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The LubMedNet services for data storage and teledistribution

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Abstract

This paper is reports several Radiological and Oncological Information Systems integrated by a very efficient medical network system. The system covers the entire image flowpath in the Diagnostic Radiology Department (i.e. image acquisition, processing, archiving, long term storage) and allows for transmitting medical images through Municipal Area Network. The system has been working reliably since November 1999. About 22000 CT examinations have been archived using our system. Over 300 special examinations for radiotherapy planning have been sent to the Lublin Oncology Centre.

1. Introduction

Several information systems, such as Hospital Information Systems (HIS), Radiology Information Systems (RIS) and Picture Archiving and Communication System (PACS) were introduced into hospitals. HIS were implemented to manage patient demographics, insurance information, billing and controlling. RIS usually manages patient scheduling, patient information, imaging technique information, radiological reports at the radiology department. PACS were introduced to meet the demands for a more time - and cost-effective image storage and transmission.

More than 15 years ago, the idea of *the filmless hospital* was created. The desire for digital storage and communication of medical images steams from the well known limitations of film-based radiology. An original film can only be in

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one place at one time. Transport of films is time consuming, and conventional film archives are labour-intensive and notoriously unreliable.

Telemedicine is a way of electronic transmission of medical information from one location to another. The first application of telemedicine was developed in 1959 at the Jean-Talon Hospital in Montreal. Video monitors were set up so physicians could view radiographs from anywhere in the building. In 1985, the American College of Radiology (ACR) and National Electrical Manufacturers Association (NEMA) published a standard which addressed the issue of vendour-independent data for mats and data transfers for digital medical images (DICOM). A revised version of the standard was published in 1988. In both versions, data transfer was defined for point-to-point connections, i.e., a network environment was not considered. ACR and NEMA have recently completed the third version of the standard which has been renamed DICOM v3.0.

Teleradiology is a subspecialty of telemedicine dealing with sending radiological images from one point to another through digital, computer assisted transmission for interpretation, consultation, or education. Using teleradiologic solutions images can be sent to another department in Hospital or to any medical centre around the world. Telemedicine and teleradiology take advantage of extremely fast progress in computer technology. Nowadays it is possible to send a huge amount of any data using local, municipal area networks or via the Internet.

2. PACS at the Diagnostic Radiology Department in the Provincial Specialistic Hospital

2.1. System Principles

Introduction of medical technology poses a very complex problem, especially in countries of low economical power. Digital technology is very costly. According to the research on PACS cost [1996], for hypothetical PACS implementation for CT, ultrasound and CR hospital need about 1 million ECU over 5 years (approximately 180 000 ECU per year). Telemedicine system costs abouts 100 000 $. Our goal was to design and establish a low-cost PACS.
The objectives of our system:

1. It should have a maximum local access time of 10 seconds to any file on any volume.
2. It should support ANSI standard media, UNIX file system, SCSI connectivity and NFS.
3. The archive software should be capable of handling both online media (hard disc) as well as offline media (CDs).
4. It should comply with the DICOM format of the images (USA standard HL 7 was not considered).

The system was designed to include PACS and teleradiology. A PACS should have a network solution, wide area digital viewing and provide a permanent digital record which may be either on-line or off-line. Our PACS is based on a multi-vendour open architecture and a set of widely available industry standards, namely:

- Linux as an operating system
- TCP-IP as a network protocol
- DICOM standards
- Digital Imaging Network.

2.2. System architecture

Our LC-PACS covers the entire image flowpath in a radiological department, starting from image acquisition at the diagnostic stage; through to on-line archiving, display, processing and long term archiving. Images can be exchanged between different offices in the same health organisation unit or between those in an Intranet (or the Internet). WWW server combined with DICOM database allows users to view cases from their PC terminals.

The presented software includes:

- data management unit,
- visualisation unit,
- image processing unit,
- patient database,
- image frame grabber driver,
- image format converters,
- WWW server,
- CD recording unit,
- image viewers.

Radiological images under Lublin PACS are collected in the form :

- temporary files (GE workstation, Sun-Spark, 10 days),
- temporary files (PACS imaging servers, PC, 6 months),
- archiving files (PACS, CD, permanent).

A capture workstation should be able to handle huge images. For a CT image with 512x512 pixels and 12 bits per pixel we have a 400 kilobyte file, and usually 15 scans are taken for one examination. Finally typical CT examination is recorded using about 6 megabytes. Usually 60 scans are taken per one examination for radiotherapy. Such CT examination is recorded using about 24 megabytes. Our system stores CT images for about 150 patients on one CD.

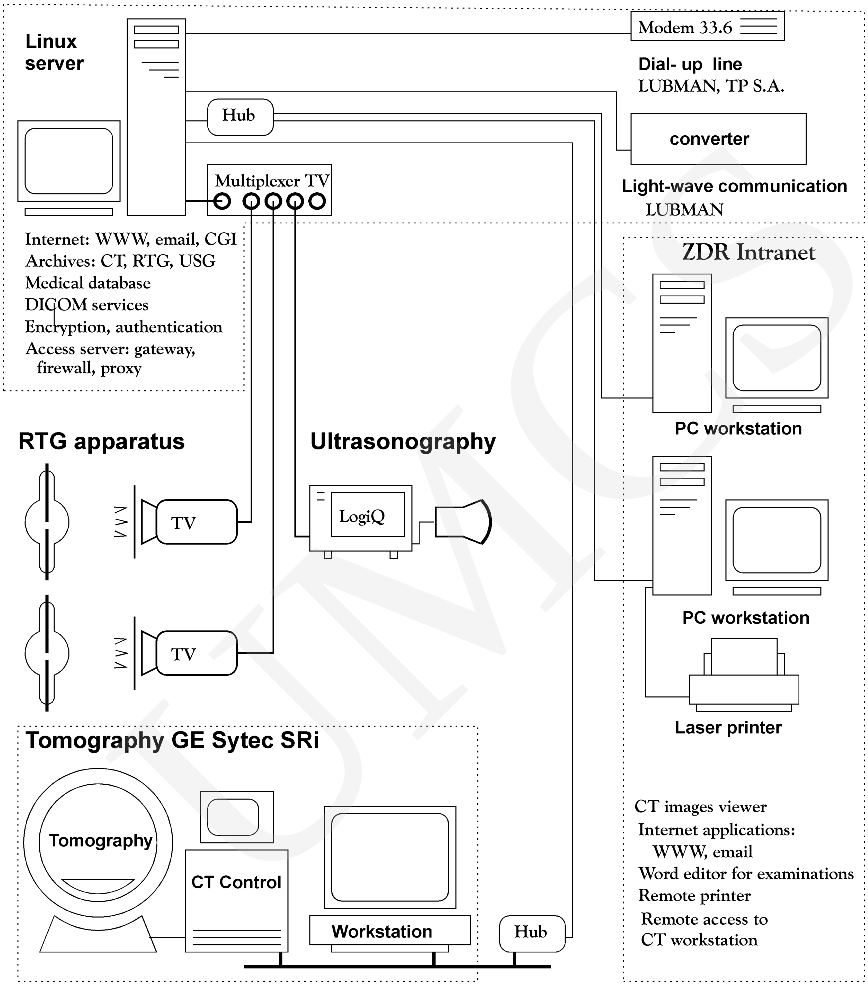

Fig. 1. Architecture of the PACS

Computed tomography pictures are acquired with the help of GE Sytec SRi CT. This system consists of a scanner, workstation and modality server. The modality server interacts with its scanner and workstation in the modality suite and supports the DICOM Storage and Query/Retrieve services. Images are automatically sent by the scanner to the modality server where they are stored on a disk and entered in a local database. We connected this GE Mini-PACS system to our PACS .

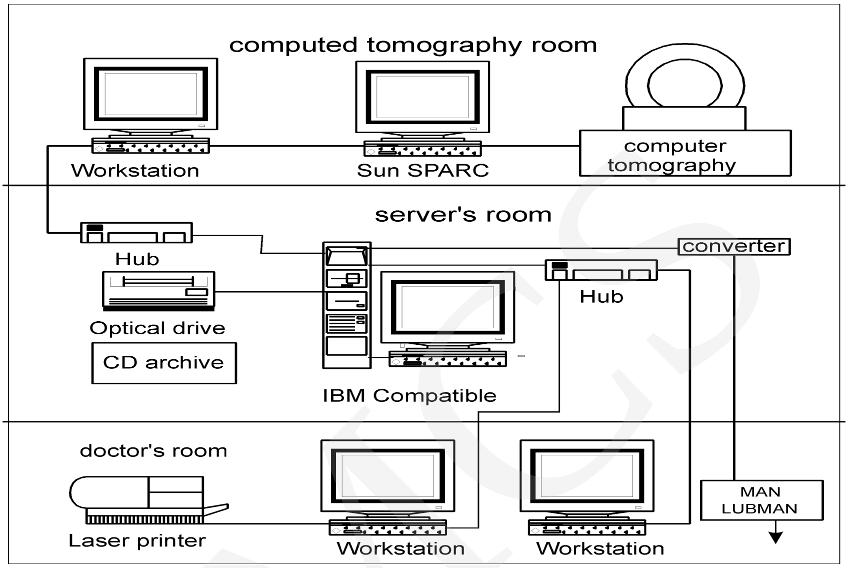

Fig. 2. Data acquisition – CT

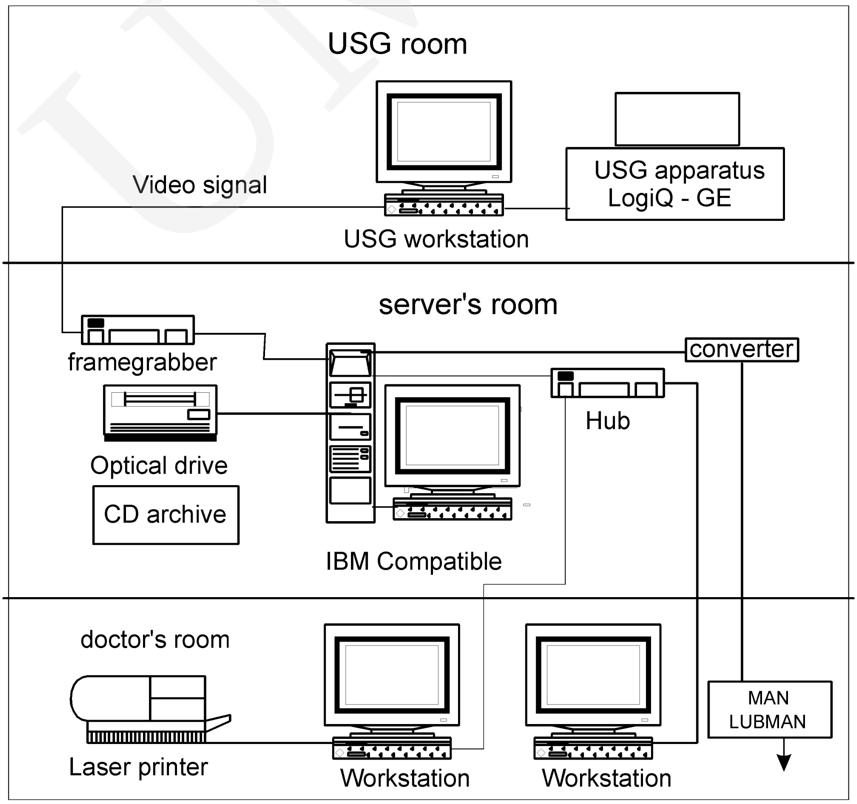

Fig. 3. Data acquisition – US

2.3. On-line and off-line viewers

Radiologists have access to four type viewers from PC workstations:

1. General Electric 2D and 3D viewers (Adventage Windows)
2. 2D viewers for CT images archived on CD
3. 2D viewers for specific CT images manipulation
4. Commercial viewers (for example Imaging Windows or CorelDraw).

For Lublin PACS simple 2D Radiological Data Viewers (RDV) were developed. The images which are locally stored at GE workstation or PACS imaging servers are available to RDV via NFS (on-line). The examination is selected from a list of locally available examinations. The images to be viewed are selected with the mouse from the overview screen. With the help of RDV, patient images recorded on CD can be analysed on PC (off line).

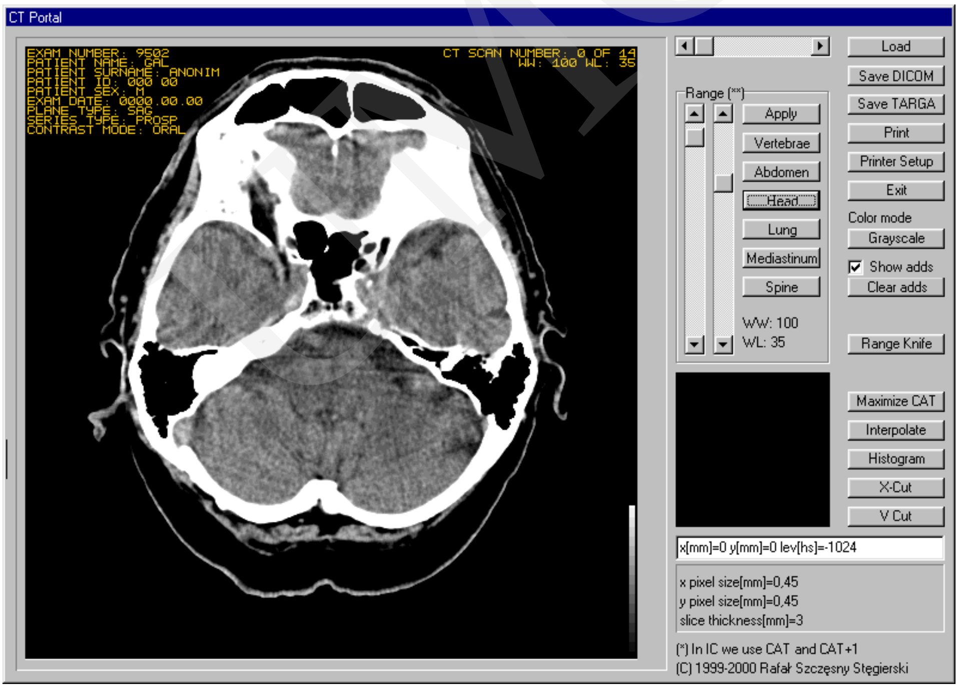

Fig. 4. 2D Radiological Data Viewer

Alongside images are recorded radiologists' interpretations, exhaustive statistical and clearing data as well as the RDV application. It should be mentioned that full information obtained from the GE computed tomography system is recorded on CD (one pixel is coded on 12 bits, image size is 512x512 pixels). Picture analysis entails Hounsfield scale measurements.

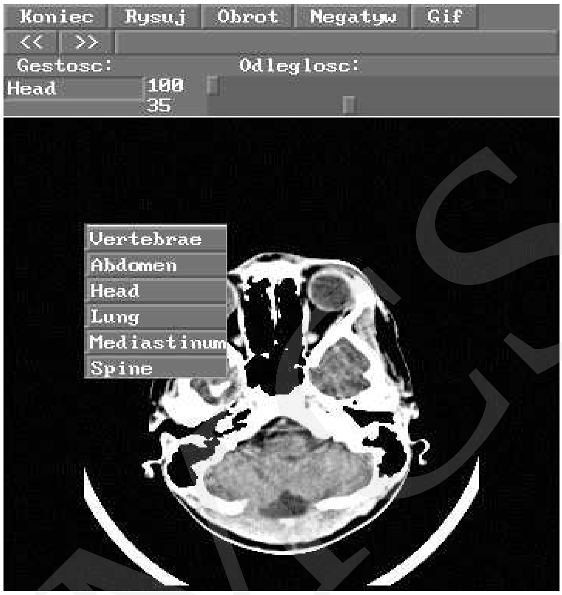

Fig. 5. CD viewer

CD-viewer options

For the specific patient, the user of RDV can employ the slider to scroll through the entire stack of CT images of one series (usually about 25 scans). With the help of this simple RDV the user can :

- choose manually window and level (Houndsfield scale),
- choose preset windows and level (vertebrae, abdomen, head, lung, mediastinum and spine),
- measure density (Hounsfield scale) and distance (cm),
- rotate,
- inverse image (negative),
- convert CT image to GIF format.

3. Lublin medical network (LubMedNet)

3.1. LubMedNet architecture

LubMedNet is based on Virtual Private Network solutions (VPN). A VPN is designed to give users the privacy of a separate network over public lines by substituting encryption and other security measures for the physically separated network lines of traditional private networks. Hardware and/or software that encrypts and decrypts transmissions sent over already-installed network cabling is usually a much less expensive proposition than installing new network cable for the purpose of keeping information private. A VPN offers the same capabilities as would exist in a private network, but with overall expenses being reduced by providing those capabilities within a shared infrastructure. Security on a virtual private network is accomplished by two levels of encryption: password and data. Password encryption is the assumed minimum level of security, with the data encryption - a more intense measure - being second-level security. Additional security may be obtained by encrypting not only the data, but the originating and receiving network addresses as well. Such encryption methods allow users to tunnel through public networks in a manner that provides the same level of security formerly available only in private networks.

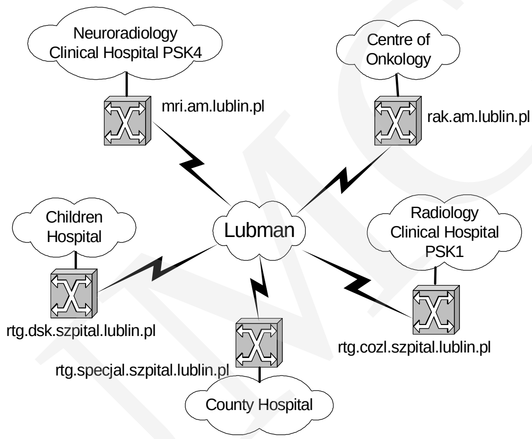

Fig. 6. Topography of LubMedNet with encrypted connection channels

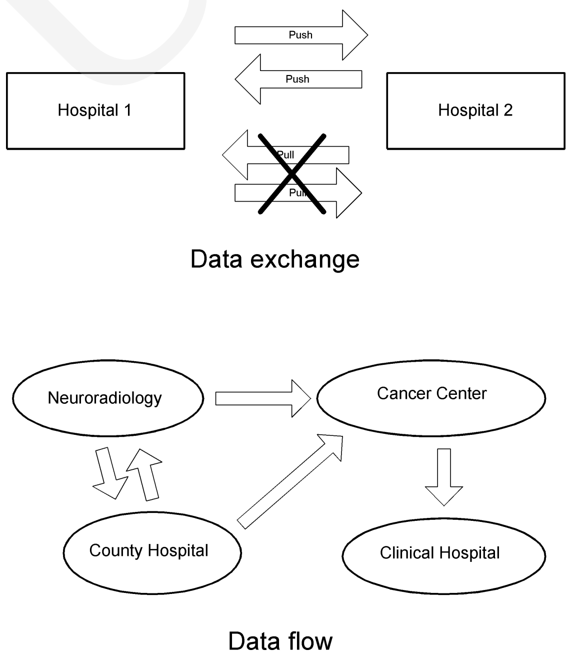

Fig. 7. Data exchange rules and data flow in LubMedNet

4. Image transmission for radiation therapy

The solution is based on the above described VPN and PACS design, which can either be contained within a single hospital or virtually distributed all over the world. Several clinical protocols have been devised and implemented. This would not work properly without adequate use of the teleradiology.

4.1. Procedure description

The major steps of the procedure are:

1. CT examination in the Diagnostic Radiology Department
2. Data transfer between the Diagnostic Radiology Department and the Lublin Oncology Centre.
3. Radiotherapy in the Lublin Oncology Centre.

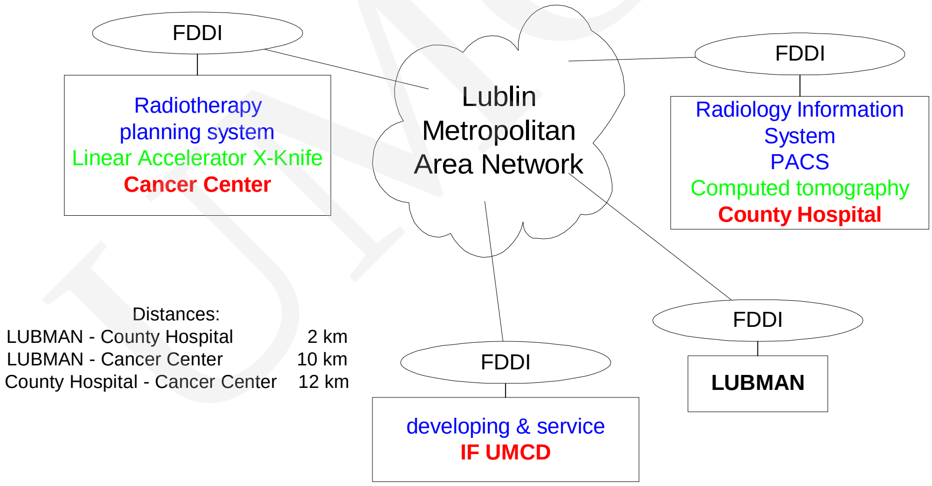

Fig. 8. Network solution for image transmission for radiation therapy

4.2. CT examination in the Diagnostic Radiology Department

A patient is immobilised in a special device which is fastened to the patient's skull with four nails inserted under local anaesthesia. Fig. 9 presents a CT image taken during the examination. This picture shows the patient's head with the mentioned device. Metal plates are clearly visible.

The CT examination is performed with the following parameters: scan field of view 42cm, display field of view 42cm, no gantry tilt, slice parameters: 135 kV, 2s, 160 mA (slice 1mm) or 130 mA (slice 3mm). In most cases non-ionic contrast media is administered (about 1ml/kg patient weight).

The range of examination should cover the lesion, the eye-balls and the brain stem. The 1mm thickness of slices is required within the lesion with 1cm border, below and above lesion slices thickness of 3mm is sufficient.

Number of scans performed may vary from 50 to 70 depending on localisation and size of the lesion.

4.3. Data transmission

Data are transmitted from the Radiology Department using user-friendly Advantage Windows 2.0 workstation. Technical details are described above. The average number of transmitted images per one examination was 65.

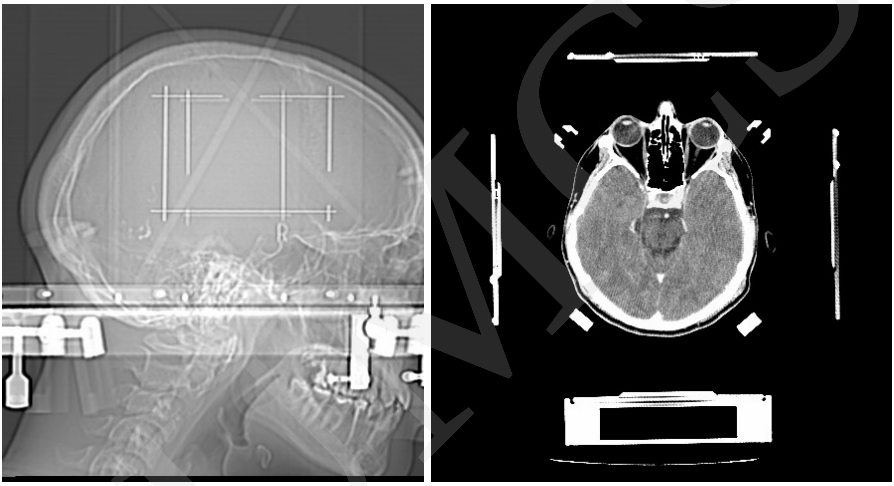

Fig. 9. Scout and axial CT image taken for radiation treatment

4.4. Radiotherapy in the Lublin Oncology Centre

The principle of radiotherapy is to deliver a high dose of radiation to the tumour while restricting the dose to the surrounding normal tissues. The obtained CT images at the Oncology Centre are transmitted to the treatment planning workstation where the data are evaluated (Fig. 10).

5. Results and Discussion

The System has been working correctly since November 1999. About 22000 CT examinations were archived using our system. Over 300 special examinations for radiotherapy planning have been sent to the Lublin Oncology Centre.

5.1. Major benefits achieved from our solutions

1. **Low costs of system implementation**. The cost of our PACS is significantly reduced - the solution was to develop suitable interface software, sometimes called "middleware" and to choose OS system like "LINUX" which gives a hospital some financial flexibility, since it allows managers to pick and choose the software modules they can afford.

2. **Reduction of the archiving cost.** One radiological film costs $3, for one examination 1 to 3 of them are needed. It makes conventional archiving costs about 12 - 36 PLN ($3-$9). The cost of electronic archiving is only about 0.01PLN per examination. We have reduced film consumption about 50%. It brings about 60000 PLN savings yearly.
3. **Reduction in a number of destroyed or lost documentation.** Additionally no need to repeat the examination. Tight security of the electronic storage is in contrast with the estimated 10-20% result disappearance from the traditional archives.
4. **Quicker and more reliable access to image database.** Our database software allows for extensive search and statistical analysis, not to mention drawing out lists for clearing purposes.
5. **Better patient care, shortening of patient's stay in hospital.**
6. **Improvement of hospitals image in the local community.**
7. **Data transmission to the Lublin Oncology Centre.** More than 300 CT examination for radiotherapy have been made so far and these data were sent to the Oncology Centre. A suitable procedure was established. From a technical point of view, as soon as the communication was correctly established by the operators, we have not had any major problem with the system. All these data have been sent successfully over VPN to the Oncology Centre. It provides almost real-time information transfer with a high degree of clinical confidence.

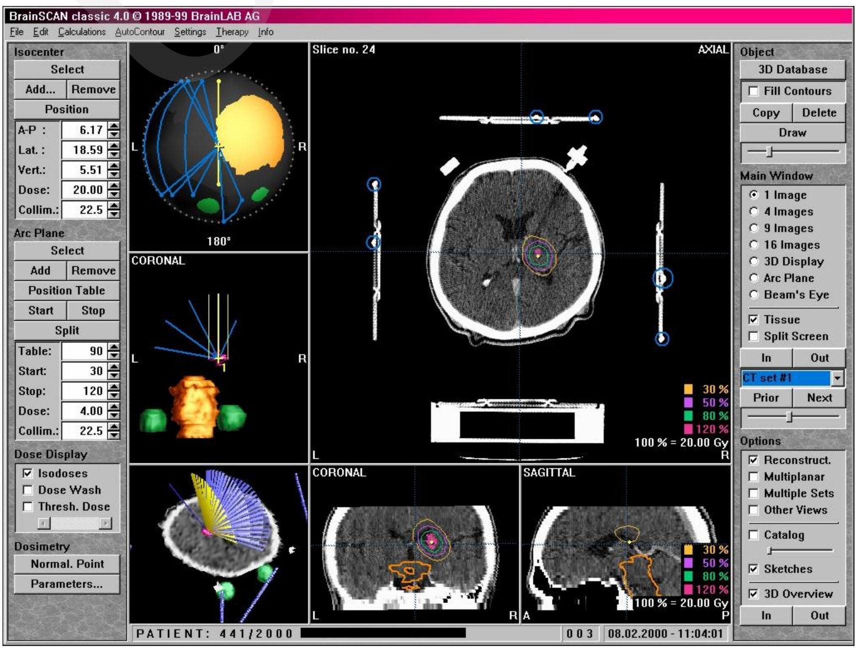

Fig. 10. Screenshot of treatment planning software at the Oncology Centre

Teleradiology technologies are now mature and widely available and there are well established, open standards for software. The communication infrastructure is, however, often the weakest link in the provision of a widespread service.

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