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RADIOLOGY INFORMATION SYSTEM

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The development of information systems in health care is approaching the process of integration of various systems used in a single computer so that we witness today the omnipresent idea of merging the functions of the clinical-hospital (CHIS) and radiology (RIS) information system. Radiological Information System (RIS) is a technology solution to complete computerization and modernization of the work of the radiology center, and transition from film to paper and ful electronic management and digital recordings. RIS creates the digital radiology center where information is always available at the right place and at the right time. Within the realisation of RIS, it is necessary to follow the standards and systems relating to the specific RIS, which are: DICOM (Digital Imaging and Communications in Medicine), PACS (Picture Archiving and Communication System), HL7 (Health Level Seven). The relevant links of modern RIS are teleradiology and mobile radiology. The authors conclude that the introduction of RIS, HIS and other information systems are reflected in the automation, reduction of possible errors, increase in diagnostic and therapeutic quality, lower costs for materials, the increase in efficiency, saving time and others. *Acta Medica Medianae 2012;51(4):39-46.*

Key words: *Radiology Information System, hospital information system, PACS, DICOM, teleradiology, mobile radiology*

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Introduction

Radiological center within the hospital information system (HIS) requires a special and its own information system - radiology information system (RIS) (1-11).

Radiology information system (RIS) requires a developed infrastructure (network), hardware and software (3-7). The reason for this lies in the facts that radiology represents a pictorial branch of medicine, that radiology uses images in daily work, that radiological images are in a digital form, that radiological images as files contain a large number of data, i.e. bytes, that X-ray machines are digitized, that examinations by computed tomography (CT), magnetic resonance imaging (MR), mammography, ultrasound (US), digital X-ray machine and other radiological imaging devices give radiological images in digital format of 1- 600 MB, sometimes over 600 MB.

In the implementation of RIS (Figure 1), it is necessary to follow standards and systems relating to the RIS specifics, such as: DICOM (Digital Imaging and Communications in Medicine), PACS (Picture Archiving and Communication System), HL7 (Health Level Seven), teleradiology, mobile radiology, etc. (11-22).

In RIS, as in any other information system, a special attention must be paid to the security and confidentiality of data.

RIS implies a large disk space necessary to store a huge quantity of data in the form of digital media, as well as the fact that the radiological examinations of patients must be kept for a certain time in different formats, which makes the speed of access to the data various, depending on the "age" of review.

RIS must not slow down the functioning of radiology center, but it should ensure better patient flow from every part of the organization unit, so that access to the data storage in RIS must be fast and easy.

In parallel with the development and integration of RIS occurs the development and integration of teleradiology, which is a powerful tool in the diagnosis, consultation, education of medical students, doctors and paramedical staff, research, administration, management, planning, promotion of public health.

National Alliance for Local Economic Development (NALED) in 2012 presented the pilot project "Introduction of telemedicine in eastern Serbia," supported by the company MSD, which is the initiator and the original creator of introducing telemedicine in Serbia. On that occasion, the participants of the project - Clinical Centre Niš, Health Center Boljevac, Health Center Zaječar and NALED, signed a cooperation agreement (1).

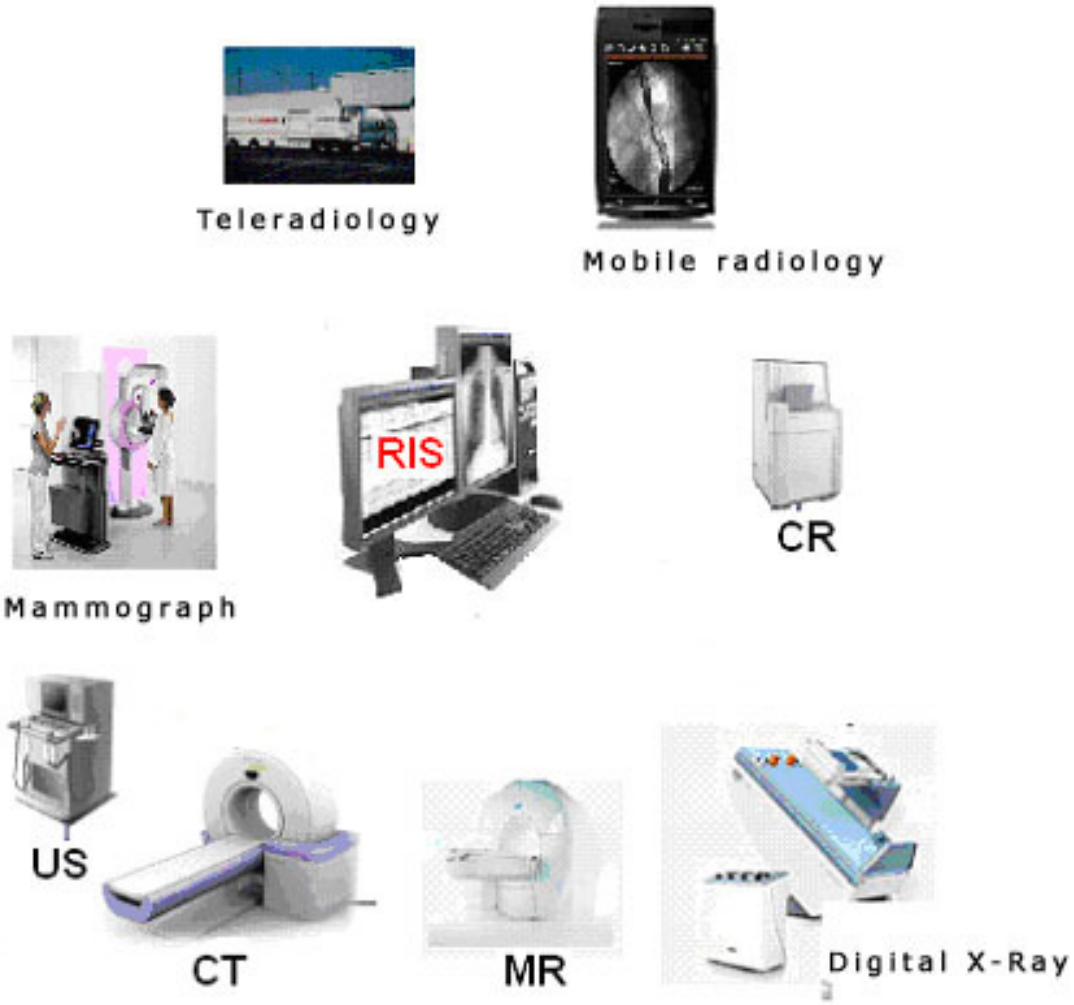

Figure 1. Radiology information system (RIS)

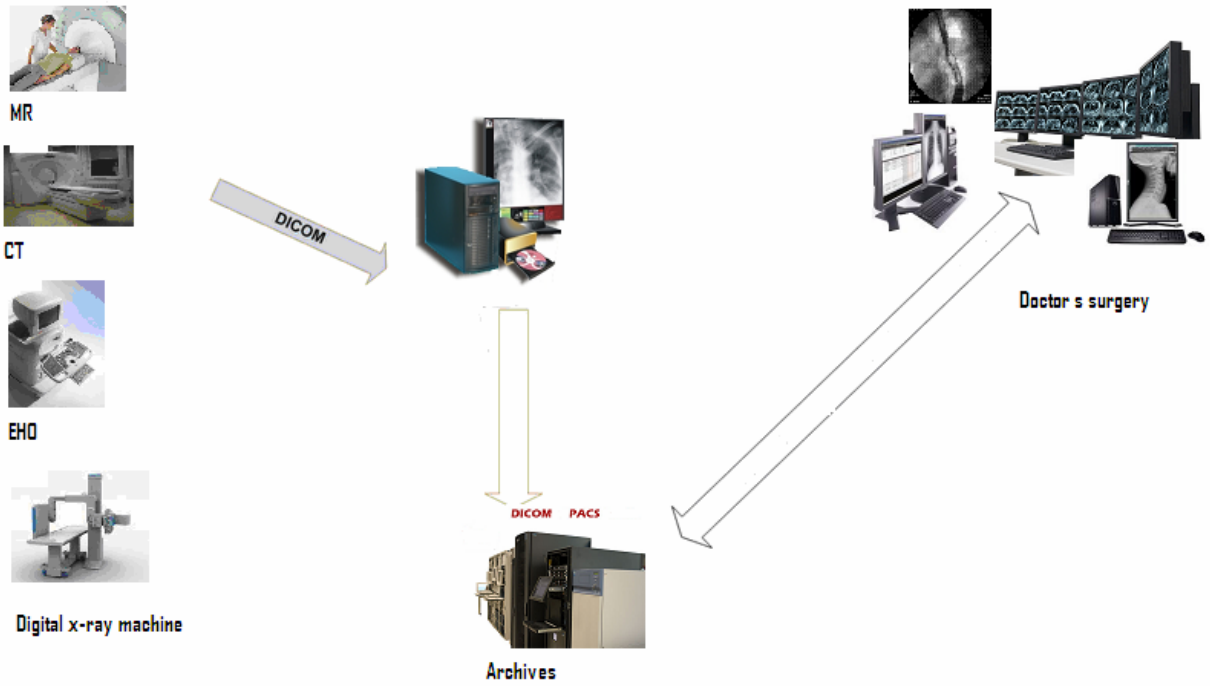

Figure 2. Picture Archiving and Communication System (PACS) network

Integration of RIS and HIS

The imaging center is a part of the hospital, thus is the RIS a part of the HIS. As the system is integrated with HIS, the information that RIS and HIS exchange would be: the patient registry (new patient data, updating data of existing patients), examination of the patient (which type of review is requested, who requested radiological examination, the diagnosis, urgency, etc.), the status of examination and reports (radiological findings, report of a specialist, laboratory findings, etc.), delivery of findings and distribution to patients, synchronization of data in HIS and RIS (methods of examination, doctors, departments, etc) and other pieces of zinformation.

In order to achieve an integration of RIS into a unique HIS, it is necessary that information systems communicate by exchanging messages (information) according to HL7 (Health Level Seven) standard (10, 18,23,24).

HL7 (Health Level Seven) standard

HL7 standard enables the exchange of medical information between different information systems of healthcare organization units within one hospital (cardiology, radiology, laboratory, eye department, otolaryngology, surgery, etc.) irrespective of the written program language and the platform they are realised at (10,18,23,24).

HL7 is not a software application, but a standard that includes thousands of pages that contain detailed explanations, which presents the concept of the standard, allowing analysts and programmers to implement it technically.

In the OSI reference model (International Standard Organization), communication between software and hardware is divided into seven layers. HL7 standard is primarily focused on issues and problems that occur on the seventh application layer (level 7). Data, time of data exchange and communication are shared at this level, where errors between certain applications can be seen. However, the needs of protocol related to lower levels of the OSI model are sometimes mentioned in order to assist in implementation and understand the context of the standard.

PACS (Picture Archiving and Communication System)

Picture Archiving and Communication System (PACS) is a modern system for image archiving and communication. It is designed as a computer system for paper and film archiving. It is based on the web technology. It deals with medical records and information. PACS provides archiving, viewing and distribution of medical images to radiologists, physicians of other specialties, doctors in other hospitals. It communicates with hospital information systems, radiology information systems, departmental information systems and allows data to be accessed from different locations within a health facility or outside the health care facility (10-14,16,23,24).

PACS can be integrated into radiology information systems, hospital information systems or other medical information systems; still, PACS is the most used in the radiology i.e. RIS. Among other things, PACS combines the functions of teleradiology services and systems for archiving, searching and reviewing of medical images and patient data.

PACS stores images from various medical devices (modalities): ultrasound (color Doppler, ultrasound, etc.), MRI, CT, mammography, angiographic, digital X-ray machines, PET scanners, nuclear medicine cameras and other devices (12,13).

PACS is an integrated system (Figure 2) which consists of devices for medical diagnostics, workstations for data access, servers, and a computer network that connects the system components, databases and interfaces to other systems.

In PACS are networked the central computer (server), with medical files stored, and operating units (modality) such as CT, MRI, ECHO, digital X-ray machine and other apparatuses that send processed images to the central computer.

Each computer is identified by its network address in the PACS network.

PACS requires hard drives with larger capacity and modern monitors to display the images in better quality (Table 1). For instance, monitors with 3 megapixels are good for the interpretation of standard radiographs, and monitors with 5 megapixels are sufficient to interpret mammograms (2,12,13,23,24).

PACS system has six main components (Figure 3):

- Acquisition of Image (Image Acquisition) requires the existence of medical devices with the appropriate interface of PACS, such as CT (Computed Tomography), MRI (Magnetic Resonance Imaging), digital X-ray machine and other. These medical devices must be compatible with DICOM (Digital Imaging and Communication in Medicine) which is an international standard for defining the mode of transmission of medical information and images that provides interoperability between different devices. If the standard is not supported on medical devices, then there must be a device for converting medical images (gateway).
- The communication network transmits images and attached data, e.g. name of the patient, date of birth, etc. Network structure has a crucial influence on the efficiency of the entire system. Indispensable network infrastructure of PACS system depends on the type of images that are used in this system.
- Patient Data - Hospital Information System (HIS) and Radiology information system (RIS) must have the interface according to the PACS system. The HL7 (Health Level Seven, 7th OSI layer protocol) is the standard that enables it.
- Display of images is done via personal computer in the office. The qualities of personal computers in the office are reflected in the monitor's physical characteristics (Table 1). There are low-resolution monitors (512x512 pixels) and high resolution monitors (about 1Kx1K pixels). Computers need to have an interactive user interface with a possibility to adjust image contrast, zoom and move images and display data of the patient.
- Recordings' archive - A system for archiving recordings should be centralized, with support for DICOM and HL7 standards.
- Web server - Application that resides on a Web server should provide adequate access and display of data to employees in medical institution and distant users.

Table 1. Resolution and size of digital images (2)

Modality	Resolution	Color palette	Size of uncompressed images
US	512x512	x8	256 KB
Digital x-ray machine	512x512	x8	256 KB
CT	512x512	x12	384 KB
MR	512x512	x12	384 KB
Digitized (scanned) radiographic images	1024x1024	x12	1,8 MB
Digital radiography	1024x1024	x8	1 MB
Mammography	4096x4096	x12	24 MB

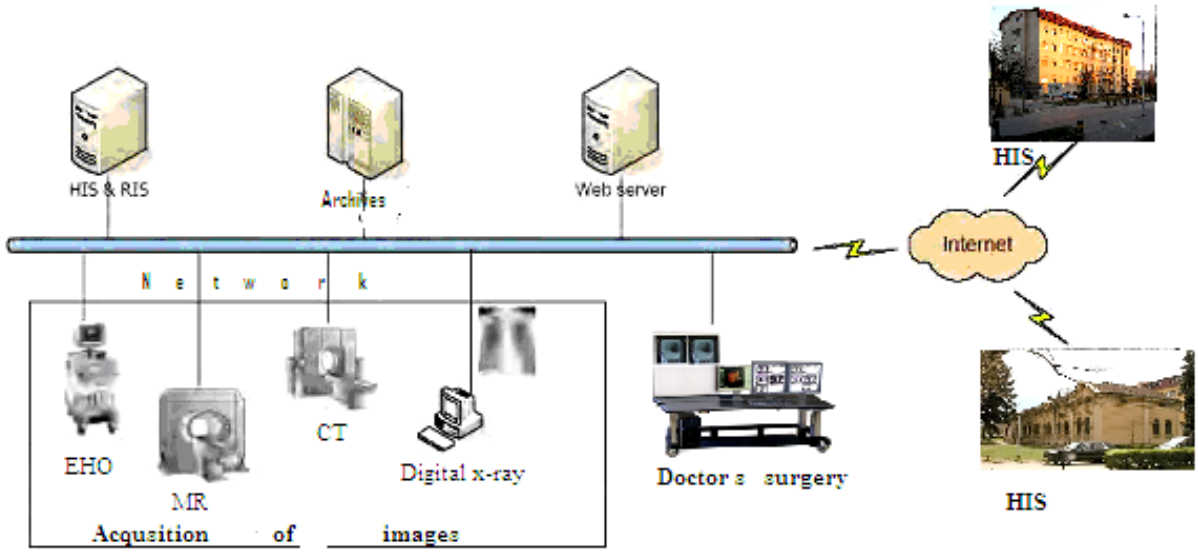

Figure 3. Picture Archiving and Communication System (PACS) components

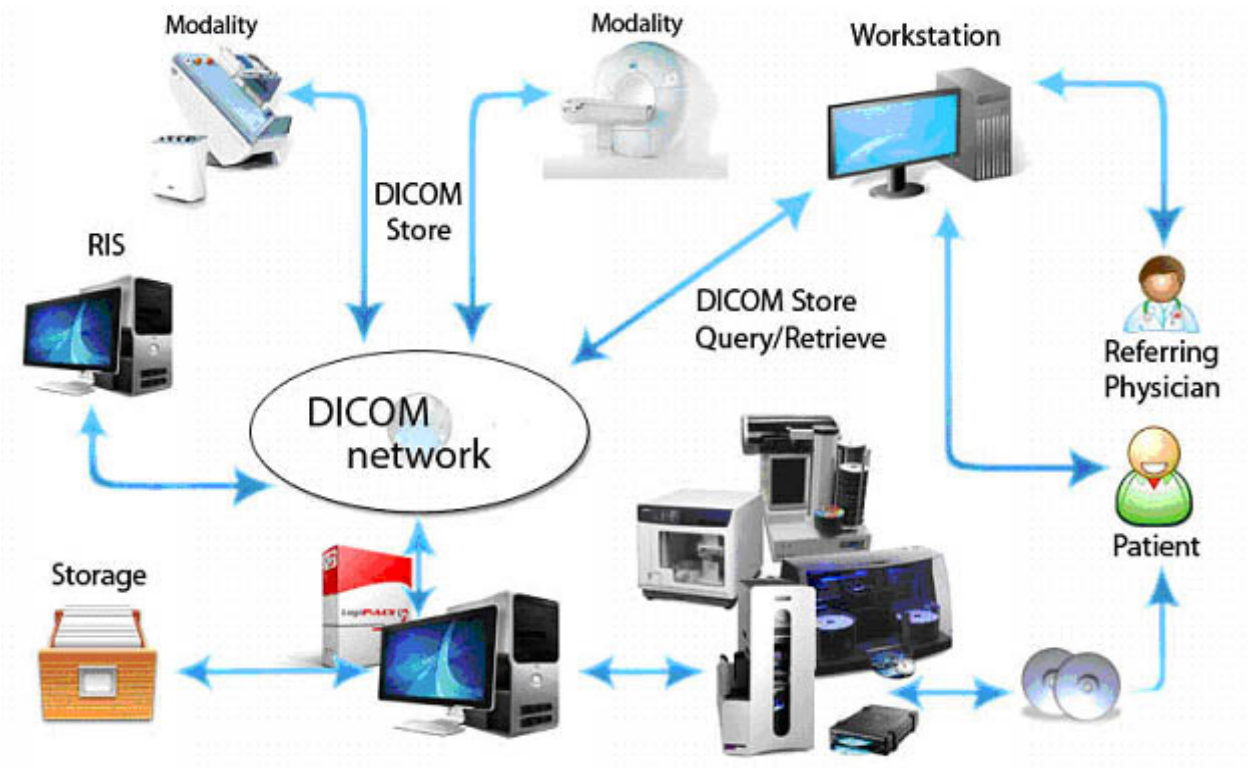

Figure 4. Digital Imaging and Communications in Medicine (DICOM)
(source: http://www.neologica.it/eng/LogiPACS.php)

Implementation of PACS is reflected in: saving space and time for archiving X-ray images, their search for educational purposes, because the x-ray records are stored on computer disks in electronic form; significant material saving - there is no need for buying X-ray films because x-ray images are moved on compact disks (CD) whose price is lower; improved X-ray image quality and speed of diagnostic radiology; possibility to view images from remote locations; better utilization of human resources; possibility to networking computers of one or more health facilities; modernization of work; reduction in service costs and material consumption, etc.

DICOM (Digital Imaging and Communications in Medicine)

Digital Imaging and Communications in Medicine (DICOM) is a standard for handling, storing, printing and transmission of information in medicine (Figure 4). DICOM is a set of rules that allows the exchange of medical images and information between computers and hospitals (15-17). DICOM establishes a common language that enables the usage of images and information, made on one type of manufacturers' equipment, in digital systems of other manufacturers. It should be noted that DICOM is not only a file format; it is directly related to the PACS.

Today, it is hard to imagine modern medicine without DICOM and PACS (11-16).

DICOM consists of files, definition and network protocol communication.

DICOM basic functions are: communication and sharing of digital medical images, regardless of the manufacturer; to enable PACS to become a part of hospital information system (HIS), radiological information system (RIS) and other information systems; to ensure that the database of medical images become available irrespective of browser distance; to enable the functioning of teleradiology etc.

Disadvantages arise in: searching the database and image processing; simultaneous display of multiple images on the monitor when the quality of individual images is decreased or certain segments are cut off; appearance of false coloring which appears in the adjacent gray level, false coloring in contrasting colors, etc.

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 (Figure 5) (10,11,15-21,23-25). For data transfer teleradiology uses the Global System for Mobile Telecommunications (GSM), General Packet Radio Service (GPRS) and 3G systems, which allow the transmission of multimedia content at high speed. One of the requirements of teleradiology is that information and communication technologies allow the transfer of relevant medical information at distance with compliance with medical and technological standards, relating to the acquisition, storage, transmission and retrieval of medical images, video, audio and other radiological information on standardized and high quality equipment and systems for teleradiology, but also on the levels of quality computer and telecommunication equipment and telecommunication channels and connections.

Web technologies in teleradiology enable, with appropriate rights (security and confidentiality), the use of the internet explorer, access to images and findings, to browse, view and write the radiological reports on any computer in any location.

The appliance of teleradiology is possible in imaging centers that have digital radiology apparatus, and Digital Imaging and Communications in Medicine (DICOM) (2,3,8,17,18). Problems arise where the analog radiographic apparatus is in use, because the question is how to digitize and store radiographic images and put in order the radiologic findings, how to connect radiological findings with images, how to make available radiologic information to the information systems in the center for radiology, clinical hospital center etc.

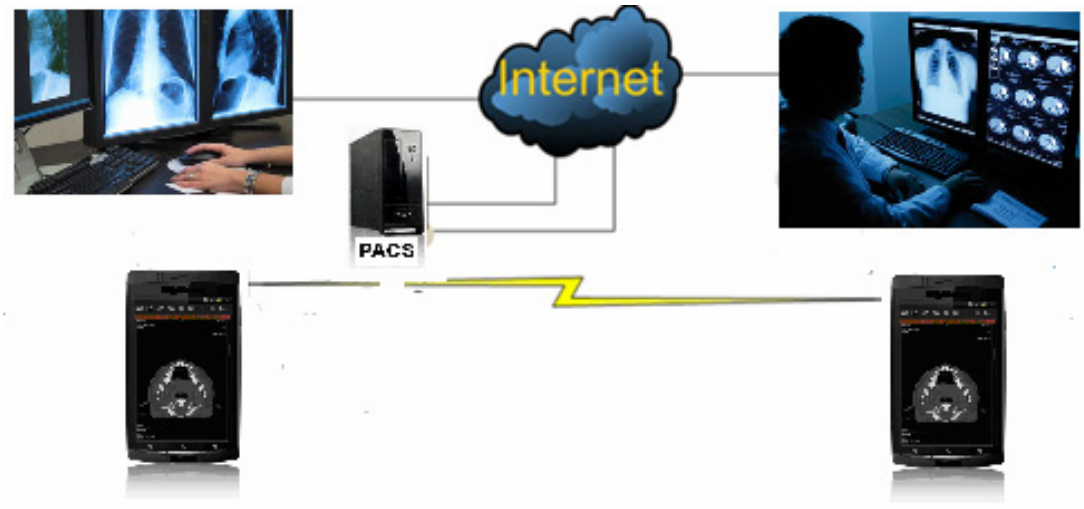

Figure 5. Teleradiology

Apart from the most frequent scenario of remote writing of radiological findings, there are several other processes that can be implemented as teleradiological solution: a second opinion, the council opinion, insight into the findings and images by the GP, extending of these scenarios with other systems (shata, video chat, whiteboard, etc.), complex solutions for teleradiology centers, 3D reconstruction, etc. All these scenarios are different variations of the basic radiological workflow.

Mobile radiology

The development of mobile radiology is linked to the Maria Sklodowska Curie (25-26). This brilliant idea today is used by the well-known manufacturers of the X-ray machines who install x-ray machines, CT, MRI, mammogramsd and other radiological devices into trucks with trailers, thus making them mobile and accessible to all communities, in all weather conditions, in peace or war. The drawback of these devices is their limited mobility. Therefore, the development of telecommunication led to the idea to increase the mobility of radiological devices by using a mobile phone. In this way, the new form of mobile radiology is developed- radiology through mobile phone (Figure 6).

Mobile radiology via the mobile phone is just one part of teleradiological chain (21). The usage of mobile phones in teleradiology i.e. in telemedicine enabled broad availability of radiological images and other relevant medical information.

The relevant features of mobile phones for mobile radiology in teleradiology are: 3 inches wide screens, light from 250 cdl, RAM memory of 256 Mb, 800 MHz processor and the mobile Internet that supports HTML5 standard and JavaScript.

Figure 6. Mobile radiology via mobile phone

Conclusion

The basis for the introduction of new technologies in medicine is the digitization of medical equipment. Application of web technology has made that health services become available to all, to give fast and effective treatment, and provide information to others at the right time. It is necessary to follow the standards and systems relating to the specificity of RIS, including: DICOM, PACS, HL7, teleradiology, mobile radiology etc. United and intertwined medicine and information technology lead to the progress of mankind.

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RADIOLOŠKI INFORMACIONI SISTEM

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Razvoj informacionih sistema u zdravstvu vodi prema integraciji nekada raznorodnih sistema u jedinstvenu informatičku celinu, tako da je danas sveprisutna ideja o objedinjavanju funkcija kliničko-bolničkog (KBIS) odnosno radiološkog (RIS) informacionog sistema. Radiološki informacioni sistem (RIS) predstavlja tehnološko rešenje potpune informatizacije i modernizacije rada radiološkog centra i prelazak sa paprinog i filmskog na potpuno elektronsko poslovanje i digitalne snimke. RIS stvara digitalni radiološkoi centar gde su informacije uvek dostupne na pravom mestu i u pravo vreme. U okviru realizacije RIS neophodno je slediti standarde i sisteme koji se odnose na specifičnost RIS, a to su: DICOM (Digital Imaging and Communications in Medicine), PACS (Picture Archiving and Communication System), HL7 (Health Level Seven). Relevantne karike savrevremenog RIS čine teleradiologija i mobilna radiologija. Autori zaključuju da uvođenje RIS, HIS i drugih informacionih sistema ogledaju se u automatizaciji, smanjenju mogućnsti greške, povećava se dijagnostički i terapijski kvalitet, smanjuju se troškovi za materijale, povećava se stepen iskorišćenosti sistema, štedi se vreme; sprovodi se modernizacija sistema i dr. *Acta Medica Medianae 2012;51(4):39-46.*

Ključne reči: *radiološki informacioni sistem, bolnički informacioni sistem, PACS, DICOM, teleradiologija, mobilna radiologija*