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## Teleradiology - Radiology at Distance

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### SUMMARY

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, with all the appropriate rights (security and confidentiality). Diagnosis, consultation and education of students, doctors and paramedical staff, scientific research, administration, management, planning and improvement of public health got in teleradiology new and powerful tools. In this paper, the authors try to give the right answer to the following questions: what is teleradiology, why teleradiology, the benefits of teleradiology, teleradiology success, teleradiology failure, radiology workflow, teleradiology scenarios, mobile radiology etc. The authors conclude that today's teleradiology creates the future radiology.

**Key words:** teleradiology, mobile radiology, telemedicine, radiology workflow, radiology

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## INTRODUCTION

Reduced cost of computer equipment and rapid development of telecommunication technologies have made a revolution in medicine, enabling the provision of almost all forms of assistance to patients at a distance (islands, mountains, forests, boat, etc) (1-9). Diagnosis, consultation and education of students, doctors and paramedical staff, research, administration, management, planning and improvement of public health got in telemedicine i.e. in teleradiology new and powerful tools. Radiology greatly contributed to the development of telemedicine, because all the novelties of telemedicine were first implemented in teleradiology.

### From the history of telemedicine and teleradiology

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 (5, 7).

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), which uses the Integrated Services Digital Network (ISDN) standard for receiving high resolution images.

Serbia entered the world of telemedicine in 1997 when experts in Military Medical Academy (MMA) and Control Data Company Ltd. from Belgrade formed the first network between the Military Medical Academy and Institute of Pathology, Faculty of Medicine in Niš. Today, Military Medical Academy and several university institutions and centers in Belgrade, Niš and Sremska Kamenica give a valuable contribution to the development of telemedicine in Serbia and achieve successful international cooperation (5). In the field of telemedicine in Serbia, the following results have been achieved:

- Implementation of telemedicine center - MMA and connection of the Military Hospital in Niš and MMA in a unique telemedicine network (1998);
- Delivery of information system for organization of pathology services, MMA, Belgrade (1998);
- Delivery of information system for the organization of pathological services, Clinical Center (CC) Novi Sad (2000);
- Establishment of an information system for organizing pathology services, Faculty of Medicine - Belgrade (2001);

- Consulting and revitalization of angiographic equipment, hardware repair and reinstallation of the system, Clinical Center Niš (2002);

- Implementation of the interface system for radiological diagnostics (CT, MRI), Center for planning and therapeutic radiation unit (linear accelerator) by DICOM3 Standards, Institute for Oncology and Radiology of Serbia, Belgrade (2003);

- Repair of digital angiography production GE Medical System, Military Medical Academy, Belgrade (2004);

- Implementation of PACS system for linear accelerator Siemens, Clinical Center Niš, (2005);

- Delivery of PACS - DICOM3 servers and workstations to radiological services MMA Sigmex, Belgrade (2005);

- Delivery of the software for image analysis in medical purposes, Sigmex Belgrade (2007);

- Repair of angiographic diagnosis type Advantx GE production, MMA, Belgrade (2008);

- Delivery of ASTREOS PACS - DICOM3 cluster server, the Institute for Oncology and Radiology of Serbia, Belgrade (2010);

- Delivery of mini PACS - DICOM3 servers, Institute of Nuclear Medicine, Military Medical Academy, Belgrade (2011);

- Delivery of DICOM Viewing workstations, Institute of Nuclear Medicine, Military Medical Academy, Belgrade (2011).

The first site in Serbia of telemedicine, "Telemedicine" (<http://www.telemed.co.rs>) (5) attempts to promote the Serbian medicine and make medical services more accessible in the farthest parts of our country and provides access to excellent diagnosticians etc.

### What is 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 1) (4, 5). 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.

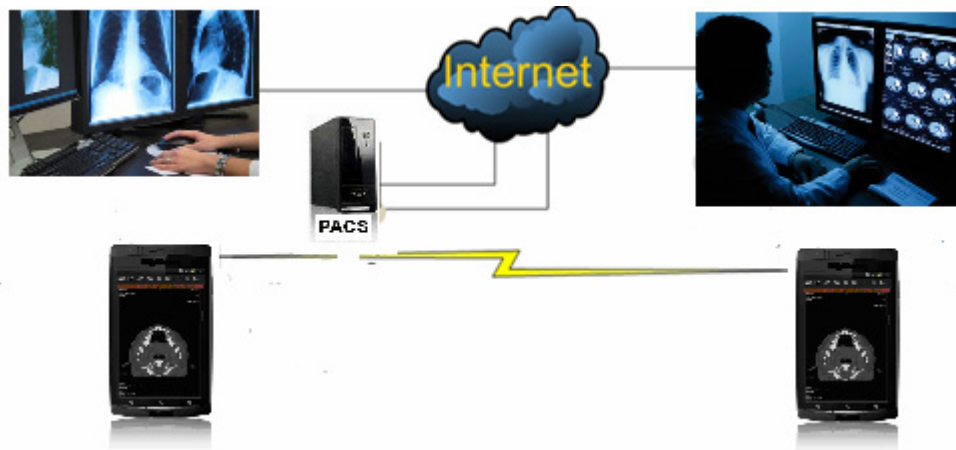
One of the requirements of teleradiology is that information and communication technologies allow the transfer of relevant medical information at distance, with compliance of medical and technological standards, relating to the acquisition, storage, transmission and retrieval of medical images, video, audio and other radiological information on standardized and high quality equipment and systems for teleradiology, as on the levels of quality computer and telecommunication equ-

ipment and telecommunication channels and connections.

Web technologies in teleradiology enable with appropriate rights (security and confidentiality) using the internet explorer, access to images and findings, to browse, view and write the radiological reports on any computer in any location (1-5).

The appliance of teleradiology is possible in imaging centers that have digital radiology apparatus, and

Digital Imaging and Communications in Medicine (DICOM) (9). 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 radiologic findings, how to connect radiological findings with images, how to make available radiologic information to the information systems in center for Radiology, Clinical Hospital Center etc.



**Figure 1.** Teleradiology

### Why teleradiology?

Teleradiology should: improve further development of telemedicine in Serbia; modernize radiology centers in the country; enable availability on time of radiologic images (radiographs, mammograms, CT, MRI, scans, ECHO, etc.) and their interpretation from rural and distant areas (islands, mountains, forests and other places) to a radiology center; provide sub-specialist radiology support in radiological diagnosis at certain moment (medical council etc) and radiological consultations in health centers that do not have a radiologist; to improve the radiological finding on the basis of identical examples or some rare diseases; enable distribution of radiological images to other imaging centers for consultation; to provide education and improvement of radiological knowledge etc. (1, 5).

### Benefits of teleradiology

The benefits obtained from the appliance of teleradiology are: modernization of the radiology center; digitalization of radiological apparatus; the possibility of obtaining text information, radiological images, video or moving images, their interpretation and sending back to determined destination via Internet; mutual consultations between remote radiologists and other specialists about received information such as x-ray images, US, CT, MRI, PET scans and other biomedical signals; tele-education of radiologists and other medical staff as an

additional possibility for knowledge improvement in medicine, radiology and other fields of medicine; interactive use of electronic medical records; medical monitoring and alarm connecting patients on home care and emergency center; transfer of radiological research data; improving health care; reduction and limitation of the growth of costs in radiology; maintaining the quality of radiological services etc. (1, 5).

Advantages for patients from teleradiology usage are: the availability of top radiologists for the interpretation of findings; radiological findings are obtained without the travel costs and accommodation in one of health care institutions; absence from work and uncertainty of the patient are minimized because the radiologic findings or other opinions are obtained in a very short notice etc.

Benefits from the use of teleradiology for radiologists are: distant specialists' support, creation and improvement of cooperation between radiologists, individual professional advancement through cooperation with other remote radiologist, cooperation of radiological institutions in the country and abroad, no need for travelling to remote locations and accommodations of radiologists in order for them to read radiological images and write radiological findings; increasing of professional competence because of the greater probability to meet statistically less common diseases.

Investors' benefits from appliance of teleradiology are: reduced need for local specialists; optimization of resource allocation; no travel costs and acco-

mmodation for radiologists; increased availability and quality of offered services; more patients; reduced cost of x-ray film consumption; grater profit etc.

Benefits of appliance of teleradiology for society are: higher quality, performance and availability of health services; the ability to provide superior health services in distant rural areas (eg. islands, mountains, forests, etc); increased employment of medical staff in remote rural areas; reduction of morbidity and mortality of the population; absence from work is minimized; health centers modernization.

### Advantages of teleradiology

The minimum requirements for the development of teleradiology would be: the delivery time of images should not be long to provide normal work conditions; the finding must be reliable, without repeating the actions because of disconnections during the process of receiving and processing images; images should be sent and received in full diagnostic quality (no compression or DICOM compression with no loss of information); the reception of images must be done with minimum number of operations; the finding of image processing and writing reports should not be complicated and must be presented with minimal number of logical and intuitive operations; it is necessary to have a 2D and/or 3D tools for image processing; computer system must be reliable; computer system must be integrated into the radiological workflow parent radiological information system to enable the connection between the patient and medical observation, images and radiological findings etc.

The aforesaid conditions of successful teleradiology work depend on infrastructure in telecommunication, informatical solution of performer and radiological workflow of the parent radiology center (8).

### Disadvantages of teleradiology

The barriers for successful implementation of teleradiology include: problems with telecommunications, energy infrastructure problems, high price and/or unavailability of the Internet. The minimal teleradiological solutions are often informatically too complicated, unpractical to use and do not have all the necessary functions etc.

### Radiological workflow

Figure 2 shows a diagram of a simple radiological workflow that integrates all aspects of the work process of a radiology center (6). Radiology workflow consists of the patient admission process, input of instructions, data (name, ID number, etc), archiving images with all necessary information about examination, display, processing and image analysis, writing radiological findings and collecting costs.

It should be noted that the primary solution of teleradiology is integrated in the radiological information system (RIS) and PACS (Picture Archiving and Communication System) in relation to the separate RIS and PACS, because the use of radiological workflow is enabled, which represents the first step of radiological origin.

Figure 3 shows the flow of teleradiological process that relies on integrated RIS and PACS.

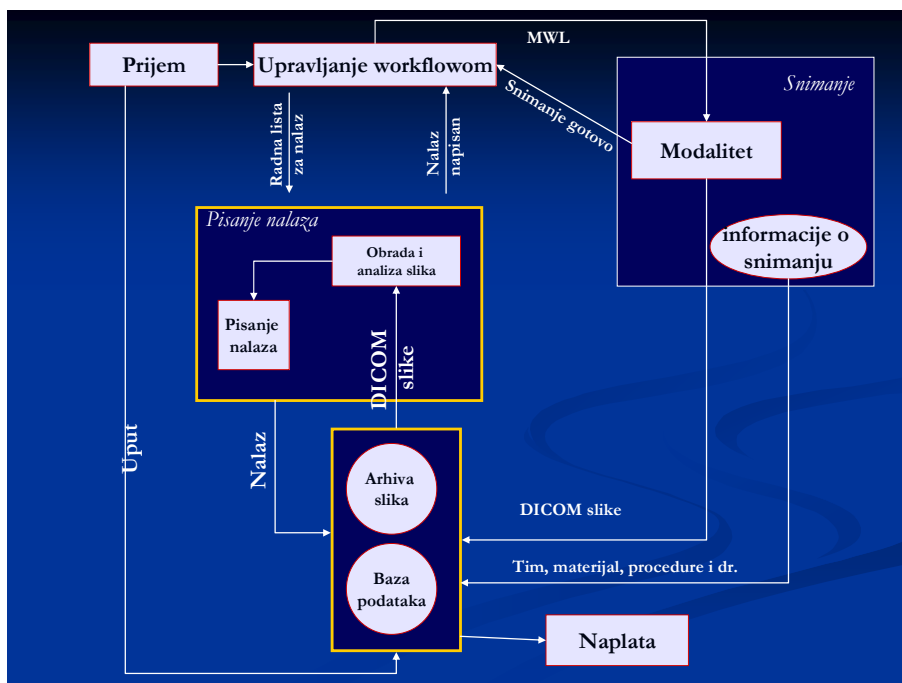
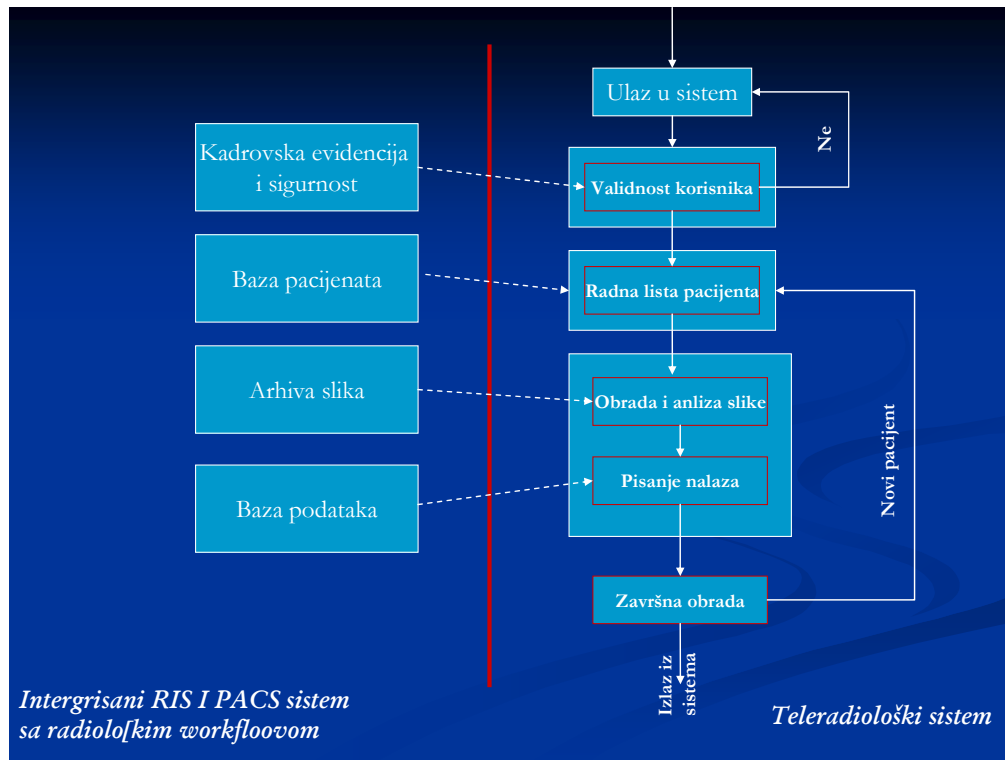


Figure 2. Scheme of a simple radiological workflow



**Figure 3.** Illustration of teleradiological system that relies on integrated RIS and PACS

### Different scenarios of teleradiology

In addition to the above scenario of writing remote radiological findings (Figure 4), 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 these scenarios with other systems (shata, video chat, whiteboard, etc); complex solutions for teleradiology centers; 3D reconstruction (Figure 4) etc. All these scenarios are different variations of the basic radiological workflow (1, 2, 5).

### Mobile radiology

The development of mobile radiology is linked to the Maria Skłodowska Curie. In fact, it was during the World War I when she introduced something new into medicine - Mobile radiological diagnosis. Maria Skłodowska Curie demonstrated how to install X-ray machine into a car and how to use the dynamo that drives a car for generating electricity for working of X-ray machines. For this use, Maria Skłodowska Curie equipped 20 cars with mobile radiological laboratory and trained 150 people to work on them (10, 11).

This brilliant idea today is used by the well-known manufacturers of X-ray machines who install x-ray machines, CT, MRI, mammography and other radiological devices into trucks with trailers, thus making

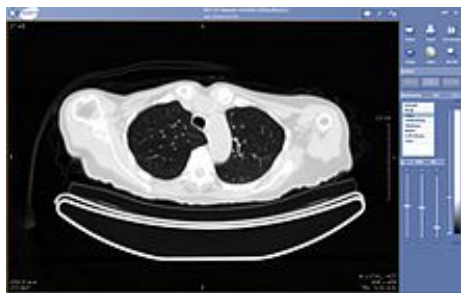
them mobile and accessible to all communities, in all weather conditions, in peace or war. The drawback of these devices is their limited mobility. Therefore, the development of telecommunication introduced the idea to increase the mobility of radiological devices by using a mobile phone. In this way, the new form of mobile radiology is developed - radiology through mobile phone (Figure 6) (12).

Mobile radiology via the mobile phone is just one part of teleradiological chain.

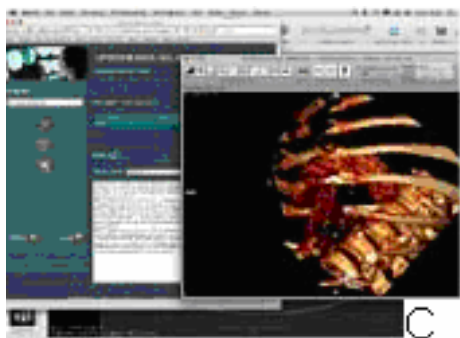
The usage of mobile phones in teleradiology i.e. in telemedicine enabled broad availability of radiological images and other relevant medical information.

To make teleradiology via the mobile phone possible and relevant, it was necessary to make a web program that can be applied on any mobile phone. There is a system that supports all the basic functions such as brightness and contrast of images, measuring, zoom, scrolling of images etc. Special attention is paid to fast image loading so a special algorithm that provides undisturbed operation in an environment of poor GSM signal is developed, and it shows its full capacity in transmission of signals using EDGE (Enhanced Data Rates for GSM Evolution).

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



**Figure 4.** Lung CT teleradiologically displayed



**Figure 5.** Scenarios of teleradiology

A) a list of patients; B) 2D images of the lumbosacral spinal column with MR; C) 3D of thorax



**Figure 6.** Teleradiology  
Mobile radiology via mobile phone

## CONCLUSION

Teleradiology is a set of procedures for transferring radiological information in electronic form. Teleradiology enables interactive connection between professionals and patients, as well as long-distant consultations. Information transmitted by teleradiology include information on medicine, radiology, static images, moving images, complete medical records, etc. Teleradiology has grown into a global service with almost unlimited possibilities. The realization of this concept of teleradiology includes possession of appropriate hardware and software resource and the use of modern radiological equipment. Teleradiology today forms the future of radiology.

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## TELERADIOLOGIJA - RADIOLOGIJA NA DALJINU

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### Sažetak

Teleradiologija je omogućila da se na bilo kojem računaru, na bilo kojoj lokaciji, sa svim odgovarajućim pravima (sigurnost i poverljivost), pomoću internet explorera pristupi slikama i nalazima bolesnika, prelistaju, pregledaju i napiše radiološki nalaz. Dijagnostika, konsultacije i edukacija studenata, lekara, pomoćnog medicinskog osoblja i naučno istraživanje, administracija, upravljanje, planiranje i unapređenje narodnog zdravlja, dobili su u teleradiologiji novo i moćno sredstvo. Autori nastoje da daju pravi odgovor na pitanja: šta je teleradiologija, zašto teleradiologija, koristi od teleradiologije, uspešnost teleradiologije, neuspešnost teleradiologije, radiološki workflow, scenariji teleradiologije, mobilna radiologija i dr. Autori zaključuju da teleradiologija današnjice osmišljava radiologiju budućnosti.

**Ključne reči:** teleradiologija, mobilna radiologija, telemedicina, radiološki workflow, radiologija