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# Picture Archiving and Communication Systems and Related Developments in Sweden

Silas Olsson

**Large PACS (Picture Archiving and Communication Systems) installations do not yet exist in Sweden, but some hospitals have had experience with limited PACS activities. At present there are four mini PACS installations in radiology departments and about 12 teleradiology systems in use in Sweden. A couple of small Swedish enterprises work in the market segment of digital imaging including PACS and teleradiology, although the radiology market is dominated by the large international companies. Interest in PACS and teleradiology in Sweden has increased during the last few years, along with advancements in technology and international experience. However, radiology is organized very differently in the United States, Japan, Southern Europe, and Scandinavia. Because of this, PACS will be introduced in different ways, and experience with PACS gained in one health care system may differ from that gained from other health care systems. This article reviews the status of PACS and related developments in Sweden.**



**KEY WORDS: radiology, PACS, teleradiology, telemedicine, medical informatics, diffusion, evaluation, quality assurance.**

ABOUT 4.7 MILLION radiological examinations are performed each year in Sweden (population 8.4 million). This does not include dental x-ray examinations or x-rays by the occupational health services. Most radiological examinations in Sweden, approximately 82%, are carried out at the 105 acute care hospitals. Another 7% are done within primary healthcare settings, 6% in private healthcare, and approximately 5% are mammography screenings, some of which are performed by the private healthcare sector.[1,2]

Apart from conventional radiological examinations, a full spectrum of imaging modalities is used, such as ultrasound (US), computerized tomography (CT), digital subtraction angiography (DSA), single photon emission computerized tomography (SPECT), positron emission tomography (PET), magnetic resonance imaging (MRI) and computed radiography (CR) with phosphor image plate technology.

If one excludes the digital imaging workstations in nuclear medicine units, digital imaging was first introduced into radiology in Sweden in 1973, when a CT scanner was put into operation. Approximately 90 CT scanners are now installed. Diffusion of modern dynamic diagnostic ultrasound equipment started to increase in the early 1980s and is now used in practically every x-ray department.[3]

DSA was introduced in 1983, and approximately 25 DSA units are presently in operation.[4] The first MRI unit was put in use in Sweden in 1984, and now 14 such units are installed.[5] At present only one CR system has been installed in Sweden.

In Sweden digital imaging modalities are used in approximately 15% of all radiology examinations performed in hospitals. This ratio is the same in other Nordic countries, ie, Denmark, Finland, Iceland, and Norway.[2,6] On the other hand, digital images account for approximately 40% of total images. The portion of examinations using digital imaging modalities is expected to increase.

With this situation, Swedish radiologists, hospital administrators, and central authorities are concerned about the efficient handling of images, as well as image distribution, archiving, etc. A solution to this problem may be the use of

*From Spri, The Swedish Planning and Rationalization Institute for Health and Social Services, Stockholm, Sweden.*

*Address reprint requests to Silas Olsson, Spri, The Swedish Planning and Rationalization Institute for Health and Social Services, PO Box 70487, 107 26 Stockholm, Sweden.*



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PACS (Picture Archiving and Communication System), which may provide new image management, better information logistics, and improved diagnostic possibilities.

## SWEDISH COMPANIES IN THE IMAGING SECTOR

In Sweden the radiology market is dominated by large international companies such as Siemens, Philips, General Electric CGR, and Toshiba. However, some smaller Swedish companies with 5 to 35 employees are developing equipment for digital imaging in the medical sector.

For example, Bildsystem (Image Systems), based in Malmö, has since its start in 1978, specialized in developing video-based products such as video character generators, mixers for the display of electrocardiogram curves and x-ray fluorographic imaging simultaneously on the same cathode-ray tube-monitor, and x-ray film markers. One widespread product is a TV demonstration unit used to display radiological images for medical conferences (rounds). Other Bildsystem products are TV surveillance systems for the industrial and horse racing (trotting) sectors.

Imtec (Image Technology) now based in Uppsala, was formed in 1982. An interactive image workstation was developed on the basis of the development of a tight-coupled image memory, image processor, and image display processor. This workstation and the fiber optic image network (Imnet) are key components in the company's approach to PACS. In the last couple of years Imtec has been busy in the teleradiology sector, and some such systems have been delivered to Swedish hospitals. Imtec is also active in the field of computerized cell image analysis.

Sectra (Secure Transmission) based in Linköping has been developing systems of image transmission for the press media since the beginning of the 80s. The breakthrough for this company came during the 1984 Olympics in Los Angeles, when Sectra products were used to transmit digital images to different newspaper editing departments via ordinary telecommunication networks. Their special areas are data encoding and image data compression, data security, cryptography, and information integrity. Sectra has recently completed a several years project in teleradiology and the first system is now being tested in Swedish hospitals.

Bildbehandling (Image Processing), based in Linköping develops systems for image processing within thermography for both medical and industrial application.

Helax is an Uppsala based company developing and marketing image processing products primarily for oncology departments.

Scanex is a Helsingborg based company developing and marketing for example interface and network products primarily for nuclear medicine departments.

Sarastro is a Stockholm-based company, developing and marketing confocal microscopy systems.

## SOME LEADING IMAGE RESEARCH CENTERS IN SWEDEN

### *University of Linköping*

One group in Linköping has centered research activities on the development of PICAP (Picture Array Processor), regarding hardware, software, and application. One of the earlier areas of application was in fingerprint recognition.

Another Linköping group has developed a special computer architecture in the GOP (General Operator Processor) concept. This signifies, among other things, the automatic detection of local structures, relating to magnitude and direction, and can be described as a complex image.

A third group in Linköping has focused on image communication and specializes in encoding and the compression of data. This group has also developed a charge coupled device chip with built-in parallel processor for image analysis, used for example in industrial production.

### *University of Stockholm, Institute of Technology*

There are different groups in Stockholm working with image processing. For example, one group at the Institute of Technology is working with basic research on computer vision and another group at the same institute is working within the confocal microscopy area.

*University of Uppsala*

The Centre for Image Analysis was started in 1988, but a research team had already been established in the early 70s. The present concentration of research is on the use of image technology in medicine and on the environment in a broad sense. Two current projects are the development of image processing methods that follow the healing process of wounds and the improvement of segmenting methods in medical imaging (magnetic resonance).

*University of Gothenburg*

A group in Gothenburg has been working for some years on medical applications in image processing. One research project in progress concerns the analysis of ultrasonic images in cardiology.

*University of Lund*

A group in Lund is working on the development of a high resolution ink jet paper printer for possible application as a hardcopy unit in medical imaging (radiology).

## TRAINING AVAILABILITY IN IMAGE PROCESSING

Basic courses in image processing are held at the universities in Linköping, Stockholm, and Uppsala, among other locations.

Training at the pregraduate level can also be found at Linköping, Stockholm, Uppsala, Gothenburg, Halmstad, and elsewhere.

There are also about 5 to 7 other training associations in this field operating on a commercial basis.

## THE RADIOLOGY ORGANIZATION IN SWEDISH HOSPITALS

The general input-output flow in a radiology department in Sweden as well as in other countries consists of a request from the referring physician. If the request is accepted by the radiologist the radiology procedure is performed. All images taken are read by the radiologist who reports the findings in writing to the referring physician.

A key element of Swedish radiology is the round-procedure (conferences). In these daily rounds, mostly held in the mornings, radiologists meet with referring physicians to explain and discuss findings of the examinations done the day before. This is also a forum to propose further examinations if needed. These conferences provide an important opportunity for radiologists to meet clinicians to get feedback about their findings after treatment is complete and the final answer is known. Such conferences also allow referring physicians to ask for the most efficient and cost-effective radiology procedure and to avoid unnessesary examinations. The interaction in the round-procedure is a very important quality assurance activity in radiology. Such cooperation in rounds is essential to establishing high diagnostic quality and to continuously improving quality.

All the images taken in the radiology departments and copies of the written requests from and reports to the referring physicians are stored in the radiology image archive or in the central hospital archive. Although loss of films occur, this is not generally regarded as a major problem compared with countries where the films belong to the patients or to the referring physicians. Furthermore, up to now the health care system in Sweden has been organized in such a way that citizens generally belong to, and receive care from, a specified hospital. This has helped keep most of the x-ray films from one patient at one hospital. However, this organization is about to be changed to allow more freedom to patients to choose their preferred hospital.

The way the health care system and radiology are organized will significantly influence the need for PACS and the way PACS will be introduced. Consequently, the advantages and disadvantages of PACS in one system may differ from experience obtained in other countries. The organization of radiology in Sweden and increased international experience with PACS may explain why the general interest in PACS in Sweden is now growing for some applications.

## PACS IN SWEDISH HOSPITALS

Larger PACS installations do not exist in Sweden, but some hospitals have experience with limited PACS activities. At present four mini PACS are in use in radiology departments, and other hospitals plan to start PACS projects. However, it is difficult to raise funds for investment in such projects.

*Karolinska University Hospital, Stockholm*

Planning for a PACS project at the Karolinska Hospital in Stockholm started in 1984 and the project commenced in 1986. The aim of the project was to investigate the possibilities of fast transmission and access of images, and to gain experience about the PACS-environment as a base for further developments. The project referred to the integration of four image sources into a network (Imnet) together with a workstation (Imtec). It was planned to extend the system with an image archive and a link to a Radiology Information System (RIS).

It was found to be difficult, however, to develop special interface with the image sources. Difficulties in obtaining necessary documentation from some of the suppliers made this work either impossible or very difficult. Two image sources could however be connected to PACS, a CT, and an MR (both Siemens).

Mainly due to financial problems, it was not possible for the project to be as extensive as planned. For example, the image archive and RIS could not be connected. The general experience gained from the project was that an individual development of interface of image sources without standards could be complicated and costly, that standards should be used as far as possible, and that handling procedure (human interface) must be very simple.[7] This project has now ended.

Another image network development at the Karolinska Hospital Neuroradiology Department, started in the mid 80s. The long-term goal was to integrate existing and new digital imaging sources as the medical need became pronounced, and as technology and financial resources became available. At present an Ethernet network (with DECnet or TCP/IP protocol) links together 1 MR, 2 CT, 2 PET, and 1 DSA. Images from those sources can be retrieved and processed on an image workstation (HP) and can be transferred to a treatment planning system and be stored on an Exabyte magnetic tape cassette system (about 2 Gbyte per tape). As yet, no optical discs, jukebox or RIS are connected to this installation.[8]

*University Hospital in Lund*

Since 1987 there has been a CR system in operation at the Lund University Hospital. This was supplemented in 1989 with an image workstation (Siemens). The system also contains an optical disc drive unit for image archiving for research purposes. There are plans to link the CR system to an image display station at the intensive care unit.

Currently, a digital CR chest stand (Fuji) is being installed and connected to the same laser film printer as the previously mentioned CR system.

Another project in Lund is centered around an image workstation (Imtec). On line with this workstation is an MR (Fonar) via an Imnet network (16Mbit/s) and a teleradiology system via ISDN (64Kbit/s) connected to a CT unit (Siemens) in a hospital in Ystad, a town less than 100 km from Lund. A CT (Toshiba) is also interfaced to the image workstation via floppy discs. There are also plans to connect DSA to the same workstation. As yet no image archive or RIS is connected to the network. Separately, a RIS is in use in Lund.

*University Hospital in Uppsala*

The University Hospital in Uppsala has recently established a network (Imnet) between a CT and an MR unit (both Siemens) and to an image workstation (Imtec). The same workstation is also used for teleradiology with Gävle and Östhammar about 100 and 75 km, respectively, away from Uppsala. A RIS system is being installed (Rados).

*County Hospital in Jönköping*

Since 1989 there has been an Ethernet link between an MR and a CT unit (both Siemens) in the new county hospital in Jönköping. A four CRT-monitor PACS (Siemens) consol is connected to this link. The PACS console is placed in the MR building and is used to send CT images to the MR site. The consol is also used for weekly neuroradiological conferences (rounds). A link has also been established recently to a dose planning system (Helax) located in the oncology department.

## PACS IN NUCLEAR MEDICINE DEPARTMENTS

About 35 hospitals in Sweden offer nuclear medicine services and are equipped with gamma cameras. Together these hospitals have about 100 cameras.

Small PACS are installed in about seven hospitals in nuclear medicine departments. The first installation was in 1989. At present, a typical such PACS consists of a network (Direct Linc) connecting two to three gamma cameras (General Electric) to a PC-based image workstation that also serves an optical 5-inch disc drive for storing images (no jukeboxes installed).

The first organizational consequence is to eliminate the floppy discs used mainly by large nuclear medicine departments for storing images for potential image processing and research. However, film is still used as the main image archive media.

## TELERADIOLOGY IN SWEDEN

The development and use of teleradiology in Sweden started in the early 80s with a small Swedish company developing equipment based on input of analoge images from a TV camera, digitizing the images into a 256 × 256, 6-bit deep matrix. The equipment and method were tested and found useful in certain applications of image transmission between hospitals.[9] Image quality was, however, limited and the public network allowed only a relatively slow image transmission. These conditions prevented the diffusion of the method in Sweden.

However, the interest in teleradiology has increased sharply during the last few years. This is mainly due to the fact that technology now permits much better image quality than previously, and that telenetworks today allow much faster image transmission.[10]

There are now about 12 teleradiology systems in Sweden, provided by three suppliers (two local and one international company). As we have no established standard for image transmission these three systems work with disparate image transmission data formats and can not be interconnected.[10,11] This naturally impedes further expansion and restricts the utilization of a teleradiology network. Faster standardization of this area would, therefore, appear to be urgent.

## PROGRAM FOR DEVELOPING PACS AND RELATED TECHNOLOGIES

The Swedish government has stimulated the development and use of information technology (IT) in different ways during the 80s. One such action is the so called IT-4 national program with a 3-year budget (1988-1990) quivalent to about 75 million dollars.[12] This program focuses on industrial developments and is not specificly medically oriented.

However, the Swedish National Board for Technical Development established a support program in 1989 with the intention of stimulating the development of digital imaging products for the healthcare sector. The program will extend over 5 years, and has a budget equivalent to about 4 million dollars. After about 1 year of operation the program has distributed funds to about 15 small companies and research teams.

Sweden is participating in some common European projects. One such project is Telemedicine within the RACE program (Research and Development in Advanced Communications Technologies in Europe).

During the spring of 1990, the government financed seven pilot studies with the aim of obtaining proposals for projects of importance for development and the use of information technology in the public sector. The pilot study addressing health care, conducted by Spri resulted in proposals for about 15 projects regarding PACS, telemedicine, and teleradiology.[13]

Spri, The Swedish Planning and Rationalization Institute for Health and Social Services, is a fully-public health-care research and development institute that advises and supports the Swedish county councils in their work to change and improve health care delivery. Spri has followed the PACS development during most of the 80s. The first Spri report on PACS was published in 1987.[6] Currently, Spri is conducting a new PACS project with the goal of reporting in 1991 on the status of PACS in an international perspective.

## CONCLUSIONS

Due to technical achievements and increasing international experience, PACS and teleradiology has received more interest in Sweden over the last few years.

However, radiology is organized very differently in the United States, Japan, Southern Europe, and Scandinavia. The way radiology is utilizied as well as the way that radiology service is organized influences significantly the need for PACS and the way PACS will be introduced in

each health care system. Consequently, the advantages and disadvantages of PACS in one system may differ from other health care systems.

Although some very limited tests have been carried out with PACS in Sweden, we lack experience in using somewhat larger PACS in clinical routine applications. It is necessary to gain experience from daily routine work in order to evaluate the suitability of PACS, telemedicine, and teleradiology, and to determine whether they can contribute to improving in the Swedish health care environment.

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