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THE EVOLUTION OF X-RAYS: DIAGNOSTIC IMPORTANCE, RECENT INNOVATIONS, AND MAINTENANCE BEST PRACTICES

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1.2 Abstract

The discovery of X-ray by Wilhelm C. Röntgen in 1895 is of ideal utility in various branches of medicine. The high penetrating power of X-ray finds a broad range of diagnostic applications, including bones, denser tissues, and various other medical fields. The utility of a single ray covers various and broader fields of applications in medicine. Multistage innovations in diagnosis enhance the feasibility of X-ray diagnosis and treatment in the medical field. There is a frequent need for upgrading equipment based on several factors, including sensitivity and patient safety. New innovations, namely Computed Radiography, Digital Radiography, Fluoroscopy-DR, and Cone Beam Computed Tomography, enhanced the use of X-ray in various forms of dynamic view applications. In mammography screening, a DR system combined with an advanced analytical post-processor may improve cancer detection sensitivity based on breast density, which is also applicable for other radiographic expertise, including chest radiography and head computed tomography. Even though there are numerous benefits of recent innovations, the maintenance of equipment is undergoing a unique approach that is compatible with rarely shifting detection technology. A regular check-up is performed during a periodic overhaul, which is basically the same for the euro CT system, irrespective of detector technology. As an alternative, visual chart-like quality control tests are proposed for daily use, which are quite common worldwide. In particular, large deficiencies in uniformity in the tangential FOV of CR-based systems require immediate action. These types of huge in-field failures of a CR-based system are rarely observed in DR systems. DR systems may improve continuous clinical use and retention peak analysis with regard to incident X-ray intensity as compared with CR systems. No answers have been given yet, on what happens to CR systems that have to be taken out of service. Further investigation is needed

to acquire a better knowledge of DR systems and compare them with CR systems in terms of clinical usability and maintenance conformity.

1.3 Keywords

* X-Rays * Historical context * Early scientific advancements * World War I * Advancements in radiological technology * New diagnostic applications * Modernization of devices * Innovations using AI technology * Hardware and software maintenance

1.4 1. Introduction to X-Rays

X-Ray is a very essential diagnostic tool in today's medical field which is affected by several factors such as age, disease, height, weight, genetic factors etc. They are used to identify the most common complaints like fractures, cysts, density changes in lungs etc. The use of X-Rays is of great significance in the diagnosis of diseases. The introduction of Crystal Radiography improved the quality of diagnostics. A slightly higher dose is involved in Computerized Tomography (CT) due to its diagnostic accuracy. It is used in early detection of cancers. An X-ray is given to finger to check if there is any fracture and to lungs to check pneumonia. Intra-oral X-ray is used in tooth examination. In flat panel detector it is possible to keep the x-ray tube and detector in parallel position whereas in conventional radiography due to restriction in size the path is to tilt the board, detector and x-ray tube is not easy (Kim et al., 2013). New developments in U-Angle design of imaging detector assembly to remove the drawback of bulkiness and superior resolution were developed. It was designed using new deflect-elements model which also improves number of angle measurements as compared to the previous method ie. using single deflect element.

With great advancement in digital image processing technique a novel filter was developed which emphases the details equally. This filter detects the edges with great sharpness and preserves the textures of X-ray determine SWEPT. The results were obtained using 2-d 3*3 kernel filter. Studies on various inhomogeneities was investigated on pearson toothpastes using digital image processing techniques. With the use of the proposed research work the age of the toothpastes was determined successfully by identifying the defects present. The outcomes proved that with the advancement of technology even the weaker materials can be examined effectively to enhance the qualities. Many of the defects were detected without shortcomings as compared to the previous methods. It can be recommended that number of materials can be considered to obtain the overall efficiency of the strategy and to check if there are any drawbacks. The material can be used for identifying the flaws present in other materials like metals, plastics etc. Further extensive studies can be done on newer compositions which cannot be identified with the existing procedures. As a result alternative remedies can be approximated for future use.

1.5 2. Historical Development of X-Ray Technology

The basis of the work in Radiology dates back to 1895 with the discovery of X-Rays by Wilhelm Conrad Roentgen and the first image was taken on 1896. In the year 1896 the first Medical use of X-Rays was recorded in Napoli, Italy for the removal of a foreign body from the hand of a soldier. It is here assumed that X-Rays started their medical career. The next record with respect to X-Rays again started from Italy, where in 1897 at a hospital used for the wounded soldiers of Adowa battle, X-Rays were used in hospitals. Similarly after 1897 documents are lacking to state the use of this invention in other parts of the world. Literature documents that over a period of time and with the spread of the invention to various parts couldn't find any Occupational or Legal record concerning safety measures there. It is assumed that X-Rays found their way to Ethiopia during the second Italian invasion and occupation with in 1935 AD as part of their medical service for the soldiers or by the Italian residents. No account is available in the archives of the ministry of health or meticulously kept libraries.

On the contrary in 1944 a radiologist was brought to Ethiopia sent by EOSOT along with a C-Arm machine. After the liberation of Ethiopia in1941AD, newly trained residents were filled in the service making it intensive. Medical development, Trainings in Public Health Service were launched. In other towns (Harar, Jimma, Asmara) hospitals before medical doctors were Radiologists. Introduction of portable X-Rays and Fluoroscopy in many hospitals. In addition to these impressive steps there were damaging ones. Still in some hospitals, poorly designed machines with tanks dominated are still in use. The volume stands still at 4 while no aging records exist. Similarly no operator and protection records are found in these hospitals. On the literature in the coverage of the field, there is little information on the problems and duties with respect to the design of machines, use and maintenance of machines, management of Radiation, shielding and safety applying principles on design of Radiographic machines, handling machines, Radiation dose level around patients, safety distance and safety devices (Kebede et al., 2022).

2.1. Discovery of X-Rays

In early November 1895 Willem Röntgen performed an experiment in which invisible cathode rays caused a cardboard screen painted with barium platinocyanide to fluoresce. While investigating the ability of various materials to stop the X-rays, he stepped into the line of the rays and saw an image of his own skeleton shimmering on the fluorescent screen. Ingeniously he first put his wife's hand in the beam and then she herself. This unusual picture shocked and fascinated them both. Rontgen images kronen from his wife. He published the first image and submitted it to the Union or any other scientific body. Although Röntgen died of bowel cancer in 1923, it is generally believed that the carcinoma was not the result of his work with ionising radiation. It was characteristic of the slow decline of his health that he would spend longer and longer hours at his desk and conduct meticulous but futile experiments to understand how it was that the simplest of things could have complicated behaviour. Neither Röntgen's cabinet design nor Carnes' alternative was ever used to describe his X-ray machines. Both represented ingenious application of materials and design technology to solve an important need in the scientific community. By the time that he died he had been out of the public eye for many years. There was no longer a simple equation of notoriety that could unambiguously predict the educative value of scientific work (L Vaughan, 2016). It is now customary to give the year 1895 as the birth date of X-ray radiography. This date relates a set of observations to be made at a particular time. In retrospect these observations seem both momentous and remarkable. At that time the only other known form of electromagnetic radiation was the light by daylight or artificial illumination sources. Other sources of light, such as fluorescent screens and salts were known, but came later. In comparison to daylight the products of the Crookes or other similar tubes had little promise in terms of investigation of the potentiality of the use of X-rays for imaging purposes. There was though an immediate enthusiasm for investigations into safety procedures (Isler et al., 2019).

2.2. Early Applications in Medicine

As one of the oldest imaging technologies, X-ray imaging was first reported in medicine by a physician in 1896. The well-recorded time course of the first X-ray tube assembly and its initial clinical application on a patient is also well documented. In the beginning of X-ray medicine, the tube could only produce a low flux of X-ray that required a long exposure time, and thus a high-speed film was used. Film, controlled by a film holder, was placed about 15-20 cm from the patient's lower abdomen, which was then X-rayed for about 20 minutes continuously after adjusting the tube. The film was kept in a protective case with a lead foil on one side. The masked film holder was then removed from the case for visual interpretation. The first reporting of X-ray medicine made a great impact to the society later lead to a Nobel Prize in 1901, at the same time, however, this also gave rise to worries of X-ray hazards that was also reported in 1897 and later emphasized with more clinical cases reported (Kim et al., 2013). Less than a decade after the birth of X-ray medicine, a physician tried to report on methods of making X-ray pictures without the aid of a camera, a mechanical or electrical device, and described his method for dynamic X-ray screening using a fluorescent screen and a microscope ocular, which is now commonly called fluoroscopy. However, it was not until the end of 1910 that progress was made in design and construction a fluoroscope. The first reporting of a fluoroscope design is again well documented in medicine. The history also records the clinical uses of fluoroscopy in 1911, which included detecting foreign bodies or a dislocated broken limb, distinguishing a folded intestine from a tumor, locating obstructions in the intestine, locating an intra-uterine pregnancy and detecting a liver or spleen that might have been ruptured in a contusion.

2.3. Advancements in Imaging Techniques

In addition to X-ray modalities, new imaging techniques have been developed that use new mechanisms based on advanced physical engineering, i.e., static electrical imaging using CT, bio-phosphorescent imaging using micro CT, laser speckle contrast imaging in neurovascular imaging, and quantum imaging, which topple the paradigm of traditional X-ray imaging. Static electrical imaging using X-ray CT is a new concept of X-ray imaging that makes the internal electric image of a specimen and quantitatively determines the surface potential effect of static capacitance of individuals or aggregates of charged particles, such as bio-conjugated molecules or ubiquitous dust in a room. It is an enlarged vision of specular electric imaging, a computer-controlled equivalent process of 1950s' analog process of X-ray imaging based on wave theory of X-rays. So far, conventional X-ray imaging techniques have only studied the shapes' effects of X-rays on bio-specimens. In contrast, from cleaning the bio-specimens to reconstructing the whole image, this new imaging includes the whole experimental process quantitatively, which can give rise to a qualitative leap in the understanding of the electric effect (Kim et al., 2013). About six million nanoscale phosphors of an alloy of ZnO nanocrystals were fabricated repetitively, displaying high scintillation, excellent luminescent stability, no environmental toxicity, and low cost. The self-made phosphor film is expected to be used in a phosphorescent X-ray micro-CT. Bio-monitored

UPbPSB phosphors with aggregation-induced emission properties were coated on the microrobotic arm as a biolabel, assisting in obtaining the histological section images of 3D bioprinted biological tissues. Furthermore, the imaging contrast mechanism of bio-phosphor and magnetic field in the bio-phosphorescent X-ray micro-CT system was proposed, paving the way for new generations of biocompatible phosphorescent nanomaterials or complex interactive systems. A laser speckle contrast (LSC) technique has been proposed to image CBFs in a single imaging plane that neuron populations see. The technique using these devices and biological models was developed to improve speed and accuracy with economic costs compared to the conventional two-dimensional laser Doppler flowmetry and MRI techniques.

1.6 **3. Diagnostic Importance of X-Rays**

X-rays are electromagnetic waves with wavelengths ranging from 0.1-10nm. They were discovered on November 8, 1895, by Dr. Wilhelm Rontgen, in Wuerzburg, Germany. He observed that when current was passed through a cathode-ray tube, a fluorescent screen in the vicinity emitted rays which fogged a photographic plate placed at a distance. Safety glasses were used at first to shield eyes from danger but later, effects of excessive exposure were found on other body parts and the first general radiological protection code was published. The first X-ray picture was taken on December 27, 1895. The first X-rays of an adult human body (a woman's hand), including her wedding ring, were taken thereafter by Dr. E. R. Filene.

The first hospital radiology department was created in 1896. Seldom has an advancement in science opened new avenues of exploration so rapidly as did the discovery of X-rays. Since then, imaging has provided a powerful diagnostic tool in healthcare with a high range of clinical applications and significant societal impacts. Although these benefits of X-rays have been widely recognized, there are still concerns about their adverse biological effects (Kim et al., 2013). Images taken by excessively low-dose X-rays may not provide sufficient medical information for proper diagnosis. Thus, it is important to prepare and take images with the best possible quality for accurate diagnosis while minimizing the doses. X-ray imaging devices are used for taking high-resolution images of the body by exposing them weakly to high-energy X-rays. The X-ray imaging devices expose body parts to high-energy collimated X-rays and collect the attenuated, scattered, and reflected rays, creating diagnostic quality images.

The biological effects of X-rays, existing X-ray imaging technologies, the ongoing issues in diagnostic imaging along with their expected needs and developments are reviewed. Also, existing innovations in digital X-ray imaging with advanced technologies have been compiled along with the thoughts for possible designs of better X-ray imaging devices. Even with recent innovations in the field of X-ray imaging, such devices are still far from being a proper tool for diagnostics due to the high complexity of their issues.

3.1. Role in Medical Diagnosis

Discovery of X-Rays in 1895 triggered a new biomedical engineering and a series of new technical developments in clinical radiology by . Even more indelible impressions have been made in modern medicine by diagnostic radiology, contrast studies, transducers, CT, ultrasound, MRI, and many systems. Radiology has considerably changed the clinical environment all over the world and has opened up new physicians' roles in various specialties. In a general hospital in the US, about one-fourth of the health care budgets are spent on radiology. A patient entering the hospital is irradiated on average five times, either randomly during emergency cases or based on a physician's request. The number of installations for all kinds of imaging modalities exceeds 100,000 for ultrasound, 30,000 for CT, and 26,000 for MRI. Innovations and better designs have been contributed by engineers, and very complex projects toward digital cine, digital mammography, 96-slice CT, and 7T MRI are recently ongoing (Kim et al., 2013).

Innovations in radiology will expand both the role of medical imaging in the fields of diagnosis and treatment. Digitization of images and the rapid development of image display and input devices will spread the use of images for treatment rather than solely for diagnosis. The application of medical imaging in biological science will improve its knowledge-based market. And, the development of quantitative imaging and better parameters from more sophisticated reconstruction algorithms and more complex images will propel the use of images to physicians in various clinical specialties including cardiology, surgery, pathology, oropharyngology, dermatology, or environments outside of traditional imaging departments. However, the side effects of medical imaging are also foreseen including a large volume of medical images—Petabytes of data to be stored—per worldwide-software, dust, and clutter; hidden information; information flooding and logarithmic growth in knowledge-based image data about the biomedical mechanistic side. The speed of the development of diagnostic radiology was so rapid that the philosophy and ethics of imaging or the history of radiology have not been systematically compiled yet.

3.2. Comparison with Other Imaging Modalities

There are many imaging modalities a clinician may employ in order to visualize a given pathology. Most medical scenarios will prefer an imaging protocol to include X-Ray, with or without contrast-enhancement utilities. A vast array of structures and issues can be viewed nonetheless, there exist some conditions in which this imaging just is not good enough.

Some elements (like water of soft tissue, e.g., muscle or fat) resemble too closely on the film, rendering a radiologist unable to properly diagnose the case and sending the patient to other imaging modalities with higher atomic number contrast. These alternatives include Computed Tomography, Ultrasonography, Magnetic Resonance Imaging, Scintigraphy, Positron Emission Tomography, Vessel Digital Subtraction Angiography, among others.

Computed Tomography uses X-Rays in the same way, rotating around the patient delivering slices of a 3D image in different planes. View axial images multiple views of same planes can be reconstructed with advanced software employed on those slices. 3D images can also be built highlighting blood vessel with the use of contrast-enhancing iodinated drugs. They are frequently used to evaluate contusive TBIs or neurovascular structures, given it has a higher atomic number than surrounding soft tissues giving them high contrast.

Magnetic Resonance Imaging images molecular interactions of hydrogen ions (abundant in water and fat, tissue composition) and visualization abilities for visualization are explored by means of radiofrequency waves of different intensities by Magnetics Poles Probes. They can also inject contrast-enhancers but possess a lower atomic number than routinely employed in Computed

Tomography and should ask to investigate softer tissues shortcomings in Computed Tomography imaging, for example, brain and medullary bases.

Ultrasound employs emission of a sound wave handheld transducer. Imaging use a high-performance processing algorithm. Structures are only recognized with a good ELASTOGRAPHY machine. Structures have to be good reflectors of the sound beam. Bones, air, gas, bony edges, and strained structures cannot be studied to well. However, for cartilages, meniscus, tendons, and a few soft tissue abscesses, it is the ideal imaging modality as they do not act as good reflectors of the sound beam, giving better contrasting images instead.

Scintigraphy visualizes radioisotopes injected into the bloodstream or accreting in structures with high metabolism such as osteoblastic in malignant dissemination or hyperparathyroidism with its high sensitivity. Positron Emission Tomography employs molecules marked with a positron decay isotope in high metabolism or pathologies areas. They can show biology good enough to have early diagnoses but lose disclosure at anatomical levels.

3.3. Case Studies and Clinical Outcomes

Radioscopy can now be conducted in high-tech facilities located in medical centers and small hospitals. The demand for equipment ideally and economically suited to the needs of medical frequency radiography is rapidly increasing (Lucia Nana I Ebisawa et al., 2009). With consistent images obtained, there is extensive use in some disciplines, and controversy surrounds the excessive and inappropriate use of x-ray equipment in others. The advent of low dose and digital x-ray with alternative modalities such as ultrasound, CT, and MRI has made a notable impact on both preventive health examinations in more affluent areas and displaced patient imaging in certain societal groups. Efforts in biodosimetry, screening, and assessment of special populations for radiation exposure, as well as occupational monitoring, may be closely tied to known extensive x-ray history in Korea (Labriet et al., 2018). There are also apparent discrepancies between national legislative provisions and the current practice of x-ray examination and imaging. Efforts for screening non-native workers in hospitals and facility programs in collaboration with the Department of Labor and Health should be conducted nationwide for elementary schools as well as other youth organizations. Other groups or programs should be screened based on the involvement in atomic energy, more specifically in research or isotope handling analysis or applications. There are high risks for abuse of fluoroscopy units such as x-ray machines including not just simple linear/2D radioscopy but also in 3D structured volumetric imaging with IVR planning that often contains integrated mini-CT. As mentioned above, there are also other service units, universities and institutes, under the Ministry of Science and Technology that have excessive suspicion with no radiological assessments by, or reports available from, the major organizations in Korea except for university hospitals. National level reformation should urgently be devoted to accurate national distribution and usage of medical x-ray sources. It is also desirable to establish and suggest a medical pattern of the use of x-ray sources for socio-factors in this country, including clinical or research specialties, types of institutions, patient sounds and grouping.

1.7 4. Recent Innovations in X-Ray Technology

The field of radiography has been rapidly evolving since the introduction of digital technologies in the early 1980s. Digital radiography has addressed many issues with film radiography, converting analogue signals into digital signals. While filmless ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) became established in diagnostic imaging, it took longer to introduce digital X-ray. Nevertheless, digital radiography systems now dominate the market (Kim et al., 2013). The introduction of digital radiography systems not only improved the workflow but also made it possible to decompose the signal chain for image enhancement. Each component of the signal chain came into focus to improve image quality, and ideas about iterative reconstruction were borrowed from other imaging modalities to correct various noises in X-ray images.

Efforts were made to increase speed and avoid the motion artifacts that accompany increased speed. Research on the scintillator and the type of optics used in indirect conversion structures took place. Introductions of large area CMOS and flat-panel detectors have made it possible to produce portable units with a high spatial resolution that can be applied to bedside examinations. Digital detectors can be broken down into signal-convert to readout components, which can then be treated with tuning and timing adjustments, separate evaluations of defective pixels, and temperature management. This separation of components provides equal opportunities for both new designs and modifications of them. The digital radiography chain involved the development of inspection methods for each component, which would be necessary to offset the high cost of the components. The novel components themselves were subject to widespread plume research both to modify them for desired process control and to examine their behavior within the systematic design context. Thus, it can be said that a great deal of simple and complex research on X-ray imaging had started in the 1990s.

4.1. Digital X-Ray Systems

Digital X-ray systems represent a subset of digital radiography methods where images are obtained using irradiation with X-rays. An electrically activated image-capturing device allows for the conversion of X-ray images into an electronic form suitable for computer processing and archive storage. Digital X-ray systems in hospitals can be broadly classified as direct or indirect systems, depending on the technology used for capturing images.

When X-rays are incident on a photosensitive surface such as an amorphous selenium sensor, electric charges proportional to the X-ray intensity are generated, which can then be read out sequentially (Yoshihara et al., 2021). In indirect systems, typically, thick layers of phosphorescent scintillator convert the incident X-ray signals into soft-light signals which are then detected using a charge-coupled device or a complementary metal-oxide semiconductor sensor. Both types of systems can handle large-scale areas as however excellent systems are developed, digital X-ray sensors will be constructed in specific categories of fixed-sensor size, while the conventional X-ray units are more flexible in changing tube-to-detector distances and field sizes. To better suit patients and applications, many hospitals keep multiple types of systems, consequently creating growing issues of enormous management of large amounts of image data in multifarious systems

(Oborska-Kumaszyńska & Wiśniewska-Kubka, 2010). To improve efficiency, the monitoring tools of digital single-system, or multi-system-server architecture, for storage and recall of images based on international standards in DICOM formats are urgently required.

4.2. 3D Imaging Techniques

Computational tomography (CT) scans have several advantages, such as non-destructive evaluation, volumetric imaging ability, and preservation of three-dimensional data for re-visualization at later times. Therefore, CT has been extensively used in various fields, such as industrial product integrity testing, geophysical and geological research, agriculture, and security and safety controls (Kim et al., 2013). Conventional X-ray imaging is a projection imaging technique and creates two-dimensional information despite the three-dimensional nature of the observed objects. This single projection viewing leads to loss of important information inside the object and to difficulties in determining the existence or absence of defects and their proper recognition. Hence, there will be demands for high CT imaging performance: better spatial resolution that must be improved to examine small items, larger planar coverage to allow larger object scans without moving the object, wide dynamic range to allow inspection of dense beams, and increased frame rate without deterioration of performance, and improvements, such as faster processing algorithm suited for real-time CT imaging, proper display devices, and data storage devices suited for a large amount of data acquisition (M Martin, 2017).

Recent advances in three-dimensional (3D) imaging techniques are discussed, their importance, applications, and directions for further developments are elaborated, as well as considerations for their relevance in preclinical imaging. Image reconstruction techniques suitable for application-specific requirements, such as speed, accuracy, and enhanced functionality, are also introduced. Some typical examples that incorporate required design considerations and innovations are also reviewed. Storing volumetric 3D data acquired from 3D imaging systems would result in a large data storage burden. Compression is a process that uses specialized algorithms to translate and encode the data representation of 3D images into a smaller digital footprint. The storage space of CT-analyzed 3D images can be reduced by approximately 90% through interpolation compression. Wavelet transform, multiscale air compression, run-length encoding, and quadtree coding are other techniques used to compress 3D image data.

4.3. Artificial Intelligence in X-Ray Analysis

X-ray imaging technology has been utilized for various industrial uses for decades. X-ray tubes are used in the aviation industry, for example, to detect structural defects or foreign objects in airplanes. X-ray computed tomography system is also widely used in oil and gas industries to analyze welding quality. Furthermore, owing to its ability to penetrate the entire object, X-ray computed tomography scanners are frequently employed in industrial production. X-ray safety and security screening systems detect contraband for cargo inspection, baggage inspection. Moreover, X-ray computed tomography screening systems detect hidden threats in large and thick objects. Conventional X-ray imaging systems acquire a 2-D projection image or conventional X-ray computed tomography systems scan a three-D object slice-by-slice. The raw data is then processed using algorithms to reconstruct 3-D cross-sectional images by a computer. The 2-D projection or

3-D cross-sectional images are typically analyzed manually, and this is a daunting task. In addition, as the amount of scanned images grows, some objects of concern may be overlooked and missed. As a result, there is an increasing need for computer-based automatic analyses of these images. The recent development of computer vision and machine learning techniques has made it easier to assist or even automatically process X-ray images (Koenigkam Santos et al., 2019). Based on these techniques, several machine learning-based object detection, classification, and segmentation methods have been recently employed in X-ray image analysis.

Recent advances in X-Ray machine learning-based methods have shown promising detection, classification, and segmentation performance, and the trend is moving towards deep learning networks, given sufficient training sample sizes. First, the applications of X-Ray image analysis are provided, followed by discussion of preprocessing techniques and a comprehensive review of machine learning-based object detection, classification, and segmentation methods. Finally, the benchmark datasets are examined, and areas for future research are identified.

1.8 5. Radiation Safety and Patient Care

Radiation is a widely used tool in today's healthcare systems. It can be used for diagnostic and therapeutic purposes in collaboration with many medical devices, which are all known as X-ray equipment. Radiologic devices should be used with caution. Despite their advantages, radiation sources may have hazardous effects on living tissues. The unequal distribution of radiation can lead to exposed body cells producing reactions such as radiation sickness or even cancer after a long session of exposure. On the other hand, every clinician should remember that the responsibility of patient care and safety starts with him/her. Although radiation-inducing devices are potentially hazardous, they may be used in a manner that is efficient and safe for patients (Farzanegan et al., 2020).

Evidence-based management of pain and/or suspected bone injury in children should be a priority for high-level trauma centers. A clear imaging protocol based on individual risk stratification for CT scans to minimize the radiation dose is needed. Pediatric RIR guidelines should be used to monitor X-ray use in EDs and can be adapted for use in other diagnostic or therapeutic imaging departments. The key recommendation before deciding to perform X-ray imaging of children presenting with a musculoskeletal injury is to explore ways of examining and managing them without using this technique. In some instances, new educational tools or improved staff training are needed. When paediatric X-ray imaging is performed, an effective technical approach should be used along with ongoing quality assurance measures.

Radiology must take steps to minimize patient exposure within the framework of C-ARM procedures as radiation cannot be felt. Avoiding radiation cannot be achieved directly. Only controlling the apparatus or adjusting the exposure time is indirect exposure avoidance. Education, maintaining a distance from radiology, and using personal protection to stop direct radiation should be part of the procedure. There is no need for a large dose of radiation since the study purpose can be achieved with lower dose examinations using Polaroids. The physician in charge must watch-out for exposure time. Economic constraints such as paying low rent have a direct relation to dose and must be discarded. It is expected that the radiologist, personal, patients, etc., look after their safety in practice.

5.1. Understanding Radiation Exposure

Diagnostic X-rays include radiography, fluoroscopy, and computed tomography (CT). These procedures are performed worldwide within an overall medical system with limited resources and frequent personnel changes. A reliable and efficient radiological procedure requires a careful preparation of the local conditions (system check), organisation, personnel, and homogeneity (training). Therefore, these tests provide a longitudinal continuum of high-quality, affordable, and understandable imaging (A. Oakley & E. Harrison, 2020). Radiologists should furthermore describe clinical findings according to standard nomenclatures and lexicons to obtain a reliable and reproducible second opinion in case of an over-read test. This description can also help borderline cases to be transferred to improved levels of review.

All too often healthcare practitioners are met with concerns and opposition to receiving this important and common diagnostic modality. Many of these concerns and worries are unwarranted fears based on common but ill informed ideology versus current standard best practice understanding of the lack of risks from low-dose medical radiation that are in the exposure ranges of X-rays and CT scans. The routine use of low-dose diagnostic radiation has been established for nearly a century and has been intensively studied and evaluated for safety and efficacy. The early discovery of X-rays led to a plethora of scientific investigations of their physical properties, leading to numerous potential applications in medicine, but also in criminology and material science. The innumerable medical uses led to an abounding medical literature, with both basic studies in anatomy and physiology using X-ray imaging it was the emergence of radiograph, fluoroscopy and CT.

5.2. Best Practices for Patient Safety

Patient safety in radiology departments is of utmost importance as dose optimization helps to lower the risk of radiation-induced health problems. The application of the ALARA principles is essential in this regard, especially for pediatric patients (Lucia Nana I Ebisawa et al., 2009) (Farzanegan et al., 2020). The effectiveness and appropriateness of measures for improving diagnostic reference levels depend on an elaboration of methodology. Actions toward dose reduction must be based on a review of patient safety practices already in place at the facility and careful selection of clinically relevant audits, special investigations, or remediation steps. Dose optimization must then be implemented across a wide range of department and machine types. All measures must be carefully verified, with the facility’s stated position on the issues updated as appropriate. Patient protection policies should clearly differentiate between approaches to patient safety that apply to patients receiving non-ionizing radiation versus those receiving ionizing radiation.

Daily, weekly, monthly, or quarterly quality control measures, including serviced machines, helped to center patient safety on operators. With respect to image quality and dose, the radiologist had a significant role in patient safety measures. This encompassed activities showcasing the effectiveness of patient safety measures to the public and presenting their role in film appreciation.

Actions promoting activities that focused on reducing the risk of incidents in digital modalities but also improving current modalities assured the concepts of patient safety. Radiographers concerned with acquisition technique optimization and referring physicians dealing with justification and the adoption of alternative modalities were essential for efforts toward a safer and more sustainable analysis. Technologists trained in DR system design rules and the detailed operation of digital scanners, scanners, lasers, ultrasounds, and modalities producing ionizing radiation were also essential for patient safety.

5.3. Regulatory Guidelines and Compliance

X-ray equipment and other imaging facilities must comply with regulatory guidelines and hardware specifications based on specific governmental directives and recommendations. Good manufacturing practice, user specifications, and compliance with the radiation protection regulation greatly contribute to prevention. The preventive maintenance use of appropriate diagnostic tools need to be standardized for all manufacturers. Almost every country, which has had X-ray equipment installed, has some legislation on the operation of those equipment and for protection against X-radiation (Lucia Nana I Ebisawa et al., 2009).

In most countries, sold out equipment need to be licensed. The country agencies concerned with licensing procedure under the appropriate governmental department issue regulations. The licensing guidelines prescribe as a minimum requirement, for each X-ray facility submission of documents by the applicant in six aspects: 1) technical description; 2) safety device; 3) engineering design; 4) main control unit implementation; 5) conspicuous warning signs; and, 6) cooperation with radiation protection service station to ensure protection. For mammography equipment and computed tomography; additional specification or documents on patient dose as legally required may need to be submitted prior to, or after installation.

At continuous X-ray facilities, or, newly commissioned equipment X-radiation levels for the first few weeks of operation need to be posted at wall surfaces meters away from the primary beam path. Acceptance tests need to be carried out after commissioning; regular tests are made and records are kept. At shop floor areas, warning signs shall be conspicuously displayed. Primary beam protective barriers need to have value tolerance of 0.15 mSv/week and 1.0 mSv/year. Secondary barriers should not exceed 1/20 of the primary barrier levels. Users also need to fully comply with manufacturers recommendations. At public areas, evidently shield walls or curtains should be installed with control rooms at a certain distance from the primary beam sources. As far as it is technically possible, bypassing, disabling, and modification of treatment unit interlocks shall not be permitted.

1.9 6. Maintenance Best Practices for X-Ray Equipment

Maintaining X-ray equipment in top condition is crucial for achieving optimal image quality and patient safety. As X-ray systems play an increasingly important role in healthcare, the use of digital detectors is rising rapidly. Consequently, the traditional film-based systems that served as an industry standard in the past are slowly disappearing. Therefore, understanding which steps can be taken or should be taken is essential to retain quality and reliability in the new digital era. From changing light bulbs to performing a quality control check, this section will discuss routine maintenance procedures, troubleshooting common issues, the importance of calibration, and quality control. Routine maintenance of X-ray equipment by trained staff is one of the most important factors in optimizing the system's lifespan. Although some of the maintenance procedures are incredibly straightforward, it must be ensured that they occur regularly. Secondary protective shields can become dirty over time, obstructing the view of the X-ray beam. If these shields are dirty and the staff cannot view the beam correctly, no one can ensure that patient protection is optimal. Two tips to prevent dirt build-up on secondary shields is the correct placement of the shields and the use of a small barrier to block the X-ray beam during the repositioning of the shields. The optical density of the secondary shields should also be checked regularly, which can be done using a radiation dose prediction program. Troubleshooting common problems is essential for the maintenance of X-ray equipment. The most common error resulting in the loss of detection and imaging in digital systems is the production of images with multiple lines. This can be solved by ensuring that the imaging plate's edges do not touch the input surface. Loss of image acquisition and scaffolding due to the integrity of the ionization chamber can result in image halo processing or incorrect dose calculations on a digital treatment planning system. A common error resulting in poor image quality is a missed parameter with calibration verification. A picture of the X-ray tube and the copper filter should be taken to check whether they are working correctly and if the parameters are still consistent. Once a quality assurance method is implemented, a quality control (QC) check should be performed regularly, ideally weekly. This is crucial for ensuring optimal image quality and patient safety. Regardless of the mode of operation, a QC check should be performed regularly that influences the parameters of the most critical stage of the process. If robust quality assurance is followed, the whole X-ray chain will be protected, and the robustness of durability will be retained.

6.1. Routine Maintenance Procedures

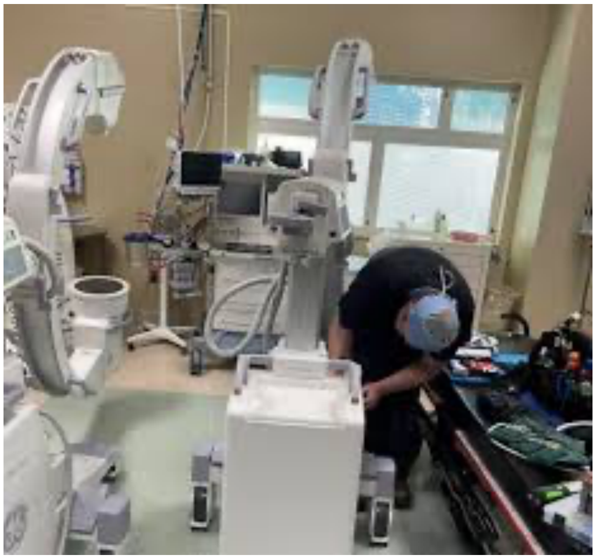

Fig1: routine X-ray machine maintenance

Preventive maintenance is a procedure performed on an X-ray machine to reduce the likelihood of buying a costly repair service and service trap. Preventive maintenance consists of X-ray machine maintenance performed regularly to keep it running efficiently and prevent any irreparable breakdown. The most common form of preventive maintenance on X-ray is keeping the equipment clean, including the unit itself and the room. The following procedures should be performed regularly:

1. Dust and wipe off the exterior of the X-ray unit with a soft damp cloth. The dust particles absorb the heat and cause the machine to overheat. This creates actuator failure and cascades to prompt the service trap.
2. Inspect the integrity of the electrical power supply for the X-ray equipment. The X-ray machines have a power tolerance of about 10%. Use a clamp ammeter to measure this.
3. Test the touching grounds. Test the X-ray equipment with an insulation resistance tester. The ground point should be close to 30-ohms resistance.
4. You must check the integrity of the X-ray shielding and protect against leaks. Observing the integrity of the lead lining and lead-glassed window ensures that no unwanted radiation escapes the fixation station. A qualified radiation safety specialist must perform the leak tests, and a physical barrier must be put into place if there is a failure of the tests. An obvious other immediate conception is to post a sign at the area. This aware of outsiders of X-rays.

There are fumigants and disinfectants that destroy the films. Films can be damaged by blasting something on the surfacing or staining with liquid that would stop the reaction. Empty boxes of films are recyclable, and many companies use them to package and ship several products. Make sure the boxes don't leave the workplace without being recycled. It is worth putting out an X-ray junk box for the bulk storage of the boxes. Generally, X-ray film boxes are made of such creature comforts that many recyclers wouldn't like to take them. They'd like a box to hold the recycling, so even the trade-offs are pretty favorable. An interesting point is that the films are enveloped in black plastic bags before going in the box. These bags should go to a dumpster because they're not recyclable.

If a tech takes the time to recognize what is going on with a machine, it may save them from a service trap later. There should be a curve explained by the maintenance department that covers some of the problems that can ordinarily be noticed before a technician is called and some solutions that a technician might try. The initial four examples mentioned on the maintenance card can apply any time a piece of equipment is down, but some other factors can come into play during off hours. The major points that come under the most scrutiny during a check are that nothing is caught in the film path and that all access doors are closed. This knowledge can go a long way toward having a good startup after hours. It may help to arrange the check points in ascending order of complexity level.

6.2. Troubleshooting Common Issues

Issues with patients being barred from X-ray examination facilities or leaving them unattended appear to center on motivation and boredom. While patients wait their turn, particularly if they're holding aching tissues, they should not be left to their own devices but instead watched over by staff. Patients should never be compelled to receive X-rays, and if they refuse they should be signed off without X-rays and thoroughly advised in writing about the consequences of their refusal (Y. Sungita et al., 2006).

X-ray room doctoring and personal protection have an importance that far surpasses the simple health and safety duty of care. Each unit of health and safety training pays for itself in lower absences from accidents and routine illnesses, lower staff turnover, greater productivity, higher productivity standards, reduced losses to theft, vandalism and unattended units, greater goodwill with the public and lower litigation costs (Lucia Nana I Ebisawa et al., 2009).

The general impression of diagnostic X-ray installations is less favorable than it should be. Also, it is apparent that equipment security can be improved vastly, that this will not cost much money and that a dentists' returns for the X-ray investments he makes are inextricably linked to his investment in larger installations. It is suggested that most of procedures recommended can be done as works of excellence.

6.3. Importance of Calibration and Quality Control

With the benefits of high-quality diagnostic X-ray images being well known in the detection of disease and even guiding therapeutic procedures, it is essential to have in place, good quality control (QC) programs to ensure the production of such images (Y. Sungita et al., 2006). The risk to individuals from the X-ray equipment used in medical diagnostics is considerably small compared to the benefits that accurate diagnosis and treatment can provide. Many users do not understand the basic principles of radiation protection and how to minimize the associated radiation risks to patients with the current rapid increase in the number of X-ray units in Tanzania. Despite the understanding of the importance of quality maintenance of diagnostic X-ray machines and the medium and long-term availability of spare parts, many users still operate their equipment without adequate QC and maintenance. The importance of having quality control (QC) policy, strategy, and QC procedures for all QC items and tests is compromised under these conditions (Lucia Nana I Ebisawa et al., 2009). Irrespective of whether a nation uses or intends to use objective assessment of radiological images and international image quality guidelines, unifying X-ray-imaging practices nationally and internationally for clinical, research, teaching, regulatory, and other purposes could not be realized without the notion of establishing a functional QA and QC regime for it. Current proposals, guidelines, and peer-review processes on X-ray imaging quality require assurance that minimum diagnostic quality would be maintained in clinical practice in order not to unduly expose patients to ionizing radiation. It is not solely a problem facing developing nations either. There needs to be starting points to build quality into developing medical X-ray imaging services. Accordingly, the current status of the various components of the diagnostic X-ray services (equipment designs, supply, ownership, and procurement), personnel training, maintenance and servicing resources and practices, and QC in Tanzania is surveyed, based on which proposals in the form of generic QC improvements and policy recommendations are presented aimed at overcoming the glaring deficiencies therein.

1.10 7. Future Directions in X-Ray Technology

Since the discovery of X-ray in 1895, radiology has opened new technical developments in medicine, with a broad range of clinical applications. The clinical demands for optimal imaging, maximum patient safety, and cost effectiveness have provided the push for new innovations, with the consequent further developments of computed X-ray imaging systems in the broadest meaning, that is, including fluoroscopic and stereotactic systems, CT scanners, etc. Reducing doses while obtaining the same performance (i.e., understanding noise and artifacts, correcting for beam hardness, adjusting parameters to prevent aliasing), as well as the availability of new technologies seem to allow further radiological progress and considerable dose reductions.

The initial idea of integrating the fluoroscopic unit into a radiographic unit appeared in the late 1940s, realizing a monoblock unit capturing the full set of any conventional projection images instantaneously via a very long imaging plate at a single rotation of the tube, and increasing the speed of acquisition and lowering the dose considerably compared to sequential radiographic units. The positive influence on tube loading and the image storage in conventionally processed films or in a separate x-ray camera provided for further technical improvements. The approach to digitization and storage of images on stimulable phosphors or directly onto CDs has been developed, allowing the storage of the image on a laser-disc behind the console. Digital image transmission and accessively increased efficiency has opened the road to screen-based digital display.

With the introduction of digital photographs in 1975, further optimizations appeared, such as image compression, data security, etc. The two-dimensional digital image now is ready for further manipulations, adjustments, and more rapid interpretation.

It is likely that many of innovations developments with respect to speed, quality, accuracy of diagnosis and capacity will be discovered soon. Accessing Web on a TV is a recent development of non-geographical limitations. On the other hand, imaging of small anatomical structures is ongoing, e.g. arteries of 0.5 mm, including the heart. Robotic interventions for biopsy, theragnosis, guided therapy, etc. will set off a build upon wave in the near future. While megatrends mentioned above were all focused on technical developments new demands are arising.

Functional and quantitative imaging has moved item number one with application-specific PACS (Kim et al., 2013) with built-in support. These demands stemmed from the era for evidence based medicine. 7T scanners, high positional precision (0.1 mm) multi-stages and improve resolution are ongoing.

7.1. Emerging Trends and Research

Recent innovations and refinements to the technology behind radiography have produced better results through faster and lower dose techniques. Notably, the importance of computed radiography systems (CR, digital imaging and communication, DICOM, networks, digital displays, etc.) has increased. However, with the large increase of digital technology comes new responsibilities and questions. These high-tech marvels need regular status checks and quality assurance (QA). Even before examination, important system characteristics, such as processing speed of CR systems or response times of monitors, must be checked regularly. The entire imaging chain should be tested on hire resolution test objects. All results are recorded and evaluated. It is essential to apply moderate automatic performance check daily before starting the examination. Cheap testing devices are available for this purpose; most manufacturers offer simple inexpensive devices as accessories. Increasing sophistication of systems leads in turn to a growing number of parameters whose status should be monitored regularly. Though high radiation doses were once a concern in fluoroscopy, low dose investigation has been enhanced by remarkable innovations (Kim et al., 2013). Undoubtedly, intense research is still ongoing in many directions—refinement of secondary detectors, new approaches like real-time dosimetry with an avalanche photodiode, and new algorithms for the retrieval of the point source location through the constant curling, filtering, or inversion of the data set. Models of the patient dose cubic, which could complicate the design of the detectors, are also being developed. The revolutionizing impact of this research will probably first affect industrial radiography, which often profits from lower prices or simpler systems than clinical X-ray imaging. It is vital that all countries adopt similar practices in their own industries to realize the maximum benefits from this advance.

7.2. Integration with Other Technologies

Several new technologies have recently emerged, including Health smartphones, mobile health and personal medical devices, worldwide networks and big data, and data visualization tools. Mobile health can be defined as medical and public health practice supported by wireless devices. Personal medical devices include health monitoring equipped on portable devices such as smartphones, bands, arms, and watches. Data visualization tools intend to help users monitor their large, diverse, and complex data intuitively. These new technologies form an ecosystem to support health management. Based on this ecosystem, the mHealth industry has caused rapid and large-scale paradigm shifts in healthcare, shifting healthcare and its market share from hospitals to individuals. As an unintended benefit, the public is rising in health awareness and knowledge. With its systemization, standardization, and enhancement, the evolution will likely advance to another megatrend in the near future. Integrating genetic information into a person's health management is a promising approach for early and precise disease identification. The synergy effects from the integration of these two factors will transform diagnosis into disease forecast, preventability, and curability of diseases.

7.3. Potential Impact on Healthcare

As the pressure mounts on healthcare systems to cater for an ever-burgeoning patient population, an exponential increase in the demand for diagnostic tests, especially imaging examinations, is paralleled by an increase in the need for analyzers to monitor the efficacy of the maintenance performed on these imaging modalities. Consequently, there is a critical requirement of an efficient informative system to allow the monitoring of performance indicators of diseases, diagnostic techniques, operators, and organizations. This elaborates upon the development of a descriptive, efficient X-ray diagnostic performance monitoring system to analyze the compliance of X-ray exams with reference X-ray images, quality annotations, and their respective imaging performance indicators which are automatically inferred by an X-ray analysis algorithm. Based on a rigorous observability analysis, the main performances at organizational and service levels are identified and evaluated against their targets based upon input scenarios during a considered estimation window. Furthermore, a novel X-ray diagnostic performance monitoring scheme based upon a built-in automatic knowledge manager is also conducted to optimally configure a performance monitoring system covering new X-ray systems, protocols, or procedures (Culpan & McIntosh, 2017). X-rays are one of the most important tools in healthcare. Understanding the evolution of X-rays and their applications in the medical field is essential in order to keep up with the rapid pace of innovation. Healthcare workers still depend on them for patient diagnosis, clinical imaging, and testing. Although they are one of the most dangerous sources of ionizing radiation when used incorrectly, they are critical in the identification, diagnosis, and treatment of various diseases. X-rays demand further adaptation in response to the increasing volume and complexity of high-dimensional and multi-source data (Lucia Nana I Ebisawa et al., 2009). Most radiologists' workloads consist of reviewing the results of X-rays taken a day or two prior to examination. However, overwhelming additional business and treatment data raise the risk that some detrimental findings may not be reviewed, a situation that will cause unexpected injuries and even litigation. Automated detection systems such as computer-assisted detection/diagnosis (CAD) have been developed for breast MRIs, while computerized tomographic (CT) colonography systems are commercially available. Nonetheless, automated detection of abnormal X-ray film remains a demanding task due to the variations in patient position/projection, view angles, equipment, exposure settings, and inter-image interference from other equipment or orthopedic supports.

1.11 **8. Conclusion**

In summary, diagnostic imaging is fundamental for making a trustworthy diagnosis and achieving effective treatment. X-ray equipment has developed from using film and cassette systems to computer software processing and digital imaging over the past decades. The most noticeable names in X-ray imaging innovation include the radiographic direct image receptor system, flat-panel detectors and post-processing software. All the equipment and new systems demand more precise and visible duties for overall safety and general diagnostic awareness. Daily quality control checks have to be implemented for the general detection of any deterioration and signal interference with the imaging quality. Great importance should be placed on the ancillary systems in the maintenance of equipment.

An engineering view on radiology operation inspections, especially from a physics perspective, was also introduced to illustrate the details and support an effortless gap between clinical and engineering ideas (Kim et al., 2013). The dissemination of the knowledge is mandatory to raise awareness of all the possible detection and waste of the clinical systems without proper maintenance and grading.

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