Information System for Collecting and Tracking Patient Radiation Doses as Support in Healthcare

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Abstract: - Internet technologies and modern devices are becoming more relevant in all aspects of human lives, including healthcare. Medical devices can be applied to help diagnose illnesses, save human lives and monitor different levels in all segments that directly or indirectly impact life and health. In this paper, a conceptual design of a harmonized information system for tracking, storing, exchange and analysis of patient radiation doses is proposed. This system unifies all data of patient radiation doses which are irradiated during every imaging examination of patients. It could, as a result, serve as a decision supporting system for radiographers, and patient examinations where radiation doses need to be adjusted for imaging. Such an information system could store and analyze essential data and provide suggestions for radiation exposure during examination, reduce the overall number of examinations, images, waiting lists, costs, and time spent on evaluating findings. The proposed system could be an upgrade of ALARA, which serves as an extension of the Radiation Safety Culture in Medicine.

Key-Words: - E-Health, Healthcare communication, Information system, Data harmonization, Radiation data, Radiation safety, Real-time analysis, Data tracking, Information security, Information integrity.

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1 Introduction

Since humanity started to record healthcare data, it has been trying to preserve these records in some way. For example, during the period of the Egyptian civilization all records, including healthcare-related records were stored in temples. Relatively recently, we started to store records in digital format on servers, securing them by sequences of passwords and encryption keys [1], and interconnecting them online over secured protocols.

Radiation dose in medicine refers to the amount of ionizing radiation that a patient is exposed to during a medical imaging procedure or radiation therapy treatment. The goal of these procedures is to obtain clear and diagnostic images or to deliver a therapeutic dose of radiation to a specific area while minimizing the radiation exposure to the rest of the patient's body. The amount of radiation a patient receives depends on a variety of factors such as the type of imaging or treatment, the body part being imaged or treated, and the patient's size and body composition.

Medical professionals use a unit of measure called millisievert (mSv) to quantify the radiation dose a patient receives. The effective dose of radiation is generally low in diagnostic radiology and considered safe, but it should be kept "as low as reasonably achievable", which is also known as the ALARA principle. Repetitive exposure to multiple diagnostic ionizing imaging, especially computed tomography, can increase the risk of cancer and other health problems.

Tracking dosimetry is a standard procedure for engineers that work with higher doses in interventional units during examinations in radiology departments. However, there is no central information system for patient tracking and recording of cumulative radiation doses for any examination they receive. If we want to record and enable tracking of this kind of data, we first must analyze all the methods used for data recording, standardize them and make them comparable. In this way we can model an information system that works with standard data of patient radiation doses. Once the data is standardized, it can be harmonized through different healthcare information systems that are used within primary healthcare, hospitals, departments, on the national level etc.

The existing healthcare protocol requirements, such as the Health Information Exchange (HIE) and Integrating the Healthcare Enterprise (IHE), can be met using blockchain technology as a new form of data standardization for healthcare data distribution. The HIE faces numerous problems, such as the point-to-point sharing protocols, cost per transaction, multiple patient synchronization, different standards between systems, limited access to data, and rules and permissions for access.

When thinking of how to use collected patient data and computer power in terms of artificial intelligence, which can be used for analyzing and predicting health status by monitoring parameters in healthcare, using the dosimeter is a key component for predicting healthcare outcomes. Most of the patient's health status is directly or indirectly connected to a specific radiation dose. It is known that the DNA code, its mapped parts and functions can be changed when exposed to radiation doses. Human health, eventual lifestyle limitations and possible diseases are therefore connected with radiation doses that humans absorb during examination and radiation exposure.

2 Related Work

In the United States of America, the FDA is actively working with the industry so that the next generation of radiation imaging devices will have the ability to automatically record doses, protocol data, and patient information in standardized formats [2]. In that way it is possible to ensure data in a standard format that can be collected and stored for analyses and the use in different management systems.

In a study published in 2021 [3], CT radiation doses were monitored and tracked in a six-month period using a dose management system on more than 11000 examinations. The system reported a 3% radiation overdose during examination. However, this is still not the actual information about the total cumulative dose received, just the real-time exposure that is monitored and reported within the management system during one examination.

After eight years of analyzing clinical effects of continuous dose monitoring and patient follow-up for fluoroscopically guided vascular interventional procedures, a 2019 study on the effect on patient radiation exposure [4] presented results of using a dose tracking system, where in the beginning of using this system, almost 6% of all medical examinations applied overdosed radiations. However, by using this dose tracking system this value dropped to 2%. Nevertheless, like in previous research, that is just a single examination without information about cumulative dose over a period of time.

At the webinar "Operationalizing a Vision of Safe Imaging: The American College of Radiology Dose Index Registry" [5] held on November 9, 2021, when the project named "Dose Index Registry (DIR)" was launched, with the aim of centralizing and archiving radiation dose information, the need for standardization of the radiation dose index and for collection and archiving of that information for monitoring and analysis was emphasized. It was pointed out that there is an evident need for the existence of a data standard for monitoring patients' exposure to radiation that collects and stores various types of information on the cumulative radiation doses of patients.

A recent study on the cumulative dose during examination using PET-CT [6] reported that by using dose tracking system, radiation doses were optimized in order to improve radiological protection of patients, and therefore some of the examination in a field of nuclear medicine have come into the spotlight, since high-dose examinations have been performed, even though they occur less frequently. In their conclusion, they stated that regardless of the use of such an information system for monitoring the current dose applied to a patient, the implementation of such a system reduced the dose of radiation exposure and provided key information that helped to reduce the dose in future examinations. It was emphasized that it would be more helpful if an information system would use a record of the cumulative dose of exposure extracted from patient data. This information system should, based on current radiation exposure, calculate and record the cumulative dose as an additional system upgrade.

3 Problems with Data Collection

By increasing the use of diagnostic scans with the help of radiographic medical devices, and with over 4 billion applications per year worldwide, cumulative radiation dose absorption has been increased significantly. Physicians are sending patients to medical radiographic examinations to get insights into health condition as quickly and accurately as possible and in order to describe findings and start with the necessary therapy to help patients.

However, clinical studies have shown a significant increase in applying an unjustified number of radiation examinations to patients. Nevertheless, doctors and patients are aware of the negative effects of excessive exposure to radiation, which is then manifested in the optimization of examinations and the use of the latest device technology for obtaining the maximum image quality with minimal radiation, although adequate monitoring and analyses of received radiation are still not carried out entirely.

For everyone who is exposed to an increased amount of radiation, either in their work or during the process of medical examination, it is necessary to monitor and record these doses in order to protect all those involved. The device that records radiation is called a dosimeter. Dosimeters are devices that can provide a quantitative and reproducible measurement of absorbed doses through a change in one or more of the physical properties of the dosimeters in response to the exposure to ionizing radiation energy [7]. A dosimetry system consists of dosimeters, measurement instruments and their associated reference standards, and procedures for using the system. The measuring instrument must be well calibrated, so that it gives reproducible and accurate results.

Dosimetry went through several stages throughout its history and was primarily used by medical personnel. At first, conventional dental films were used to detect accumulated radiation doses in order to compare the brightness of the film with a tester and to obtain the received dose on each film and for each user. Obviously, this kind of film could not record the current indication of the received dose, but only the accumulated one. Then, a sensor that records the received dose had to be worn on the body itself. This kind of sensor continued to record accumulated dosages over a certain period of time, for example on a monthly basis, whereas the data was transferred digitally and recorded in a table for each employee. This has been in use in healthcare institutions only recently.

Real-time analysis would mean that such a digital sensor is connected in real-time to a system that records, analyzes and compares the amounts of current doses of radiation exposure. Such a device is related to the concept of IoT (Internet of Things).

During an imaging procedure, radiation is used, and the patient is exposed to a certain dose of that radiation. To increase the patient health safety the need arises for more accurate radiation dose monitoring methods for patients using a device that records the exact dose of radiation and sends and archives them in databases with patient information and with obtained imaging results. This data is recorded on devices mounted on the collimator, whereas the radiation volume is recorded and sent along with all other DICOM data to the DICOM local storage database. DICOM stands for Digital Images and Communications in Medicine, and it is a standard for exchange of digital images and data in radiology.

However, this data is still not available on all devices that are radiating during examination, and due to the lack of standardization of generated data, using and storing this kind of information in a database is not possible.

Therefore, it is necessary to collect all these data and to proceed with standardization of data in a centralized database and in a regulated way so that we can access the total or cumulative dose information for each patient in one database. This way it is possible to analyze and predict future examinations, the amount of radiation and the required time interval between examinations for the individual in order to minimize the possibility of negative effects on the health of patients.

According to a survey conducted by the International Atomic Energy Agency (IAEA) [8] at the global level, more specifically in 76 countries, no surveyed country has a national system for tracking radiation doses received by patients.

4 Lack of a Central System for Collecting and Tracking Patient Radiation Data

Since each institution collects this kind of data and does not share it with other institutions, the total accumulated dose itself as well as the analysis and use of that data for the purpose of protecting the health of a patient have great potential for improvement. Without a central system in which all radiation dose data is recorded and analyzed in real time, individual monitoring and predicting the needs of employees and patients is not possible.

By upgrading the device that uses radiation during medical examinations, it would be possible to collect radiation dose data and to transmit it to the local DICOM database via internet, in order to record the exact radiation dose a patient is exposed to. In addition, with smart dosimeters that would send radiation data of employees working in radiation-exposed areas with radiation devices, it would be possible to obtain online data in the central database for comparison and analysis.

The creation of a central database for the collection of all data on patients and their received radiation doses from all devices is necessary for the prevention and maintenance of the health of the patients, and for the timely collection and analysis of essential information such as the patient's radiation exposure.

Fig. 1. System design

Fig. 1 represents the design of the Croatian Central healthcare information system (CEZIH), which is comprised of the Hospital information system (HIS) that exchanges data from radiation exposure using the Radiology information system (RIS) and the Central Database for Patient Radiation Dose (CDPRD).

5 Security and data integrity

As we collect, store, and analyze medical and patient data, this must be done under all regulations, EU Data Integrity standards, GDPR rules etc. Recent research suggests the use of the blockchain technology [9] in order to secure medical communication between different points in the medical or public network and on the internet. It is suggested that for better data security in healthcare, blockchain should be used in order to set up data protocols for handling health-related patient data.

Blockchain offers a solution to some of the aforementioned issues by distributing the so-called ledger to ensure exchange of data and to reduce transaction costs, using real-time data sharing and creating smart contracts with distributed permissions. Blockchain technology enables faster transactions, and the cost of operating such a system is significantly smaller than a regular health care information system [10].

Health and government organizations spend large amounts of time and money in setting up and managing information systems and enabling data exchanges. Blockchain's open-source technology, its properties and distributed nature can help reduce the cost of these operations. Blockchain-based electronic health records might enable sharing and access to data, while securing it completely. Some important healthcare actors, such as the Mayo Clinic, the Boston-based Beth Israel Deaconess Medical Center and the MIT Media Lab, have already suggested using blockchain for the standard of securing healthcare data after the successful testing of a blockchain application in a pilot system called MedRec [11].

In March 2017, IBM developed the first commercial application that uses blockchain [12], which can be used in bank transactions, document security, validation of data and healthcare communication. The idea, according to IBM's VP, was to create a blockchain identity solution that would make it simpler to verify identities while also reducing the amount of data shared on the network. National institutions and governments will be included in building such a network.

Also, following the trend set by Estonia, where a million healthcare records are secured with blockchain, and the United Arab Emirates where a private healthcare security provider announced testing blockchain technology for their database, the UK's National Health Service decided to apply the blockchain technology to secure their 65 million patient records [13]. They are turning to IBM and MIT due to their experience in this field, but also to additional startups from the pharmaceutical industry that deal with the field of drug administration and patient monitoring.

According to the MIT research lab, MedRec is a solution to keep medical records secure and at the same time available to doctors. MedRec gives patients and referent doctors control over data stored in records while keeping the data secure from potential security breaches [14].

6 Conclusion

According to all regulations and healthcare guidelines, radiation exposure to patients must be recorded, stored and tracked so it can be reduced during specific examinations. The total cumulative dose and the impact on patients' health can be reduced by predicting subsequent examinations, which can be re-scheduled for a certain amount of time that it is suggested according to guidelines on radiation exposure.

Since radiation is connected with developing some of diseases including cancer, it is a top priority to enable collecting and tracing of radiation doses that are received during each examination, in order to gather all information about the cumulative dose, so that future examinations can be predicted, the radiation dose adjusted accordingly, and so that all relevant data can be utilized for medical analyses.

Still, there is no central system for tracking and recording patients' cumulative radiation doses. Overall, such central systems are important for the evaluation of radiation exposure, the optimization of imaging protocols, and the protection of the population from unnecessary exposure to ionizing radiation. If we want to record and track data on patient radiation exposure during medical examinations, we first must analyze all methods of generating this kind of data, all types of generated data, and then suggest data standards and protocols. This can facilitate the design of an information system that is based on standardized data on patient radiation doses. Such an organized information system can help in creating a national database of patient radiation exposure for the benefit of the entire national healthcare system.

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