perception, reasoning, and action. Furthermore, Kaur and Shimi (2016) proposed an intelligent patient monitoring system for ICUs being able to acquire, store and present data to medical staff. This system is able to independently operate and it can replace, in some cases, the medical staff in nursing centers. Besides, it provides a good environment for the patients by offering an efficient monitoring and the adequate treatment.

Prajapati et. al. (2017) are proposing an intelligent real time IoT-based system for monitoring ICU patients (IRTBS), which can help to fast communication and identifying emergency and initiate communication with healthcare staff and also helps to initiate proactive and quick treatment. Moreover, Flohr et. al. (2018) designed an intelligent monitoring and communication system, namely VitalPad, to improve patient safety in an pediatric ICU. This system supports the clinical decision-making via smart alerts, cumulative risks scores and context-sensitive icons based on the assessment of vital signs and other monitoring data, drug infusion information, clinical checklists, and/or response to application messages. In a more recent study, Davoudi et. al. (2019) examined the feasibility of using pervasive sensing technology and artificial intelligence for autonomous and granular monitoring in ICU. They used wearable sensors, light and sound sensors, and a camera to collect data on patients and their environment.

3 HEALTH INFORMATION SYSTEMS AND TECHNICAL CHALLENGES

The medical field is closely related to human life, and a wrong decision is intolerable. With the intensive use of health information technology and clinical informatics, HIT-based systems tend to act more intelligent and autonomously with their operation based mainly on the computer's and technological equipment's integrity. The key features that HIT-based systems should have in general are the follow (Osmon et al., 2004; Kotronis et al., 2017):

- Accurate, comprehensive and complete data collection, which include accurate and timely recording of patients' status and clinical events.
- Interfaces with other systems that will enhance the reception and exchange of information.
- Ability to perform fast and complex queries in order to retrieve the information that is required.
- Availability of information for a wide range of clinical and administrative purposes.
- The medical history, which will be stored in the clinical information system, should be clearly identifiable, interpretable and provide only the necessary information without unnecessary details.
- At every episode of care and every patient's file, HIT-based systems should allow the performing of retrospective checks on access and processing and should be easily adapted to user requirements wherever is possible.

In this manner, a clinical information system relies on the accuracy of the data entered into it. Therefore, it is important the quality control measurements to be able to ensure the accuracy of the data retrieved. In addition, it is not uncommon for the health-care personnel to enter or extract data from the chart that are referring to an incorrect patient, which can lead to severe processing errors. In addition, the successful integration with other information (digital examinations from other laboratories), as well as the medical equipment around the patient's bed, and generally, within the unit, is highly desirable. For this reason, it is necessary the existence of strict technical standards, which will allow the necessary communication infrastructure, facilitating the access to vital information produced by all systems (Gambo et al., 2011).

The malfunctions or computer viruses, the system's incompatibility, as well as the technical damage to the equipment that make up the clinical information system can lead to the destruction of some databases included in the system. Therefore, the backup of these systems, the use of secondary power sources in emergencies and computer antivirus programs are key ways that can prevent the catastrophic loss of information included in the clinical information systems (Sellars and Easay, 2008). Some examples of technical challenges can be categorized to the following aspects:

- The ability to handle the enormous amount of data produced by recording even a minimal amount of data per patient.
- The need to ensure that all personal information is kept in a secure environment. They should be covered by legislation stipulating how electronic information will be retrieved, transmitted, and stored.
- The need to provide systems that support the availability of data.
- User-friendly interfaces that can cover the requirements for functionality and performance.
- The need for communication methods between the central clinical information system and local peripheral systems through the ability to exchange secure messages.
- The existence of a high quality clinical information system, which will be flexible and will ensure that the right data are available only to the right people.

There are also issues regarding ownership and management of data, who and how to handle the information, such as anonymity in investigations, who will have authorized access to the information and for how long, and in what ways will have access. In particular, only the treating clinicians would still have to know to whom the data refers in order to act on it.

Furthermore, the majority of HIT-based systems have been designed to diagnose individually, but it is difficult to exhaust human diseases by the rules. So, the involvement of doctors and health care personnel is required. Integrating doctors' clinical diagnostic process into a medical electronic health information system (e-HIS) with powerful storage, searching, and reasoning capabilities is expected to make a better and faster diagnosis, as depicted in Figure 1. In this direction, due to the fact that vast streams of data are generated for patients which reflect dynamic and complex physiology, data integration should be managed in the appropriate clinical context. Most of these parameters, however, are generated from stand-alone devices that do not easily integrate with one another. Some connect directly into the bedside monitor but many others do not (or do so incompletely meaning that not all the data is captured electronically). A lack of functional medical device interoperability is one of the most significant limitations in health care today.

4 I-ICCIS FRAMEWORK AND ITS MAIN CRITICALITIES

As mentioned previously, most care medical devices are not designed to interoperate, and therefore there is no universally adopted standard that facilitates

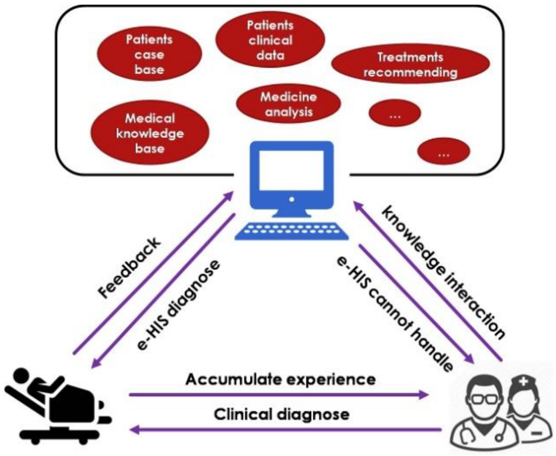

Figure 1: Integrating clinical diagnostic process into a medical electronic health information system (e-HIS).

multimodal data acquisition and synchronization in a clinical setting. In this direction, a central clinical information system that provides comprehensive, cross-manufacturer medical device integration for the care of a single critically ill patient at the bedside of an ICU is not available.

In the context of the present work, an Integrated Intensive Care Clinical Information System, namely 'I-ICCIS', is proposed which enables the health-care personnel (doctors, nurses, etc) to monitor the health status of all the patients in an ICU for further assessment and recommendations. Medical information from the patients, e.g., stemming from embedded sensors and digital vital signs, is electronically transmitted via a secure channel to clinical monitoring center of 'I-ICCIS'. In addition, critical information towards the examination results from other laboratories should also be embedded in digital form. As such, 'I-ICCIS' can be used for monitoring physiological signs and health parameters of the ICU patients in real-time. The health-care personnel should be alerted if there is a cause for concern, e.g., inferred symptoms of a health problem which requires immediate medical attention.

Based o the above, 'I-ICCIS' architecture is composed of three (3) subsystems:

- Patients' clinical data monitoring center (medical information from the patients is introduced based on various sources to enhance the interoperability),
- Data repository (medical data is stored and processed),
- Patients' health record (hand-made clinical data, demographic information, clinical history data).

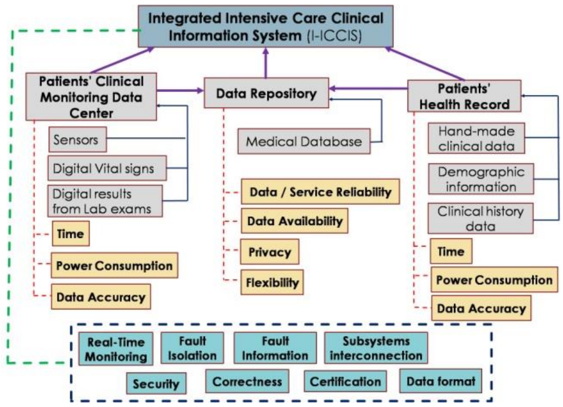

Figure 2: I-ICCIS subsystems, components and criticalities.

Figure 2 illustrates 'I-ICCIS' as a mixed-criticality system with its three subsystems in conjunction with its criticalities. In the following, we discuss the identified criticalities grouped related to each discrete subsystem.

1st Subsystem – Patients' Clinical Monitoring Data Center. It is characterized as safety-critical subsystem with a high significance in the 'I-ICCIS', due to the fact that the operation and visualization of the patients clinical data in real-time to the health-care personnel is of fundamental importance. The received bio-signals and examinations from medical laboratories outside the ICU must be presented in textual or graphical waveforms for visualization and diagnosis purposes. In addition, it is critical for the system to support multiple different platforms for the data visualization. Accuracy, time and power consumption regarding the real-time clinical status of patients in the ICU are safety-critical parameters with a very high significance.

2nd Subsystem – Patients' Health Record. It is characterized as safety-critical subsystem with a high significance in the 'I-ICCIS'. First, the accuracy and time regarding the patient's medical record are safety-critical parameters with a very high significance as it holds all patients sensitive medical data, demographic information and clinical history data. Secondly, the operation (power consumption) of the patients' hand-made clinical data to the patients' medical record is very important. In practice this subsystem involves similar criticalities as in the clinical monitoring center section.

3rd Subsystem – Data Repository. The challenge in this subsystem is the management of medical data. It is critical to protect patients sensitive medical data, from the clinical monitoring data center and patients' health record to the data repository and then to 'I-ICCIS'. Data/service reliability, data availability, privacy and flexibility regarding the data repository of the presented health-care information system in the ICU are critical parameters with a very high significance.

'I-ICCIS' as a Whole Clinical Information Framework. In general, the 'I-ICCIS' inherits the criticalities of its subsystems (clinical monitoring data center, data repository, patients' health record). In this section, we expand on the criticalities of the 'I-ICCIS' as an integrated system (Kotronis et. al., 2017).

First, the real-time monitoring process is safety-critical. The 'I-ICCIS' has functions that must react in real-time and provide time predictable communication among different devices. A failure to perform an operation within a given time may result in serious harm. The significance of the real-time monitoring is very high.

Secondly, the fault isolation is also a safety-critical parameter. Faults in an application / device must not propagate to other. Any fault must be handled by the failing application itself or by the system, while cascading failure effects should be highly improbable. In addition, the real-time behavior of an application must be correct, independently of the execution of other applications. Moreover, due to high significance of the data, the traffic leaving the devices must be encrypted, while ensuring their integrity. It is critical to avoid errors or intentional modification to the data being transmitted. In order to meet this criticality, well-known network security protocols and software suites can be employed.

The 'I-ICCIS' framework must provide fault information to the devices, applications (lost data) and system. As such, fault information occurring at the lower levels is a safety-critical parameter for taking corrective actions. Moreover, another highly significant safety-critical parameter is the systems' interconnection. All the devices (e.g., sensors, digital vital signs, digital results from laboratory examinations) must interact and cooperate. In addition, 'I-ICCIS' management framework should be developed while taking into account health care certificability for higher applicability in the ICU domain. Finally, data should have a robust and extendable standard format to be readable more or less indefinitely.

5 CONCLUSIONS

Recent trends in the world of HIT-based systems and clinical informatics to acquire and manage data, transform the data to actionable information, and then disseminate this information so that it can be effectively used to improve patient care, have paved the way for innovative healthcare services and applications. Those services and applications are most severe in critical care environments such as Intensive Care Units (ICUs) where many events are life-threatening and thus require immediate attention and the implementation of definitive corrective actions. Therefore, managing the criticalities of specific subsystems and components in such environments is of fundamental importance.

In this respect, this paper aims to identify technical challenges towards HIT-based systems, as a first step to effectively manage them in system implementation and deployment. In addition, the present study proposes a hybrid data clinic management framework, namely 'I-ICCIS' (Integrated Intensive Care Clinical Information System) to pave the way towards incorporating critical care informatics in dynamically monitoring the patient's state in ICU. Such a framework integrates all relevant patient data generated from stand-alone devices and disparate sources that do not easily integrate with one another, into a central information platform, to extract clinically relevant features and translate them into actionable clinical information. Fundamental aspects on the mixed-criticality characteristics of 'I-ICCIS' are presented in detail.

Last, this work opens the gates to a series of exciting work areas. First, a generic HIT-based architecture for supporting mixed-criticality healthcare systems in ICUs shall be specified. Second, a set of requirements regarding ICU environment can be further extended. Third, interoperation and communication issues among different sources and devices shall be explored due to their crucial importance within the context of ICUs. Fourth, additional novel healthcare oriented applications for ICUs can be investigated, through the proposed approach. Moreover, AI-enabled solutions should be implemented in the presented integrated intensive care clinical data management system for making life-critical decisions and predicting adverse outcomes before they happen, better manage highly complex situations, and ultimately allow clinicians to spend less time analyzing data and more time harnessing their experience and human touch in delivering care. Finally, what could also be investigated is to understand aspects that are likely to maximize health-care personnel (nurses, doctors, etc) adoption of intelligent integrated HIT-based systems in ICUs.

REFERENCES

Ciccozzi F., Crnkovic I., Di Ruscio D., Malavolta I., Pelliccione P. and Spalazzese R., 2017. Model-driven engineering for mission-critical iot systems, *IEEE Software*, vol. 34, no. 1, pp. 46–53.

Davoudi A., Malhotra K.R., Shickel B., Siegel S., Williams S., Ruppert M., Bihorac E., Ozrazgat-Baslanti T., Tighe P.J., Bihorac A., Rashidi P., 2019. *Intelligent ICU for autonomus patient monitoring using pervasive sensing and deep learning*, Scientific Reports.

De Georgia M., Kaffashi F., Jacono F. and Loparo K., *Information technology in critical care: review of monitoring and data acquisition systems for patient care and research*, The Scientific World Journal, vol. 2015, Article ID 727694.

Flohr L., Beaudry S., Johnson K.T., West N., Burns C.M., Ansermino J.M., Dumont G.A., Wensley D., Skippen P., Gorges M., 2018, Clinician-driven design of VitalPad – an intelligent monitoring and communication device to improve patient safety in the intensive care unit, *IEEE Journal of Translational Engineering in Health and Medicine*, vol. 6, DOI: 10.1109/JTEHM.2018.2812162.

Gambo I., Oluwagbemi O., Achimugu P., 2011. Lack of interoperable health information systems in developing countries: an impact analysis, *Journal of Health Informatics in Developing Countries*, vol. 5, no. 1, pp. 185-196.

Gulavani S., Kulkarni R.V., 2010. Role of information technology in health care, In *4th National Conference, Computing for Nation Development*, India.

Hammed, N.S. and Owis M. I., 2015. An integrated health monitoring system," *In 2015 International Conference on Advances in Biomedical Engineering (ICABME)*, Beirut, pp. 197-200.

Hayes-Roth B., Washington R., Ash D., Hewett R., Collinot A., Vina A. and Seivere A., 1992. Guardian: a prototype intelligent agent for intensive-care monitoring, *Artificial Intelligence in Medicine*, vol. 4, pp. 165-185.

Heidari M., Norouzzadeh R., Salari M., 2013. Effective factors in information technology (IT) acceptance in the view of the nurses working in ICU, *Iran J Crit Care Nursing*, vol. 6, no. 3, pp. 165-172.

IBM Research, 2016. *The future of health is cognitive*, United States of America.

Islam S.M., Kwak D., Kabir M.H., Hossain M., Kwak K.S., 2015. The internet of things for health care: a comprehensive survey, *IEEE Access*, vol. 3, pp. 678-708.

Jacobs J.P., Wernovsky G., Cooper D.S., Karl T.R., 2015. Principles of shared decision-making within teams, *Cardiol. Young*, vol. 25, no. 8, pp. 1631-1636.

James F., Power N., Laha S., 2017. Decision – making in intensive care medicine – a review, *J. Intensive Care Soc.*, vol. 19, no. 3, pp. 247-258.

Kaur A. and Shimi S.L., 2016. Patient data management system in intensive care unit (ICU) using Labview, *International Journal of Engineering Sciences and Research Technology*, vol. 5, no. 6, pp. 522-529.

Kotronis C., Minou G., Dimitrakopoulos G., Nikolaidou M., Anagnostopoulos D., Amira A., Bensaali F., Baali H., Djelouat H., 2017. Managing criticalities of e-health IoT systems, *In IEEE International Conference on Ubiquitous Wireless Broadband (ICUWB '17)*.

Kurahashi A.M., Weinstein P.B., Jamieson T., Stinson J.N., Cafazzo J.A., Lokuge B., Morita P.P., Cohen E., Rapoport A., Benjak A., Husain A., 2016. In the loop: the organization of team-based communication in a patient-centered clinical collaboration system, *JMIR Human Factors*, vol. 3, no. 1, DOI: 10.2196/humanfactors.4996.

Lee E., Wang Y., He Y. and Egan B., 2019. An efficient, robust, and customizable information extraction and pre-processing pipeline for electronic health records, *In 11th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management (IC3K 2019)*, pp. 310-321, DOI: 10.5220/0008071303100321.

Lighthall G., Guillamet C., 2015. Understanding decision making in critical care, *Clin Med Res*, vol. 13, no. 3-4, pp. 156- 168.

Lin C., Yang C., Zhou Z., Wu S., 2018. Intelligent health monitoring system based on smart clothing, *International Journal of Distributed Sensor Networks*, vol. 14, no. 8, https://doi.org/10.1177/1550147718794318.

Mieronkoski R., Azimi I., Rahmani A.M., Aantaa R., Terava V., Lijeberg P., Salantera S., 2017. The internet of things for basic nursing care: a scoping review, *Int. J. Nurs. Stud.*, vol. 69, pp. 78-90.

Milenkovic A., Otto C., Jovanov E., 2006. Wireless sensor networks for personal health monitoring: issues and an implementation, *Elsevier Computer Communications*, vol. 29, no. 13-14, pp. 2521-2533.

Osmon S., Harris C.B., Dunagan C., Prentice D., Fraser V.J., Kollef M.H., 2004. Reporting of medical errors: an intensive care unit experience, *Critical Care Medicine*, vol. 32, no. 3, pp. 727-733.

Prajapati B., Parikh S., Patel J., 2017. An intelligent real time IoT based system (IRTBS) for monitoring ICU patients, In *International Conference on Information and Communication Technology for Intelligent Systems*, vol. 2, pp. 390-396.

Qi J., Yang P., Min G., Amft O., Dong F., Xu L., 2017. Advanced internet of things for personalised healthcare systems: a survey, *Pervasive Mobile Comput.*, vol. 41, pp. 132-149.

Sellars C. and Easey A., 2008, *Electronic health records: data protection issues in Europe*, BNA International, BNA's World Data Protection Report.

Shahriyar R., Bari F., Kundu G., Ahamed S.I., Akbar M., 2009. Intelligent mobile health monitoring system (IMHMS), *International Journal of Control and Automation*, vol. 2, no. 3, DOI: 10.1007/978-3-642-11745-9_2.