Radiation safety in tomorrow's hospital

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Abstract. Despite the numerous advantages of image-guided minimally invasive procedures, there is a growing concern about the risks of exposure to ionizing radiation caused by some imaging devices. Current radiation protection practices are based on assessing exposure inside the operating/examination rooms only, therefore not always accounting for long-term effects. Instead, we present a concept for tomorrow's radiation safety, which is based on a person-specific global monitoring of radiation exposure accompanying a person throughout his/her lifetime. Such a long-term quantitative assessment has the potential of improving current radiation safety practices in medical imaging. Surgical data science is at the center of the development of this strategy.

Keywords: Image-guided procedures, radiation monitoring, context-aware systems

1 Introduction

Recent developments of imaging technologies have allowed medical imaging applications to go from diagnosis only to guidance during minimally invasive surgery. As a consequence, traditional surgical procedures are changing and are increasingly relying on imaging devices. However, among the different types of imaging modalities, X-ray imaging, computed tomography, PET and radionuclide imaging (nuclear medicine/SPECT) rely all on ionizing radiation for the generation of images. This exposes clinicians and patients to potentially harmful radiation which can lead to negative consequences varying from skin lesions to cancers depending on the received dose [3]. Hence, the impact of radiation exposure is a growing concern among healthcare administrators and improving the overall radiation safety is one of today's challenges. Large efforts are currently being done to develop tools to understand, assess, monitor and limit medical radiation exposure. To this end, three major strategies have been adopted and are herein described.

1.1 Reducing the imaging device's effective doses

Imaging devices' manufacturers work towards keeping the effective dose low while providing the best possible image quality. This is achieved through technical innovation and optimized design of the equipment. For instance, Philips' ClarityIQ

[5] low-dose X-ray imaging technology combines image-processing with hardware to obtain patient dose reductions of 80% while maintaining image quality. Similarly, while PET/CT scanning is usually accompanied by substantial radiation dose and cancer risk for the patient [4], Siemens' Biograph mCT [7] achieves dose reductions of 60% with technology reducing the scanning time. Nevertheless, even at low doses, long term exposure can still lead to negative consequences.

1.2 Reducing exposure through safety guidelines

Several strategies aim at reducing radiation doses by following the As Low As Reasonably Achievable (ALARA) principle. Concerning patient exposure, the procedure requested must be medically indicated, justified and optimized by following defined dose protocols. As for what concerns clinicians, exposure can sometimes be avoided by stepping out of the room (diagnostic) or standing behind a lead protective wall (intraoperative). Fluoroscopy guided interventions, however, require them to stand next to the patient and close to the radiation source during the procedure. In such cases, wearing protective equipment and using lead shieldings enables them to mitigate the risk. Yet, studies have shown that unprotected body-parts such as head, eyes and hands can still be importantly irradiated [1] and that the current protective measures are not always sufficient to fully avoid the adverse effects of radiation exposure.

1.3 Monitoring radiation doses

In order to assess the possible risks and set radiation protection standards, several commercial systems for monitoring radiation doses have been proposed. GE's DoseWatch [2] is a software which captures, monitors and reports the radiation dose delivered to the patient from multiple imaging modalities. The doses are estimated from readings of the imaging parameters obtained from the DICOM images or the system's API, and are used to keep track of the patients' exposure in their medical records. Other solutions such as GE's DoseMap [2] and Toshiba's Dose Tracking System [8] allow to visualize in real-time the estimated accumulated dose deposited on the patient's skin during an exam. The skin dose is approximated using the device's parameters and displayed over a generic patient's model. Such systems help assessing the patient's exposure and limiting the overexposure risks. However, they do not provide precise skin and organ dose values. On the clinicians' side, their occupational exposure has been traditionally monitored with TLD dosimeters which measure the accumulated dose over time. Recently, real-time measurement solutions such as RaySafe i2 [6] have been introduced. The measured doses are displayed on a screen enabling clinicians to monitor their exposure online and are also stored for offline analysis. But, studies have shown that exposure can significantly vary from one body-part to the other [1] and assessing dose values in a single location in the body is therefore not enough to provide a complete picture of full body-part exposure.

2 Surgical data science: a key for global radiation safety

Healthcare is changing towards adopting a personalized and predictive model. We envision that radiation safety will follow the same trend and dose monitoring will be decentralized from the OR to a person's entire life. We hereby present our vision on how surgical data science will be at the core of such a change.

2.1 Personalized dose monitoring

Tomorrow, a person's radiation dose monitoring will be performed in a global way for both patients and healthcare providers. A personalized 3D model will store the dose values received by the organs during all exposures to ionizing radiation from medical devices throughout one's lifetime. This will be possible thanks to fully context-aware operating and examination rooms where all devices are connected and their signals analyzed and interpreted by a central system acting as surgical control tower. Precise dosimetry computations will be performed by using the knowledge of the imaging device's configuration, the layout of the room and the person's pose and physiological information. Skin and organ doses delivered to both patient and personnel, respectively exposed to direct radiation and scatter, will be then accumulated in their personalized 3D irradiated model.

2.2 Global radiation safety

Data analysis of a person's lifetime radiation exposure and medical records will be crucial to improve the current dose-response models. Not only it will allow to accurately predict the probabilities of occurrence of adverse effects but also to justify and optimize following exams by providing precise dose and imaging protocols. In case of risk, the use of an alternative non-irradiating modality will be suggested instead. On the personnel's side, occupational exposure will be fully assessed and the amount of interventional procedures and diagnostic exams performed by nurses, radiologists and clinicians will be automatically managed to optimize their yearly accumulated exposure.

2.3 Minimizing radiation exposure in tomorrow's hospital

Surgical activity recognition will be at the core of global dose monitoring since it will allow to precisely assess the radiation doses generated at each step of a procedure or exam. Statistics will be generated to compare practices among personnel, procedures, protocols and hospitals regarding radiation safety. Such data will be used to devise safer surgical workflows and determine the best practices for reducing radiation exposure while achieving the required high quality images. Suggested measures will be personalized according to each subject's radiation exposure record. Moreover, such knowledge will enable the development of context-aware decision-support tools that help optimize the layout of operating/examination rooms and/or suggest imaging device's configurations which minimize the radiation doses delivered to each of the persons involved. The concept of global radiation safety is summarized in figure 1.

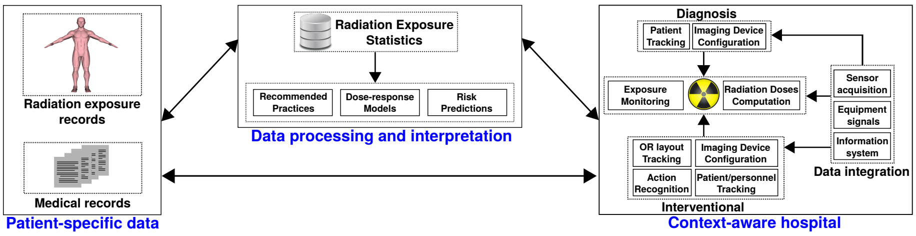

Fig. 1: Global radiation safety for tomorrow's hospital

3 Conclusion

Medical imaging devices involving ionizing radiation are nowadays associated with the noxious adverse effects of radiation. As the popularity of image-guided minimally invasive surgery increases, radiation exposure further becomes a concern for healthcare providers. There is a need to improve radiation safety at a population level. To cope with this, we envision a personalized and predictive monitoring model to assess an individual's record of radiation exposure accumulated throughout his/her lifetime. It will rely on context-aware systems capable of monitoring ionizing radiation and accurately computing the doses absorbed after each exposure. This will increase the acceptance of all imaging modalities and make its benefits accessible to a wider population. Such a model can eventually be extended for monitoring exposure coming from industrial applications and naturally occurring sources to improve the overall radiation safety of the population.

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