

Adoption-related Aspects of an Information System in a Health Care Setting

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Abstract

Objective. *The goal of this paper is to highlight some health care related issues with regard to Information Systems implementations. This case study is connected to the adoption of a Picture Archiving and Communication System (PACS) in Turku University Central Hospital. PACS is an Information System, which handles radiological film images in digital form. Benefits, costs and drawbacks are discussed.*

Methods. *The results are based on a four-year survey consisting of statistical data, cost analysis, modelling, customer satisfaction inquiries, time and motion studies, observation and staff interviews.*

Results and discussion. *Less than 1 % of the hospital budget was dedicated to the implementation and adoption. PACS was expected to eliminate the use of film- and paper prints, and introduce a new working environment. After four years of adoption one clinical customer unit shifted to filmless activity, namely the Intensive Care Unit (ICU). Availability of imaging requests, imaging studies and radiology reports was improved to 100 % from 87-88 %. A staff member was dedicated to the manual transfer of digital images to the wards. Film acquisition costs were not reduced as anticipated. Personnel tasks will reduce only to the degree to which paper and film prints will be renounced. Also, new tasks will emerge due to PACS.*

Conclusion. *Hospital staff was unprepared for the change. Inexperience regarding informatics, system behaviour, and lack of designated expert personnel slowed down the implementation process. In general there is inexperience regarding digital archiving of medical images, which hinders efficient adoption. Technology providers had not sufficient information or knowledge of clinical requirements. Budgets were not adequate for the build-up of a comprehensive cost-effective system. PACS did not overcome any of those concerns it was expected, but added new concerns.*

1. Introduction

Modern medicine is information loaded, and makes use of several elaborated test results, for example laboratory- and radiological examination results, just to mention a few. All these need to be available to the physician at the moment of decision-making. Currently, more and more sophisticated digital medical technology, including Information Systems (IS) is in use. As the rate of digital medias has grown, it has become evident that these should be connected in order to allow smooth information flow. Digital medias of health care, such as imaging and radiological image networks, commonly denominated as Picture Archiving and Communications Systems (PACS), and Electronic Patient Records (EPR) are nationally being adopted. The goal of PACS is filmless radiology, which means that electronic databases are used instead of film archives. Radiologists read images on monitors and clinicians may view them on PCs, and images are stored in tapes or discs. EPRs include patient demographic-, appointment-, laboratory- and PACS.

There is a need for integrated IS, and PACS is a prerequisite of an EPR, because imaging information is relevant for patient care. The focus of IS is on providing patient-friendly, effective and efficient services. PACS allow medical imaging studies to be sent instantaneously available in different health care units (=teleradiology). Consequently, earlier diagnoses are possible, thus allowing immediate treatment decisions. In some medical conditions this is crucial. Regardless of the location of the patient medical expertise become available, which increase patient democracy, and the quality of care. Patients need not to be

transported where the need expertise is, but their imaging results are transmitted via networks.

Finland is divided in 20 Health Care Districts, which are responsible for providing the specialized health care services. Municipal entities may decide independently how to organize basic services. There are over 200 different IS in use in a country with a population of 5.2 million people. These networks and IS often are not compatible. Turku University Central Hospital (TUCH) offers specialised health care services to half a million people in Southwestern part of the country. The hospital includes 828 beds, and it is the second largest of the five university hospitals of the country. In 2001 during 236 791 ward days it provided 51 002 ward periods of the average length of 4.6 days within the framework of a 208 745-euro budget, and a 10 % increase in costs *p.a.*

TUCH disposes of several IS, originally acquired to perform specific tasks within separate departments. The core system is the Hospital Information System (HIS), which handles patient demographic data. The Radiological Information System (RIS) handles imaging appointment data along with patient demographic data, to which PACS is parallel, and together all of the hospital IS, form the EPR. Today, it is acknowledged that these systems need not only to compatible at hospital or at municipal level, but also nationally, in order to benefit from the full potentials of telemedicine.

The Medical Imaging Centre (MIC) is a diagnostic information provider. Patient treatment is based on the imaging study results, possibly along other data. Imaging has evolved to embrace digital techniques, such as Ultrasound, Computed Tomography, Positron Emission Tomography and Magnetic Resonance Imaging. Digital archiving of this information has been seen a logical solution to handle the extraordinary digital growth of the branch. The MIC produces 140 000 yearly examinations corresponding to 5 Terabytes of data to be stored, and sent back and forth between radiologists, archives, wards and clinics. On a daily basis, 600 films bags are transported with charts within the hospital.

TUCH was the first Finnish hospital to adopt a PACS. In 1995 a 0.5 TB digital archive was installed and its' impact was studied between 1997-2001. During this period the archive was upgraded to 12 TB. In the beginning of 2004 a new all-digital, paper-and filmless annexing building will be opened. It will include departments of oncology, pulmonary diseases, and surgery. The evaluation shall be continued, and it will include an EPR system, which will be installed.

In this study the consequences of adopting PACS are scrutinized. The research target is new and demanding. It includes informatics, computer sciences, radiology and health economy. Image networks embrace vast entities of patients, personnel and new technology. The newness of the field, lack of a sufficient, adequate and compact research communities and lack of funding have prevented to achieve solid results. Existent medical literature is mostly based on assumptions; merely 3 % of available studies fill scientific criteria [1]. All aspects of IS need to be explored in order to guide the technological development into a favourable direction to create functional information systems.

The goal of this paper is to describe some particularities of health care service delivery from the point-of-view of management of information, and from the point-of-view of IS installations. Results regarding implementation costs, patient care, personnel and customer satisfaction are summarised. Benefits and drawbacks of the system are discussed. These particular questions are answered:

- *How much does a PACS cost?*
- *Does PACS improve workflow?*
- *Are patients being taken better care of with the new system?*
- *Does PACS improve information management?*

2. Methods and materials

2.1. Cost analysis

Data regarding equipment investment and rental costs was extracted from the books of the

Accounting Department, and from the Radiology Administration.

2.2. Modelling

Workflow regarding film- and filmless activity was depicted with the help of a modelling software (QPR Ltd.). The flow-charts were based on time and motion studies, observation and staff interviews.

2.3. Time and motion studies

The imaging visits of 120 patients were followed by a medical staff member, who performed the time and motion studies, filled a follow-up form, and interviewed staff. Staff was not informed that their working processes were recorded parallel to the patient follow-up.

2.4. Customer satisfaction

The end-users of the system, *i.e.* doctors and nurses, were inquired about their satisfaction regarding PACS. They filled in a customer satisfaction inquiry form.

2.5. Statistical data

General statistics was consulted to search back-up data for different situations regarding patient amounts, numbers of procedures etc.

3. Results and discussion

3.1. Alternative cost analysis of film and PACS activity

Costs depend on the level of observation. The choice of focus was that of the MIC, and only direct costs were accounted for. In 1998 the cost analysis showed a 21 % increase in direct costs. The alternative cost analyses of traditional and digital activity included the identification and calculation of merely those costs, which were expected to be affected by digital archiving. The radiologists' wage costs, which represented approximately 50 % of the unit's budget, were not anticipated to change, and they were not included

in the calculations. The PACS related direct costs represented less than 1 % of the total hospital budget, and roughly 4 % of the MIC's total expenditure.

It was estimated that a full scale PACS would lower the increase of projected costs to 16 %. The implementation of a full scale PACS would cause a substantial increase in lease and maintenance expenses, which could be partly compensated for, by further reduction in film consumption and clerical personnel. Digital archiving increased the cost of investment in equipment and maintenance. PACS induced costs were split between equipment purchase, 32 % (archives, workstations, data network, film digitisers), maintenance 8 %, and supplies 22 %.

PACS lowered the cost of personnel wages and supplies. The need for film printers will decrease, as film printing will be reduced. Less digitisers will be needed as more and more images are electronically stored and available. In the first years of the partial PACS only 10 % film savings (2 % of total costs) were observed. These film savings were partly due to a change in the use of printing options, and only partly due to the fact that the digital archive was in use. Personnel wage savings represented a 9 % reduction in total costs. These savings were partly due the increasing use of CR, and only partly due to digital archiving. The need for clerical staff and darkroom technologists decreases as digital activity develops further. Work duties will change. Partial digital archiving was pursued parallel to traditional manual activity. Initially, two radiology nurses, in addition to their normal duties, were assigned to PACS related tasks. No PACS personnel were hired. This has been a general hospital policy in the early days of PACS. Presently one PACS engineer is hired.

The choice of focus affects essentially the results of cost analyses. Two alternatives are compared when results are expressed in percentages. The alternative against which costs of digital archiving are compared may be a part of the costs of the imaging department, all costs of the imaging department, or all costs of the hospital. The bigger the focus the lesser the costs appear.

Early on, there were suspicions about the profitability of PACS. An increase in costs is an inevitable consequence of new investments. In fact, in Hammersmith Hospital, London, PACS substantially increased running costs in addition to

yearly investment costs of 2,8 million euro, and no convincing evidence of a reduction in length of inpatient stay was found. In addition to PACS, demographic and medical variables, physician and hospital related variables may explain variations in hospital-length-of-stays [2]. However, Pilling [3] pointed out that recent technological improvements and cost reductions in hardware, software and networks, together with the increase in advanced CT image presentation encourage further installation of PACS. He suggested that the strategic goal of PACS and added value should be clear, and circumstances should affect decision-making, predicting that still further technological and positive economic developments were underway, and that PACS is part of the EPR, which will eventually gain more territory.

The gradual implementation of PACS augmented both workload and costs. Film printing was continued because of the lack of a sufficient number of workstations, especially in the doctor's offices. The savings were dependent on the degree to which old procedures were replaced by new procedures. Film material costs decreased only to the extent to which viewing monitors were installed, and printing ceased. A considerable number of work processes will be eliminated as more monitors are installed. The lifetime of display monitors, and their quality control will affect both costs and efficiency.

Dissimilar data protocols need to be interfaced, and PACS needs to be merged with existing activity. This was particularly complicated, since it was done in-house. Inevitably, PACS is to be integrated with the other hospital IS, which will further complicate to allocation of expenses to a particular IS. It has been suggested that, developing one-time in-house expertise can be wasteful, especially if skilful consultants are available [4]. In 2000 Chopra [5] argued, that the payoff for PACS was not fully realised until widespread clinical use. He proposed the Application Service Providers model (ASP), based on the pay-as-you-go formula, and ideally has the advantage of reducing the initial investment costs and the need for IT personnel. However, organisational learning will not take place.

Costs and savings represented merely one aspect of the digital archiving project. There were some indications of efficiency and quality improvement, but further studies are needed to verify the economic impact of PACS on a hospital-wide scale. Evidence regarding PACS is strongly

circumstantial. It is a natural result of the variation of the clinical circumstances and activity. The bigger the institution is, the larger the network and the greater the amount of activity. The size, location and architecture of the imaging units affect costs. The closer imaging facilities are to each other, and to the wards, the simpler the network and hardware architecture and activity re-organisation. The underlying disagreements of the impact of PACS are the different cost and circumstantial assumptions [6]. Gradual implementation and varying base assumptions about cost have affected the results. Whilst there has been agreement about the existence of non-financial benefits, these have not been accounted for. The results of an economic evaluation will vary depending on the factors included in the comparison. It is advisable to include as many criteria as possible. Those criteria, which may have a minor impact, should also receive minor attention. A meticulous cost analysis would even consider the time of costs and the cost levels of different countries and even changes in costs.

Cost analyses are easier to carry out in comparison to benefit analyses. It is more convenient to agree about how much hardware is needed, and how much the cost is, than to reach consensus about the benefits. The fact that digital image folders are created by a radiologist for demonstration purposes in the ICU premises, instead of a technologist hanging the images on view-boxes in the radiology premises, is a benefit to the ICU clinicians, but from a cost point of view is a drawback to the imaging department. What is a benefit in one place might be a loss at another place. The difficulty lies in determining the value of benefits and drawbacks, whatever the chosen measure is, because value is connected to priorities, and priorities are connected to people.

It was predicted that in some cases the shift to hospital-wide PACS could take two to three decades, and as a consequence of running to parallel systems, it would be necessary to provide floor space and other resources for both traditional and digital systems Naylor [7]. There are indications, that insufficient imaging information availability might lead to indirect costs. Recently PACS has been seen a means of saving dollars. However, in this case PACS introduced expected and, unexpected costs for example in the form of database migration. There is also evidence that PACS is not infallible [8]. Magneto-optical discs were thought to be invincible against other than

physical destruction [9]. In a study conducted in TUCH, high rates of optically stored images remained inaccessible, for unclear and unexamined reasons [10], because of cost justifications. Jorulf et al. [11] observed a loss of six examinations of 50 000 examinations.

The proliferate PACS publications offer a wide range of varying results, and based on these, it is possible to sustain nearly any claim. Many are theoretical works, based on estimates and assumptions, which *per se* does not minimise their value, but limits their applicability. They give a valuable framework for research but little true-life information for decision makers. There is now enough evidence that PACS does indeed trigger unexpected costs of which there should be more knowledge.

3.2. Workflow, patient care, and personnel satisfaction

Imaging procedures themselves are in most cases short. Both traditional and digital activities were followed with the help of a stopwatch. During the survey periods imaging visits usually took an hour, with a variation of 12 minutes to nearly two hours. In 30 % of the cases the prior comparison images of the patient were not available at sign up. Bottlenecks, identified by the activity analysis, caused patient queuing, and thus to unnecessarily prolonged visits. Problems were identified which were related to the organisation of the delivery of imaging services: examination availability, image and report delivery. The large number of work processes and personnel involved suggested that the adequate production of services was sensitive to organisational arrangements.

There were several work processes before patients' arrival. It was measured, that the film activity involved up to 36 work processes for one imaging visit. Image folder search, archiving, identification, and gluing of various colored tags alone prompted 12 work processes. As patients signed-up for an imaging study, radiologists requested existing previous images from the same anatomic area. Film jackets for inpatients were usually located in the wards, available for review by clinicians. If the patient underwent several imaging studies in the same day, the film jacket traveled back and forth from the ward to the MIC. In order to locate film jackets, medical and clerical

staff frequently called the archives and wards, of TUCH or even other hospitals. The use of several paper prints complicated the activity and added to material cost, and were misplaced or lost temporarily.

In a large working environment it is a challenge to match the patient with the jacket including the correct images at exactly the needed time. Searching for films in the archives and delivering them to the imaging departments and wards is human resource consuming. The flow chart regarding the digital activity demonstrated that theoretically digital archiving could reduce work processes from 36 to 9. During the study period, historical data was not always in digital form, nor could the hard- or software meet the prerequisites of a completely electronic environment, and some analogue activity was driven in parallel.

In the future, the scheduling of an imaging study will automatically trigger the prefetch of previous images from the archive server, and previous reports from the RIS / PACS broker. With regard to urgent unscheduled patients the entering of the imaging request will trigger the prefetch. Radiology technologists will archive the images on a WS after quality assurance. Images will automatically be routed to the imaging and WEB servers. The clinician may review these previous images and reports on a WS via the WEB server simultaneously with radiologists and radiology technologists.

3.3. Patient care

After 6 years of PACS adoption the first clinical client unit shifted to filmless, namely the Intensive Care Unit (ICU). PACS allowed a remote high-occupancy unit to receive diagnostic imaging information at the site. Before PACS the ICU doctors used to walk to the MIC to view their critical patient's images and discuss treatment with radiologists. The benefits might compensate for the costs of PACS, but this was not measured in this study, due to limited research resources.

Patient care in the Intensive and Emergency Units has been estimated to benefit from rapid access to diagnostic information [12]. In demanding patient care settings the uninterrupted presence of doctors is desirable. In one set-up PACS substituted a 20-minute daily walk by several clinicians to the imaging section. Substantial improvement of imaging information

availability has been observed [13,14]. Improvement of efficiency of information provision *per se* might not necessarily lead to significant improvement of patient outcome.

Efficiency of patient care has been demonstrated to increase with PACS [15]. In other clinical settings such an increase of efficiency has not been documented [16,17,18]. These contradictory findings further suggest, that the impact of PACS is circumstantial. Faster delivery speed was found to have an accelerating effect on clinical decisions [15, 19,20]. It was argued that organisational factors other than PACS appeared to determine the instigation of image-based clinical actions [21]. It has been predicted that PACS might have an impact on patient-length-of-hospital stay, which in this was not shortened [22], nor has it been observed elsewhere.

The work processes diminished by 50 %. Conferences were held in the premises of the ICU, instead of MIC. Digital conference folders for each patient were created by radiologists, instead of technologists hanging films. Images were available when they were needed simultaneously in a procedure and in a conference, instead of missing from the conference room. Erroneous data on digital images was corrected already at archival before conference, instead of films being brought upstairs and re-labelled during conference. Computed Tomography (CT) examinations produce over hundred images, the digital option allowed only relevant CT images to be copied to the image folder, instead of entire sheets being hung onto the light-boxes. These changes suggest that the quality of conferences improved.

Sometimes imaging requests are not entered, although intended, to RIS in the ICU for several reasons. Entering protocols might be unfamiliar or cumbersome, or there may be something more urgent requiring the attention of the physician. Sometimes the imaging study might not be correctly connected with the request. It has been estimated that from 3 to 5 % of requests remain unbilled due to failure of information entry [23]. The non-entered requests represent a loss of income to the imaging department, because budgets are based on expenditure. It has been pointed out by Langlotz et al. [24] that the availability of accurate billing data would help to evaluate the economic impact of PACS. Correct charge entries are a measure of the size of the activity and may be converted to corresponding costs.

Each time an imaging request was entered to RIS an accession number was created for identification and later prefetching purposes. The archive did not accept images of patients whose imaging requests were not introduced to RIS. Wards and clinics were charged for performed imaging studies accordingly. During the survey period, a 12 % decrease in the loss of income occurred due to the elimination of non-entered requests. Reports were entered into the radiology information system on average one hour 20 minutes earlier in the soft-copy follow-up period, which was due to working arrangements caused by the use of PACS. Missing requests and reports were eliminated. The availability of images increased from 88 % to 100 %. The use of image manipulation in the preparation and presentation of each patient case contributed to increased quality of softcopy conferences.

Resource-saving and meaningful changes require adjustments in the whole process, which should be anticipated by comprehensive planning and timing. Planning and training was executed with existing resources. Flowcharts demonstrated the simplification of the processes. The rationalisation of entire cross-departmental processes took time *inter alia* because of the several administrative protocols. Staff needed to be informed of coming changes and prepared or trained for them. Daily conferences added to the departmental workload, and they were an essential part of patient care.

The results suggest that by introducing PACS between intensive care and MIC, it was possible to improve the quality of the activity, when criteria for measuring quality were material cost, availability of imaging requests, prior and recent examinations and reports. Imaging request availability was increased to 100 %, which suggests that in this respect PACS might have a positive economic impact. It is possible that similar cost savings are achievable across the entire imaging activity, wherever missing requests have been observed. The results of one client clinic or ward are not necessarily applicable to other wards, but may give an idea of additional and further hypotheses to be tested.

3.4. Personnel satisfaction

User satisfaction is crucial to adoption success. Obviously the new system needs to be better than the old system. Of 210 staff members, 135 persons answered the questionnaire (85, doctors, 40 nurses and

10 other personnel). After 12 to 24 months clinical staff were not fully satisfied with PACS or RIS. The availability of images was still regarded as incomplete. It was estimated that the dismissal of clinical patients was delayed by 15 minutes from 3 hours, regarding ward patients by up to 24 hours, and for patients from other hospitals up to four days.

Table 1. A summary of the results of the customer satisfaction inquiries performed in 1998-1999. Satisfaction level of clinical staff is indicated by percentages.

| Question | Satisfaction |
|---|--------------|
| Knowledge regarding RIS | 70 % |
| Knowledge regarding PACS | 30 % |
| The services of MIC | 26 % |
| User friendliness of the scheduling speed | 30 % |
| Request writing speed | 60 % |
| Image arrival speed | 50 % |
| Report arrival speed | 50 % |
| Digital image arrival speed | 15 % |
| Digital image quality | 50 % |
| Amount of training | 40 % |

There are altogether 2000 medicals and nurses. As a teaching hospital, part of the personnel is always new. These need training. Also, new systems are adopted, or old ones upgraded. The low percentage for PACS knowledge reflects the fact that at the time of the installation of the system, it was fairly unknown to personnel as a whole. The low satisfaction rates indicate that MIC as such was not a sufficiently efficient service provider.

4. Conclusion

PACS cost more than traditional activity when direct costs and savings were compared. The implementation adoption was too slow. It improved workflow, but with extra efforts. The benefits might compensate for the costs of PACS, but this was not measured in this study. Patients benefited from the system. PACS did improve information exchange, when it was working.

The usefulness of PACS has commonly been approached from a cost point of view. Throughout the

existence of PACS cost interpretations have embraced all the possibilities: that PACS is less expensive, as expensive, and more expensive than conventional film operation. There is general acceptance that PACS might induce some benefits. These costs should be compared with the indirect costs of delayed, incomplete or unsuccessful access to imaging information.

The pursuit of cost analysis, cost-benefit analysis and cost-effectiveness analysis, in its present form, will produce the same kind of information that is available already, and a new approach is needed. The increasing efficiency and quality demands imposed on public health care could benefit from adopting certain sound manufacturing principles.

From the point of view of workflow, digital archiving enabled fast access to imaging information. But not without sacrifices: a staff member was dedicated to retrieve previous comparison images from the digital archive. Digitalisation of film images increased workload. The archive could not select, locate or transmit imaging studies automatically to the wards, but there was a person assigned for the job.

Although, it was anticipated that patients would benefit of the system was beneficial, the imaging study visit was not shortened, because of the halfway-implemented system. However, those patients undergoing a procedure in the morning could have their images simultaneously in the operating room and in Radiology, whereas they used to miss from either. As more PCs became available, clinical staff was satisfied with the fact that images were immediately retrievable. Downtimes created extra workload in the MIC.

Nonetheless the present study indicated that certain aspects would gain from digitalisation, an increase in costs was detected. Hardcopy activity was continued parallel to softcopy activity. More resources were used and better results were achieved. Improved efficiency was only partly due to the fact that films were not used. Investments in PACS related equipment competed continuously with other investments across the hospital. Compatibility of IS would facilitate information exchange and co-operation between health care units, and improve patient care. However, an efficient information infrastructure needs efficient funding. It appears from the public discussion today there is lack of funding for basic health care operations. Information systems would come to cost

additionally. How can we justify these extra costs, when entire departments are shut down?

The study of the impact of IS installation in health care requires an adequate and sufficient research team. It is a prerequisite, that informatics, medicine, computer sciences and health economy are combined. Such team is under construction in Finland. It is extremely important now, since the Ministry of Health- and Social Affairs has made a decision that all Finnish Health Care Districts will adopt an EPR. University hospitals are used to dealing with medical students, but feel uncomfortable with outsiders. This attitude must be overcome, because these teams work for the benefit of medical staff, who themselves are qualified rather to study medicine than to study Health Care Information Systems.

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