Chapter 30
Enhancing Scientific Research Opportunities and E-Learning by Integrating Large Medical ISs

Igor Dugonjić, Mihajlo Travar, Zoran Ž. Avramović, and Gordan Bajić

30.1 Introduction

Information and communication technologies (ICT) have the potential to improve and enhance the quality, efficiency, and safety of health services [1]. Therefore, these technologies are also applied in the healthcare system. Their introduction has opened a whole range of services that may be oriented toward medical service users, medical service providers, hospital administration, technical staff, and medical devices. Some of these are EHR (electronic health record), PHR (patient health record), EMR (electronic medical record), telehealth/telemedicine, HIS (hospital information system), RIS (radiology information system), PACS (picture archiving and communication system), CMMS (computerized maintenance management system), and plenitude of other ICT systems being applied in healthcare. In addition to these relatively independent ICT systems, medical devices contain embedded software packages that support the proper functioning of hardware. They can be visible or hidden from the end user and perform complex tasks based on pre-built algorithms such as analysis of information obtained from external sensors and automatic control functions in life support devices or used for alarming and initiating appropriate procedures. They use hardware to communicate with other physically separate and remote devices of lower, same, or higher level or, in turn, diverse ISs. A very important software application in medicine and other areas is the GUI (graphical...
user interface), and the user-friendliness and reduction of the number of user errors depend on the method of implementation [2]. The basic purpose of these systems is to monitor patients and enhancing the quality of healthcare [3]. As this system is not closed or isolated, it is necessary to enable interaction with other auxiliary or external systems. Auxiliary systems include, for example, CMMS, while the education system is an example of an external system that relies directly on medical ISs. Medical information systems store and process a large amount of heterogeneous data. These include medical, demographic, economic, organizational, legal, and other data.

### 30.2 ICT Systems in Medicine

If we look at central monitoring in intensive care, we can see that it communicates with the monitors of individual patients. Monitors are connected to the patient via sensors that convert various biomedical signals (raw signals) of the patient into electrical signals suitable for further processing [4]. All relevant biomedical parameters of the patient are displayed on the patient monitor and central monitor via a graphical interface. In case of discrepancy between these parameters and the set limits, alarms of the appropriate level are activated.

On the other hand, PACS contains multimedia medical data like images obtained from a wide range of heterogeneous DICOM (Digital Imaging and Communications in Medicine) modalities (CT, MRI, analyzers, dermoscopes, etc.). Besides medical data, PACS also contains metadata. Although smaller in size, metadata are a very sensitive set of data because they contain confidential personal information about patients. In one health institution, PACS is connected to other information systems such as RIS, HIS, bookkeeping information systems, procurement, and warehouses. Although seemingly unrelated, very important data can be extracted from the information system intended for the procurement and storage of medical equipment and consumables of a health institution to which a certain geographical region gravitates. The requirement is that the system works properly and that as many parameters as possible that affect the work of the institution and the warehouse as one department are taken into account. These parameters can be the quality of the information system, the level of standardization of the procedures being carried out, the financial status of the institution and society, political influences, etc. Thus, for instance, using AI (artificial intelligence) and analysis of the dynamics of the consumption of certain medical supplies, data can be obtained that can predict the dangers and give time to prevent them. Radiology has always been closely connected with training; today, there are far greater opportunities for this than before. Radiological medical images can be classified and grouped into several categories:

- Patients they refer to.
- Modality of obtaining.
- Type of examination.
- Diagnosis and the like.
When the images are sorted by the patient, the focus is on the patient and the history of the disease. Sorting by modality and by the type of examination is important for the organizational part and workflows in the radiology department. In terms of training, all ways of grouping medical images are important, and PACS systems can filter these data by various parameters. A significant obstacle here is the confidentiality of personal information. Access to private information must be strictly regulated, and the first significant act regulating the confidentiality of medical data is the 1996 HIPAA (Health Insurance Portability and Accountability Act) [5]. To use medical data for educational purposes, they need to be anonymized. It is often necessary to perform this procedure on a whole series of data by grouping medical images by one patient in order to follow the history of the disease and by removing the personal information in a way that the identity cannot be disclosed even by using sophisticated procedures. Personal information could be used by insurance companies, banks, malicious individuals, etc.

30.3  Integration and Sharing of Medical Information

There is a relatively high degree of integration of the said ICT systems in every individual healthcare institution, while the integration among different institutions is relatively in its early stages. This task is facing significant safety; interest; organizational, economic, and legal; and other challenges. On the other hand, scientific research communities may be a very important stakeholder in this process. The reason is the possibility of instant access to a huge amount of relevant, quasi-real-time field data.

As epidemics of Ebola, MERS, and other diseases, as well as the COVID-19 pandemic, threaten the health of nations, ICT combined with social distance and other physical protection measures can be a very powerful weapon against these threats. The use of ICT in healthcare has many aspects, from very complex and advanced technologies to simple technical forms in the form of broadcasts. An example of ICT tools against infectious (but also non-communicable) diseases can be the term “going viral,” which is the term most commonly used to describe fast-spreading and vast-spreading online content [6]. There is also an example of the use of a social media platform for cell phones in the fight against coronavirus: namely, using the incorporated GIS (geographic information system) and legally personalized mobile devices, the locations of these devices are marked in people diagnosed with COVID-19 on the virtual map. When an uninfected person is near an infected person, an alarm goes off, and a map appears on the display of the mobile device. Another form of using mobile phones is the timely provision of useful information and censorship of misinformation. The downside of this use of ICT is the violation of privacy.
30.4 Artificial Intelligence

State-of-the-art devices, increased workload of radiologists, and new imaging procedures make the amount of produced and stored medical data on PACS systems increase progressively [3]. On the one hand, this can be a difficulty as it is necessary to provide procedures for storing and managing these data, while on the other hand, this is a great potential in terms of available learning and research material. The obstacle is the centralization of medical ISs in a single institution. In order to enable interoperability, optimal use of data, and quality training in healthcare, it is necessary to change the way of managing centralized sources of medical data and enable integration with external ISs. The integration could use cloud technology and should be able to manipulate a large set of data (Big Data). Although there are numerous algorithms for managing such data, AI (artificial intelligence) is currently the most suitable tool to serve the purpose [3]. Big Data is a large and complex set of data that cannot be managed and processed with traditional database management tools. In this case, relational databases are replaced by the so-called NoSQL databases, which are perfect for storing large amounts of data in distributed systems and the cloud [7].

Many challenges can affect the integration and sharing of medical data for healthcare, e-learning, and research purposes, and we can divide them into technical and organizational human-related. The main technical (including safety) challenges are availability, confidentiality, access control, data ownership, privacy, and authentication [8]. To ensure availability, it is necessary to ensure a systematic and standardized connection between heterogeneous local ISs and the cloud. Cloud should also offer a service that incorporates compatible medical image viewers to avoid losing window and level DICOM functionality in, for instance, format conversions. It is also necessary to parse DICOM files in order to separate the metadata from the medical image [9].

Besides the benefits, the introduction of new technologies brings new challenges like organizational human-related. In the implementation of new ICT solutions for healthcare purposes and training, we distinguish the following: preparing physicians for online educated patients; raising awareness of the benefits of ICT for healthcare technologies; motivating students and technicians to use ICT for information, learning, and development; and, ultimately, changing the medical training methods [10].

Integration should not be limited to large systems and clouds; fog computing should also be taken into consideration. Unlike cloud technology, where data and applications are processed in the cloud, which is a time-consuming task when working with Big Data like medical imaging series, the concept of fog computing and the IoT (Internet of Thing) significantly reduces data size [11]. Ready, prepared, and usable information is sent over the network, while local biomedical signals are not sent to the cloud.

The integration should support DICOM (Digital Imaging and Communications in Medicine) and HL7 (Health Level 7) standards. It should also be in line with IHE
recommendations, especially the XDS profile. To achieve data protection, Oliveira proposed an XDS-π (private) profile that combines the two concepts of XDS-I and public cloud [12].

The COVID-19 pandemic has led to a sudden increase in volume of sharing medical data, online notes, deep learning, and forming large repositories. Never before has so much communication activity been recorded between participants in this process; however, there have also been problems related to infrastructure, legal issues, and issues related to standardization [13]. Restrictions imposed by the GDPR (General Data Protection Regulation) have also been observed. The GDPR has strict data protection rules that limit the collection, use, and exchange of medical data and hence the ability to jointly combat the spread of disease [14].

Radiomics, a branch of AI-based radiology, is a method of extracting large amounts of features from medical images using data-characterization algorithms and deep learning. It usually involves several serial steps, starting with image capture, region segmentation, feature extraction, predictive modeling, and model validation (Fig. 30.1). Regarding the use of AI in the fight against COVID-19, opinions are divided; on the one hand, it is believed that CT (computed tomography) of the lungs when using these tools based on a well-balanced and well-controlled data set can answer the question of whether it is COVID-19 or not [14] [15]. On the other hand, we know that SIRM (Italian Society of Medical and Interventional Radiology) does not support the use of CT and AI screening tools for COVID-19, although it

![Fig. 30.1 Radiomics workflow of data process and users](image-url)
provides recommendations for research into the use of AI as a predictive and prognostic DSS (decision support system) [16]. The fact is that radiologists really can’t get convincing cases of using AI and deep learning if they don’t have the necessary data and infrastructure [17].

For the purposes of e-learning, Ranschaert favors pseudo-anonymization over complete anonymization, where each patient is assigned a code associated with medical images. This method is practically simpler and faster and in line with GDPR [14]. The issue of e-learning in this area is very important and takes several stakeholders into account: students, medical staff, IT staff, etc. The areas of interest of these groups overlap in part, but there are also important specifics.

Medical students are primarily interested in accessing repositories with processed and sorted medical case studies. Medical staff is also interested in this content, but also in training to work with new IT technologies such as AI. There is an initiative from EuSoMII (European Society of Medical Imaging Informatics) to introduce training in the application of AI in radiology as a standard throughout the training of radiologists [13]. It is certainly important to mention that two groups of researchers are directly interested in AI-related research, in medicine and in informatics, each in its own field. As traditional PACS is not sufficiently flexible for scientific research [18] and, on the other hand, it is very suitable for routine operations with its robust, secure, and simple interface for working with imaging data in clinical practice, integration and model for sharing this data should avoid the shortcomings of traditional PACS that occur in the research process. These shortcomings relate to data protection, legislation, loss, duplication and corruption (occupancy) of data, high overhead costs, organizing and indexing files as a volume, increasing the complexity of image studies, etc.

By sharing medical resources and after the integration process carried out to a certain level, the possibilities of new services occur – such as telemedicine, knowledge management, and more optimal workload of professional staff. Accordingly, healthcare at a higher level can be achieved with already existing medical staff, using bidirectional communication and data transmission in places without the physical presence of specialized medical staff. It is primarily in remote and inaccessible areas, islands, overseas ships, etc., with the help of ICT infrastructure and the use of online services of specialist doctors located in another geographical location.

### 30.5 Conclusion

There are many dedicated ISs that find their application directly or are largely based on healthcare. Some of these systems store medical data accompanied by personal data of patients (PACS, EHR, KIS, etc.). When all these systems are viewed globally in a geographical region, they are a significant resource that can be exploited through adequate integration using ICT. This paper emphasizes the potentials of this
resource such as e-learning, health and technical training, fight against epidemics and pandemics, overall improvement of healthcare through new telemedicine services, and significant expansion of opportunities for scientific research in both medicine and ICT. The paper points out great importance of AI in combination with Big Data. This is still an underdeveloped area, and future research should focus in that direction. The paper also points out certain challenges – technical and nontechnical.

References

1. S.G. Sampada, R.V. Kulkarni, Role of information Technology in Health Care, in Proceedings of the 4th National Conference, INDIACom-2010 Computing for Nation Development, (Bharati Vidyapeeth’s Institute of Computer Applications and Management, New Delhi, 2010)
2. Y. Zhang, P. Masci, P. Jones, H. Thimbleby, User Interface software errors in medical devices: A study of US device recall data. Biomed. Instrument. Technol. 53, 182–194 (2019). https://doi.org/10.2345/0899-8205-53.3.182
3. E. Ranschaert, S. Morozov, P. Algra, Artificial Intelligence in Medical Imaging Opportunities, Applications and Risks: Opportunities, Applications and Risks (2019). https://doi.org/10.1007/978-3-319-94878-2
4. D. Boskovic, O. Lepara, Biomedicinski signali i sistemi (ISBN 978-9958-629-68-6, 2018), p. 14
5. HIPAA, Federal Register, Vol. 68, No. 34, Rules and Regulations (February 20, 2003)
6. P. Abbott, S. Barbosa, Using information technology and social mobilization to combat disease. Acta Paul. Enfermeria 28, 1 (2015)
7. R. Vrbić, Data mining and cloud computing. JITA – J. Inform. Technol. Appl. (Banja Luka) – APEIRON 4 (2012). https://doi.org/10.7251/JIT1202075V
8. M. Anuja, C. Jeyamala, A survey on security issues and solutions for storage and exchange of medical images in cloud, in International Journal of Emerging Trends in Electrical and Electronics, 11–6, (2015), pp. 27–32
9. A.W. Kamaau, S.L. DuVall, R.J. Robison, A.P. Liimatta, R.H. Wiggins 3rd, D.E. Avrin, Informatics in radiology (infoRAD): Vendor-neutral case input into a server-based digital teaching file system. Radiographics: a review publication of the Radiological Society of North America, Inc 26(6), 1877–1885 (2006). https://doi.org/10.1148/rg.266065707
10. T. Karsenti, B. Charlin, Information and communication technologies (ICT) in medical education and practice: The major challenges. Int. J. Technol. High. Educ. 5, 68–81 (2009)
11. M. Maksimović, Implementation of fog computing in IoT-based healthcare system. JITA – J. Inform. Technol. Appl. (Banja Luka) - APEIRON 7, 100–107 (2017). https://doi.org/10.7251/JIT1702100M
12. L. Ribeiro, C. Costa, J. Oliveira, Curr. Trends Arch. Transmission Med. Images (2011). https://doi.org/10.5772/27959
13. P. Ward: Pandemic leads to surge of interest in informatics. https://www.auntminnieeurope.com/index.aspx?sec=log&itemID=618901 (2020)
14. P. Ward: COVID-19 crisis shows limits of GDPR, Ranschaert warns. https://www.auntminnieeurope.com/index.aspx?sec=log&itemID=618746 (2020)
15. X. Xie, Z. Zhong, W. Zhao, C. Zheng, F. Wang, J. Liu, Chest ct for typical 2019-ncov pneumonia: Relationship to negative rt-pcr testing. Radiology 0(0), 200343., pMID: 32049601 (2020). https://doi.org/10.1148/radiol.2020200343
16. SIRM, SIRM issues guidance on CT, AI use in pandemic. https://www.auntminnieeurope.com/index.aspx?sec=log&itemID=618722 (April, 2020)

17. M. Bassett: The Reality of Deep Learning/Artificial Intelligence in Radiology: They Will Redefine the Specialty. In rsna.org. Available from: https://rsna2017.rsna.org/dailybulletin/index.cfm?pg=17mon05 (2017)

18. S.J. Doran, J. d'Arcy, D.J. Collins, R. Andriantsimiavona, M. Orton, D.M. Koh, M.O. Leach, Informatics in radiology: development of a research PACS for analysis of functional imaging data in clinical research and clinical trials. Radiographics: a review publication of the Radiological Society of North America, Inc 32(7), 2135–2150 (2012). https://doi.org/10.1148/rg.327115138