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Implementations of PACS and Teleradiology Systems: An Updated Review of the Literature

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Abstract: Radiology by its nature is intricately connected to the Internet and is at the forefront of technology in medicine. The past few years have seen a dramatic rise in Internet-based technology in healthcare, with imaging as a core application. Numerous Internet-based applications and technologies have made advancements of wide steps into medicine, and for radiology it is more effective than in other clinical specialties.
Picture archiving and communication system (PACS) is a computerized means of replacing the roles of conventional radiological film: images are acquired, stored, transmitted, and displayed digitally. When such a system is installed throughout the hospital, a filmless clinical environment results. Teleradiology has made using the Internet explorer possible to access to images and patient findings, to browse, view and write radiological reports on any computer in any location.
Teleradiology can provide services in rural areas where there is no a specialized radiologist at any time. As well, in developing countries or where there is radiologists shortage in any country. PACS underwent a rapid development for the past 15 years, influenced by new technologies, faster network connections and other technical improvements, aimed to replace former film based medical images.
This article aims to clarify the terms, roles, importance's & Implementations of PACS & teleradiology.
Keywords: PACS, Teleradiology, Imaging Informatics, Filmless Radiology.

1 Introduction

Radiology by its nature is connected to the Internet and is at the forefront of technology in medicine. The past few years have seen a dramatic rise in Internet-based technology in healthcare, with imaging as a core application. Numerous Internet-based applications and technologies have made advancements of wide steps into medicine, and for radiology it is more effective than in other clinical specialties [1]. Teleradiology can provide services in rural areas where there is no a specialized radiologist at any time. As well, in developing countries or where there is radiologists shortage in any country [2].

PACS has become an essential element in many radiology practices. To use it most effectively, radiologists must understand the technology underlying the digital environment. It is also helpful for radiologists to have additional software that expands the functionality and efficiency of PACS [3].

Users of a PACS include technologists, image library personnel, radiologists, physicians/clinicians, and nurses [4].

PACS & Teleradiology have a great role in more exploration and identification of new emerging diseases such as COVID 19, helping to analyze all its imaging criteria and comparing more number of studies and following cases in easier and quicker manner, that enable radiologist to acquire better results [5].

2 Imaging Informatics

Informatics is the study of how information passes from person to person and from place to place and how information is processed. Imaging informatics (previously called radiology informatics) is sometimes thought of as the study of how images get from one place to another, but in reality imaging informatics has a much larger scope. Imaging informatics is a distinct subspecialty of radiology that aiming to improve the efficiency, accuracy, and

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reliability of radiologic services within the medical field [3].

User acceptance is a critical factor in the success of healthcare IT adoptions. The best and most expensive IT system will be ineffective if it is ignored or resisted by its users [4].

The scientific researches of medical imaging informatics – which seeks to manage and apply biomedical imaging information – has grown significantly in the past 25 years, as shown by the number of publications indexed each year in PubMed from 1990 through 2014 [6].

3 Teleradiology

Teleradiology is a form of medical information system, which requires the use of telecommunications systems in the form of satellite, internet, mobile phones, computers etc. for the exchange of data, images, video, audio or other radiological information in order to secure radiology services between remote locations [7]. In 1948, the first transmission of radiological images was made in the USA over telephone lines between West Chester and Philadelphia (Pennsylvania), at a distance of 24 miles. Based on this experience, the Canadian radiologists created the first teleradiology system in 1950 as mentioned in Kayser K. et al., 1990. As long as the image is electronically collected, stored, and communicated to another system successfully, the productively of work will be increased, diagnosis will be precisely performed, the patient will be treated accurately and quickly, and health services will be improved [13]. The use of teleradiology in war zones dates back to the wars of Afghanistan and Iraq. However, the practice of teleradiology during the Syrian crisis presents a new challenge to the international medical community given the repeated attacks on medical personnel and health-care facilities [8].

The United States National Aeronautics and Space Administration (NASA) successfully pioneered the first extraterrestrial application of teleradiology by establishing a real-time link between experienced sonologists in Johnson Space Center, Houston, TX, who guided the crew aboard the International Space Station (ISS) in performing sonographic evaluation of shoulder integrity and the first extraterrestrial ultrasound examination of the genitourinary tract and the retroperitoneum in real time. The positive outcomes from these projects prove that teleradiology has incredible potential both on Earth and beyond. In the future, the remote delivery of image-guided therapeutic procedures using robotic assistance will become a reality [6].

4 PACS

The availability of a teleradiology system is for all the time (24/7/365) which truly improves the patient care. PACS & Teleradiology removed the need for patients to travel anymore to seek for a radiology expert diagnosis and opinion [2]. Today, Japan is one of the leading countries in the world when it comes to the use and development of Picture Archiving and Communication System (PACS), while the Kyoto University has developed the first telemedicine system to transfer images in High-definition television (HDTV) [9]. "PACS" term was coined in 1982 shortly before the First international Conference and Workshop on Picture Archiving and Communications Systems in California. Since then, there were many conferences concerning PACS technology, e.g. the meeting of the Japan Association of Medical Imaging Technology (JAMIT) since 1982 and the EuroPACS since 1984 [10].

4-1 Two Main Types in Designing PACS

"centralized" or "distributed". Centralized PACS stores images on a central server and needs high-speed transmission hardware to transmit the images to PACS workstations. Distributed PACS routes the images from the imaging device to the appropriate work-stations based on rules reflecting typical workflow. For a distributed PACS system to be effective, the work must be predictable so that images can be sent from the imaging device to the correct workstations [6]. In summary, PACS workstation computers are not that different from high-performance desktop computers used in other industries except for their video adapters and displays [11] .Server is a computer that facilitates communication between and delivers information to other computers. A server does not usually have a person working at it; the server responds to requests from other computers on the network rather than to commands from a person. Clients are computers that rely on servers to supply them with information. Radiologists will generally interact only with client computers, such as desktop personal computers. A workstation is a client computer that is dedicated to a particular use [3].

5 Securities

Network security is a topic that receives vast amounts of attention in finance and industry because of the threat posed by data loss, theft, or corruption. Despite the passage of the security regulations in the Health Insurance Portability, network security remains one of the weakest aspects of many hospital infrastructures [12]. Using of PACS in different Arabian hospitals & countries is vary in time , for example The PACS was first introduced in the radiology department of Mubarak Al-Kabeer Hospital in Kuwait at 2004 [13].In 2009, one-third of PACS

installations in the region took place in Saudi Arabia [4]. While for example The Hammersmith Hospital in West London has been operating as a totally filmless hospital since March 1996. Films are printed only for use at outside institutions [14]. User acceptance is a critical factor in the success of healthcare IT adoptions. The best and most expensive IT system will be ineffective if it is ignored or resisted by its users [15].

6 PACS Economics

The greatest economic role of PACS & Teleradiology is saving lives. cloud-based workstations and mobile applications allow radiologists and physicians to access diagnoses, reports, and images no matter their location via PACS. Hundreds of scans can be analyzed and reported in as little as 8 minutes using this technology, This allows both radiologists and physicians to provide proficient and excellent care for the patient while reducing the risk of spreading or contacting COVID-19. Many radiologists have begun to view images at home, dictate notes with voice recognition and sign off on reports electronically. COVID-19 case images can be analyzed remotely via teleradiology to help determine courses of treatment for infected cases [16]. PACS can increase the productivity of a radiology department and lead to positive financial outcomes, depending on various other factors such as the vendor used and location of the radiology department. However, careful financial consideration must be applied [17]. Using PACS in hospitals has innumerable benefits at various levels. At the management level, this technology has direct implications for cost reduction, rendering the film production process redundant. At the departmental level, the technology enhances productivity, as all tasks are performed digitally and swiftly; at the clinical level, image interpretation and diagnosis become more precise and accurate. For these reasons, health care organizations are increasingly adopting PACS in their clinical radiology departments, despite the high costs, to benefit from the full advantages of using the technology [13]. An insufficient number of work stations in PACS system could be dangerous for its function sufficiency, while a higher number of them represent a waste of economic resources for the organization [18]. Major categories of costs of PACS are one time cost & recurring costs. One Time Costs: Are costs that are paid once over the useful life of the investment include payments to the system vendor for cost of Hardware (servers, computer workstations, or LCD monitors) and software (operating systems). Recurring Costs: These costs are incurred as a result of operating the new system. internal incremental operating costs such as additional staff to support the system and maintenance[19].Telereadiology services now are more and more extended .Extension of teleradiology services to an unexpected sites e.g. Cruise ships, may needs no extra costs in the radiology department at the tertiary hospital , It did not need additional servers, computer workstations, or LCD monitors [20].

7 PACS & FUTURE

PACS & teleradiology is not the final target in advancement of the field of medical imaging & informatics. Knowledge regarding the automated analysis of medical images has spread rapidly. Radiologists are among the first physicians to be directly affected by advances in computer technology. Over the last decade, there has been growing importance of data analytics as well as growing appreciation of the potential usefulness of so called big data in transforming personal care, clinical care and public health, and related research [21]. PACS is now not only a service to be supplied to hospitals & medical units only, but it extended to involve a places wasn't expected to be part of this system , either it is a motile places such as travelling ships or beyond [20]. USA federal government recognized the role telehealth technology during the coronavirus pandemic, It allows beneficiaries to receive a wider range of services from their doctors without having to travel to a healthcare facility. This regulation enhances patient care and restrict further COVID-19 spread. Teleradiology services can become a major solution to the COVID-19 crisis and beyond. Making these types of services more accessible to radiologists across the United States will give more protection and diagnostic productivity. More reads will be analyzed and diagnosed while allowing radiologists to have precautions in working remotely to reduce viral exposure. Teleradiology isn't the only solution to the COVID-19 crisis, but it can be an important step as it becomes more common throughout our health care systems [16]. Big Data is the term given to datasets that are incredible large, with sizes and complexity beyond the ability of traditional data processing applications to deal with. Data is everywhere, generated by increasing numbers of mobile devices, computers and sensors. Machine Learning (ML) is a subfield of AI that gives "computers the ability to learn without being explicitly programmed" Artificial intelligence (AI) is defined as "the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception and decision-making" [22]. Artificial intelligence (AI) will bring changes to the professional life of radiologists, just as it has modified many other aspects of our lives. Since the invention of electricity, the internet, and most recently AI, general purpose technologies have made it possible for societies to progress and improve their quality of life [23]. Computer-Aided Diagnosis (CAD) are a powerful tool, being able to help in interpreting imaging findings, reducing interpretation times and especially in minimizing errors or misinterpretation [22]. Advances in the field of computer vision have begun to produce improved sensitivity in the detection of tumor in histo-pathological specimens when compared to human analysis [24]. An

example of a radiological big data solution, known as PACS mining, was presented by Re et al. at ESR Vienna 2017 , where an algorithm designed to automatically extract bone data from computed tomography (CT) scans in the PACS found an inverse relationship of bone density to increasing age. While the result is no surprise, it is an example of how patient data from one million CT samples can be post-processed by a single user in a clinically feasible time frame [25]. The implementation of AI techniques in medical imaging has particular challenges. Diagnoses are not always confirmed; classifications and concepts are not always unanimous, nor are they eternal. The structures of the human body present great variation in terms of their normal dimensions and textures, such variation potentially masking pathological conditions [26]. Artificial intelligence must be guided by general human intelligence. For example, a radiologist will intuitively recognize a swallowed foreign body on radiograph as a coin, while the AI will merely detect an anomaly. it will be the task of the radiologist to interpret the findings in a global understanding of facts which will be intrinsically hidden in-between different specialties. Accurately diagnosing a new disease by AI also takes time as it requires millions of data sets to reach an acceptable level of accuracy and biases in data could lead to skewed results [27].The first annual Conference on Machine Intelligence in Medical Imaging was held on September,2016, in Alexandria, Virginia, under the auspices of the Society for Imaging Informatics in Medicine (SIIM) [28]. PACSs are based on digital communication, and information technologies have revolutionized the practice of radiology, and the entire medicine during the past 10 years [29].

To summarize the relative disadvantages of teleradiology are; expenses of installing, maintenance, technical issues, legal aspects of a teleradiology system, medical license and certified practitioners in different countries, training tele -radiologist is required. To improve teleradiology, many asking to decrease teleradiology cost, train more Radiologists and network experts on teleradiology systems, decrease the number of teleradiology systems breakdowns, start accreditation programs for teleradiology globally, allow more access for previous studies and patients' histories, and allow more communication between tele-radiologists and local clinicians for better understanding. Teleradiology is a huge problem-solver, but many issues need to be solved first to allow teleradiology positive impact on patients' lives worldwide [2].

8 Conclusions

PACS can provide great services for either radiology department or other emergency departments in hospitals where it implemented, saving lives, time, efforts & money, serving in better archiving, teaching, tele-training learning, and more than one opinion consultations and providing more data for better researches. PACS system has a great benefit as explained and may be more but when human factor use & maintain it probably, while it can lose most of its value, or completely destroyed if they did not consider this values and applying it strictly.

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