From the Department of Radiology
Göteborg University, Göteborg, Sweden

Economy in Radiology

Jonn Terje Geitung

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ECONOMY IN RADIOLOGI

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I Geitung JT, Göthlin JH, Uhde A, Aslaksen A. Calculation of internal costs in a department of diagnostic radiology. Europ J Radiol 1988;8:180-182.

II Geitung JT, Gadeholt Göthlin G, Göthlin JH. Cost appraisal of automatic daylight film processing systems. Radiol Diagnostica 1994;35:62-64.

III Geitung JT, Wikström T, Zeuchner J, Göthlin JH. Cost-effectiveness of colour duplex sonography compared with angiography of the pelvis and lower limb. Eur Radiol 1995;5: in press.

IV Geitung JT, Rosendahl K, Sudmann, E. Cost-effectiveness of ultrasonographic screening for congenital hip dysplasia in new-borns. Skeletal Radiol 1996;25: in press

V Geitung JT, Göthlin JH. Economic consequences of patients arriving late or not keeping appointments: evaluation in and comparison between two departments of radiology. Eur Radiol 1994;4:172-174.

VI Geitung JT, Göthlin JH. Where is the doctor? Waiting for radiologists. Eur Radiol 1994;4:63-64.

ECONOMY IN RADIOLOGY

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ABSTRACT The present economic squeeze in the public health care sector necessitates investigations in resource allocation and resource use. As radiology has high technology equipment rather than beds, it is commonly regarded as a suitable department for developing models of cost analysis and cost-minimization, cost-benefit, cost-effectiveness, cost-utilization analyses. Such analyses may change planning, administration and organization of radiology departments and stimulate research in other medical disciplines.

Ultrasonography (US) is a rather inexpensive modality often operated by non-radiologists. US, as a method, has been tested in three clinical settings. The first setting involved the replacement of intravenous urography with US and yielded positive results for possible cost-minimizing interventions. The analysis of US versus pre-operative angiography in patients with critic ischaemia did not give results indicating US to reduce costs. Finally, US screening for congenital hip dysplasia in babies was found to be cost-effective only for defined risk groups.

The replacement of conventional roentgen film dark room processing with automatic daylight film processors amortized the investment within two years and also yielded substantial annual savings.

Cost-analysis of time utilization due to patients either being late or not showing up for their appointments yielded substantial economic losses. Factors, which could be changed to improve this situation include patient registration and transportation, as well as physician availability.

Key words: Health economy, cost-benefit, cost-effectiveness, clinical utility, effectiveness, efficiency, resource allocation, waiting-time, personnel utilization, administration, ultrasonography, angiography, congenital dysplasia of the newborn hip, automatic daylight systems, intravenous urography.

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Articles

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Abstract

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Key words

Health economy. Cost-benefit. Cost-effectiveness. Clinical utility. Effectiveness. Efficiency. Resource allocation. Waiting-time. Personnel utilization. Administration. Ultrasonography. Angiography. Congenital dysplasia of the newborn hip. Automatic daylight systems. Intravenous urography.

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Preface

A path through politics, organizational work and research in the fields of social care and public health lead me to some «unorthodox» radiological research, namely economics in radiology.

My supervisor, professor Jan H. Göthlin, introduced me to this kind of research as he found it to be in accordance with my previous works and interests. He has been an inspiring source of support throughout all my investigations, and I especially wish to thank him as I reach the milestone of presenting a thesis.

The research has been conducted at Haukeland Hospital in Bergen and East Hospital in Gothenburg. I have at times strained the resources of the personnel at these hospitals. It is now time to say «thank you» for filling in my forms and answering my questions.

Applying problems of economics to the medical profession may not always be suitable. However, as more of my colleagues confront the reality of dwindling resources, there will be an increased understanding of the necessity of this type of investigations.

I would like to express my gratitude to the Nordic School of Public Health in Gothenburg and the Institute of Social Economics in Bergen. These institutions provided advice concerning health economics and resource allocation.

Doing research in the two countries, and having had the opportunity of comparing hospital routines, have been an interesting experience. Although we are dealing with two countries with as similar systems as Norway and Sweden, it has been rewarding and has widened my knowledge of the health care systems.

Göteborg, April 18,

Jonn Terje Geitung

Contents

Abbreviations

ADS:	Automatic daylight system
CDH:	Congenital dysplasia of the hip
CDS:	Color flow Doppler ultrasonography
DSA:	Digital subtraction angiography
EH:	East Hospital, Gothenburg, Sweden
HH:	Haukeland Hospital, Bergen, Norway
HOH:	Hagavik Orthopedic Hospital, Bergen, Norway
IRR:	Internal rate of return
IVU:	Intravenous urography
NPV or DNPV:	Net present value or discounted net present value
US:	Ultrasonography
NHS:	National Health Service. The publicly financed health service of the United Kingdom of Great Britain and Northern Ireland

Definitions

Cost-analysis: Analyzing cost. A partial economic analysis(1,2).

Cost-minimizing analysis: The consequences of two or more alternatives are examined alongside costs. When shown to be equivalent, the study is a cost-minimization analysis. If two diagnostic examinations are found to be otherwise equivalent, the remaining comparable item is cost. Thus, a cost saving procedure may be undertaken on the basis of a cost-minimizing analysis (2).

Cost-benefit analysis: Determines which one of two or more projects is found to be the most profitable. An analysis of costs versus benefits are summarized in monetary terms (any local currency) (2,3,4,5,6).

Cost-effectiveness analysis: Measurement of the costs in monetary terms versus specific effective factors, e.g., improved morbidity, mortality or as is the case in most of this thesis - radiological diagnosis. No attempt is made to value the consequences (1,2,3,6,7,8).

Cost-utility analysis: Determination of the costs in monetary terms and utility gain measured in quality adjusted life years (2,7,9,10).

Net present value: The net present discounted value of the investment is the present value of the benefits less the present value of the costs. If outlays are being regarded as negative net benefits, the net present discounted value of an investment stream is the sum of all the net benefits when discounted to their present value. It is represented by

$$P = \sum_{t=0}^{n} F_t (1+r)^{-t}$$

if P = present value, F_t = future benefits or costs (benefits-costs) at year t, r = annual interest (discount) rate, n = number of years (4).

Internal rate of return: The internal rate of return is the rate of discount which makes the present value of the benefits exactly equal to the present value of the costs(4).

Opportunity cost: The utility of the second best alternative (2,3).

Cost-accounting: Cost-calculation. As a part of cost-analysis .

Clinical utility: The clinical usefulness (to either the patient or the physician) of an examination or a procedure. In radiology, the usefulness also applies to the referring physician requesting the radiological exam (2,3).

Efficacy: In radiology one may call it the amount of information an examination provides and its ability to classify disease or disease stages, when studying the examination under optimized conditions (2,3).

Efficiency: In radiology it describes an examination's ability to achieve the best possible clinical utility at the least possible expenditures. Lower monetary costs and improved clinical utility indicate greater efficiency (2).

Effectiveness: Does the procedure, service, or program do more good than harm to those people to whom it is offered? This form of health care evaluation, which considers both the efficacy of a service and its acceptance by those to whom it is offered, is the evaluation of effectiveness or usefulness (2,3). In radiology we define the service as examinations. The examinations are either offered to referring physicians or patients. Normally effectiveness is referred to as improved examinations, either improved diagnostic work, more comfortable or less hazardous (less complications) examinations.

Sensitivity analysis: Evaluates the stability of the conclusions of an analysis to assumptions made in the analysis. When a conclusion is shown to be independent of the assumptions, confidence in the validity of the conclusions of the analysis is enhanced(2,7).

Ultrasonography, Doppler, color coded Doppler ultrasonography: Ultrasonography is based upon the same principle as SONAR and RADAR. The SONAR was first invented during W.W.I in order to search for submarines. It is done by transmitting soundwaves from a source and then register the reflected sound. In a modern ultrasound transducer, the PIZO-electric crystal emits and receives the ultrasound impulses. The soundwaves do normally have frequencies between 2 and 10 MHz. The physicist Doppler first described that alterations in speed caused changes in the sound from the object having that speed. The frequency would

alter according to the speed. (A train coming towards you would emit a soundwave with an increasing frequency as it approaches). This principle has been used to calculate the speed of particles, in medicine the velocity of blood flow. By adding color, one can code the areas including particles with a velocity, and thus see a blood flow (11).

Angiography and digital subtraction angiography: In order to visualize arteries contrast media are being used (12). This contrast media is injected through a catheter which has been inserted into the artery. To perform a subtractional angiography one uses a «mask». A picture without contrast media is subtracted from the picture with contrast media. This way, disturbing artifacts may be removed. Digital Subtraction Angiography (DSA) is performed by a computer by digitally doing the subtraction (13,14).

Roentgen Rays or X-rays: In 1895 Wilhelm Conrad Roentgen first described the X-ray. Fluorescence that penetrated the skin and visualized the bone. What is used in radiology is photons omitted from a source towards an object and registered on a film behind the object. The density of the object reveals a picture used for diagnostic work (15,16,17).

Radiological contrast media: Contrast media was first used for gastrointestinal purposes. $BaSO_4$ is used as contrast media in the gastrointestinal tract. For intravenous and intraarterial purposes, triiodinated water soluble contrast media are being used. Because of higher density than surrounding tissue, the organs filled with contrast media are being visualized at fluoroscopes, films and screens (12,18,19).

Congenital dysplasia of the hip: The acetabulum does not have the proper size and depth and the femoral head will be displaced laterally (20).

The Graf method for ultrasonography of the hip: The ultrasonography transducer is placed laterally and the maturity of the hip and the position of the cartilages and osseous parts are assessed.

Darkroom and daylight developing: Traditionally the x-rays or Röntgen-rays were registered on a conventional films which were developed in a darkroom. Automatic film Daylight processing Systems (ADS) were developed to avoid darkroom working, both in order to decrease the use of labor and to reduce the need for having to work in an unpopular and

probably unhealthy place. Today several systems register digitally on a computer, and the pictures are being sent to a laser camera from the computer (17).

Introduction

Introductory comments

It is somewhat foreign for physicians to apply economic aspects on health care. However, pre world war II physicians were not used to unlimited recourses. Patients had either a private insurance or paid out of their own pockets.

After a war time of large sacrifices, the Western World rebuilt. More resources were available than had been ever before. The welfare system in many industrialized countries was developed and extended, especially health care (21). Sweden is an example of a country which developed a large and expensive national health care system (22). The GDP was growing in most Western countries. Comparatively few citizens retired on public money, and there were no evident reasons to put strains on health care expenditures. Optimism and ever changing borders for what could be done by medicine, increased the fraction of the GDP used for medicine. This was mostly hailed with enthusiasm.

Economic conditions, especially for the public sector, have changed. Not only politicians allocating resources, but the tax-paying public question parts of medicine, especially its technology(23). A future challenge not only for the health sector in Norway and Sweden, but in several western countries is the increasing proportion of elderly. It is a challenge to the future organization and financing of the health sector (24). This emphasizes questions upon how to use the resources allocated to health care (9,24,25).

In the press there has been questions on the spending on «high-tech» medicine without defining what it is. Radiologists do feel that they represent «high-tech» medicine, but seem not to accept statements that their part of medicine raises costs (26).

Much cost savings in health care have been accomplished by only decreasing the resources. Either to cut spending, or, more frequent, to curb a future increase in spending. The decreases have been done in the hope that rationalization and increased effectiveness would not considerably change results and outcome. An awareness of the advantages of

knowing most of the economical factors driving and maintaining health care has slowly emerged.

Literature focusing on economy in medicine has grown fast since the fifties, however, health professionals have not been the most eager participants. A lot of research regarding "usefulness" of technology and methodology employment is probably best performed by those handling the technology or working in close contact with it. Physicians have been their «patient's advocate» and cost-consciousness have not been of major concern. Health care professionals have mostly asked for increasing resources. This has left or even necessitated, the implementation of cost-control and cost-saving to politicians and administrators. The politicians view of the health care professionals attitude towards costs and effectiveness might be as presented by prime minister of the UK , M. Thatcher, when she describes the work with NHS during her period as prime minister (27). She describes the process of improving the efficiency of NHS and states about health professionals: «cost-conscious they were not» (27).

Radiology has not been the frequent subject of such studies but the number of investigations are increasing. Unfamiliarity with methods and conclusion-drawing has sometimes made contributions less valid for decision-making.

Aims

The main aim of these investigations has concentrated on finding ways of improving the allocation of resources within radiology, without losing high ethical and moral standards.

Radiology as «high-tech» medicine

More than most other specialties, radiology implies high technology. Even the least expensive diagnostic equipment in the department has frequently a price tag of more than 1 million SEK and the most expensive equipment around 15 millions SEK. Expenditures for personnel are the main costs in hospitals(28,29,30). In radiology departments, this cost is

somewhat lower due to the capital costs of equipment. At East Hospital, Gothenburg, the personnel cost amounted to just above 50 % of the department's costs. At Haukeland Hospital, Bergen and Ullevål Hospital, Oslo, estimates of costs indicate approximately a similar expenditure distribution. At clinical departments more than 80 % of the costs are personnel costs(31,32). This makes radiology a target as «expensive high-tech» medicine. However, high-technology medicine is not that expensive considering the total costs in a hospital (29,30).

In 1986 the total costs of all large diagnostic and therapeutic appliances in West Germany was reported to be less than 1% of annual expenditure on health (33). Most of this equipment is used to reduce hospital stays, and thus reduce hospital costs (30). Computed tomography has replaced angiography, conventional angiographies are performed with digital subtraction angiography, interventional radiology replaces surgical operations and ultrasonography replaces more time-consuming radiological examinations (30,34,35,36).

If it is accepted to diagnose and give medical treatment to all groups of patients, in- and out patients, treated in Nordic hospitals today, investing in radiological high-tech equipment is cost-saving but not necessarily cost-effective (30). Without such equipment, the patients would either not receive optimal diagnosis and treatment or receive more costlier procedures (30). The challenge is to optimize the use of existing resources.

Health care and radiology

Radiology, especially the diagnostic part of it, is a large discipline (or field). Radiology is mainly handling referred patients and cannot to any substantial degree influence its patient selection.

Radiologists' influence on method selection is limited, especially when resources are diminishing. The radiologists with staff become more executors of demands without much time for thinking of and making recommendations.

Radiology uses much high technology, can to a high degree use standardized methods, can deliver diagnosis and can sometimes give well defined therapy. Radiology yields

diagnosis which may be controlled shortly after, or radiology may be used for limited therapy with reasonably immediate results (i.e. abscess drainage, installing catheters, performing angioplasties). It may thus be a useful modality for economic research. However, in order to be of use for the patient much research on cost-effectiveness has to consider and assess patient outcome which has been uncommon in radiological economical investigations. In the present thesis only one (III) of the later investigations deals with patient outcome.

Radiology, medicine and the society

A major aim of the present investigations was to look into the allocation of resources within a radiology department. However, a short discussion on the use of resources for health care may give an improved understanding of the problems. Sweden and Norway have many similarities within health care structures. This applies especially in radiology. Accordingly, the issues discussed in this thesis will be mainly the same for the hospitals involved in this thesis.

In developing countries the resources for health care has diminished for several years (37). In the western world the pattern is more uneven (37). In the Nordic countries there has been a reduction in spending for health care in Sweden and a small rise in the spending in Norway throughout the last 5-10 years (22,25). The present situation is that the two countries have a pretty similar spending on health care(38,39).

The Nordic countries have politically controlled public health systems that account for most of the spending on health care (22). However, politicians are influenced by the public, interest-groups and health care professionals (22). It is difficult to achieve consensus-decisions and to have them accepted. A consensus group made an attempt to make priorities in Norway and among many other items tried to curb medical high-technology (23). The propositions of the group regarding radiology have not been followed as the rise in high-technology radiological equipment has been far larger than anticipated.

Whether or not these investments are justified, must be considered a political issue. At present, few economic evaluations exist, making it difficult to decide upon whether or not to invest public resources into radiology. It emphasizes the difficulties to optimally distribute public goods (40).

Radiology and the hospital

«The radiology department is the soul of the hospital.» This statement has been accredited professor O. Olsson of Lund University in the sixties. The idea of having radiology as the main diagnostic unit, selecting appropriate examination modalities and referring patient for therapy is old (41). Many radiologists would agree, but the view is most likely somewhat different in other specialties. The idea behind the statements, though, is worth considering. Most patients have at least one radiological examination during a hospital stay. For wounded and other critically ill patients, easy and fast access to radiological diagnosis is essential (32). Handling a large amount of patients from various departments demands functional organization, architecture and management (43,44,45).

This includes not only a well functioning radiology department, but also demands optimal communication and transportation within the hospital. Articles V-VI just about touches the problem. Within the follow-up of these investigations there were indications of lacking transportation capacity which increased waiting time.

Improved effectiveness in radiology will increase hospital effectiveness. Implementation of cost-effective methods needs close cooperation with referring physicians. If waiting times causes reduced efficiency in radiology and thus lost income, it must necessarily influence clinical department effectiveness.

Making priorities.

Analysis of costs, benefits and effectiveness

Radiologists may not understand the terms used in the literature of health economy, like health economists may have difficulties in understanding the «insider's language» of radiology. The expressions have been defined in first part of the thesis, but some frequently used phrases will be discussed.

Cost-minimizing, it is mainly a question of reducing costs. It does only to some extent include such values as results obtained, i.e. whether a radiological examination becomes better of worse. However, it does postulates that the results after a cost-minimizing procedure

are of assumed equivalent values. The most used terms are cost-benefit, cost-effectiveness and cost-utility. In a cost-benefit analysis, both costs and benefits are in monetary terms. This is a problem as the outcome is improved diagnosis, improved survival or other non-monetary goods. The effectiveness may be increased survival due to chemotherapy/some other treatment or improved diagnostic accuracy. In radiology improved diagnostic accuracy is often considered as effectiveness. In a cost-utility analysis, the utility also involves quality of life. It is usual to count in quality adjusted life years.

Articles I-IV

All articles deal mainly with selection diagnostic strategies and economic analyses based on the results, mainly cost-analyses. Articles I and III compare the cost-effectiveness of new versus established methods. The cost-effectiveness of investing in new equipment is considered in article II. Article IV deals with cost-effectiveness of screening.

Cost-minimizing analysis is defined as comparing two different methods which both can obtain the same or equivalent diagnostic information and find which one of the methods will be the less costly (1,2,3,46,47). Cost-effectiveness analysis in radiology, as used in this thesis, compares two methods which are comparable in monetary terms and has the same diagnostic purpose. The diagnostic accuracy will be the effectiveness.

Article I aimed at finding a model for assessment of internal costs and by comparing two investigations showing the importance of cost-assessment as well as cost-minimizing and cost-effectiveness analyses. In the department of radiology at HH cost-assessment was performed of two radiological examinations of the upper urinary tract, intravenous urography and ultrasonography, respectively.

The investigation was performed to achieve and scrutinize the costs of radiological examinations and to scrutinize the basis for the costs. The hospital (HH) did not have accounting for individual hospital departments. There were no figures of the costs for different investigations. When new diagnostic procedures are being introduced, they are often parallel to existing procedures, even if it is found that the new methods entirely fill the diagnostic needs. In order to evaluate both cost-effectiveness and the use of resources, the costs of the imaging methods have to be known. In article I, a method for performing cost-analysis is presented. It also shows the impact of contrast media selection on the total cost.

This study was initiated by several earlier investigations concerning the choice of diagnostic method in examining renal and ureteral diseases (48-55). These investigations aimed at finding at which clinical indications urography examinations could be replaced by ultrasonography. Two articles suggested that there were reasons for reevaluating the views upon what method to use (48,55). For the kidneys, ultrasonography has been reported as at least equal in accuracy to urography (48-53). For ureteral diseases including calculi, intravenous urography was found superior (50).

Some investigations have presented cost-effectiveness analyses in radiology (56-61). In some articles fees for different services have been used as costs, thus looking at patient's or reimbursing institution's costs (62-65). One cost-analysis in radiology was performed in connection with the introduction of a Swedish internal market at the hospital (directly translated "buy-sell" system), in order to clarify and help radiological departments when calculating costs (66). This analysis only presented a model for analyzing costs and did show some examples from one department only. The costs in articles II, V and VI are based upon a cost analysis (67).

The cost-appraisal of ADS was performed in order to evaluate the economic effects of investing in new equipment (II). It is might be considered a cost-benefit analysis of the economic benefit of investing in ADSs. However, one may also call it a cost-minimizing analysis: analyzing how to reduce costs and still achieve the same results. The aim of the investigation was to calculate the exact costs and benefits of the investment, according to traditional cost-benefit analysis principles(4,46).

Investments in radiology frequently concerns substantial sums. In a public health system costs is the main concern. This investigation presents a cost-benefit analysis of an investment which was done in order to improve working conditions. As it both improved working conditions, removed the dark-room work, and the benefits exceeded the costs, the investment may be said to be cost-effective and to give a pay-off.

Cost-benefit analyses are well known in economic literature, but rarely performed in radiology. The articles found, have emphasized cost-effectiveness or efficiency. The present cost-benefit analysis however was performed according to accepted economic principles (4,46).

The second article investigates clinical usefulness and cost-effectiveness of a defined procedure, CDS, using contrast medium angiography as gold standard (III). The intention was to evaluate if the less expensive examination, CDS, was sufficient as a preoperative

examination in patients with critical ischaemia. If CDS could completely or partially replace angiography, a substantial saving could be done. In order to evaluate this, an investigation of its clinical utility was performed and based upon this a cost-effectiveness analysis.

It is important, not only to evaluate the maximal efficacy of the investigations, but its cost-effectiveness. According to existing literature, it is known that CDS at the present stage is not as diagnostically accurate as angiography, especially in the abdominal aorta and pelvic vessels (68-72).

The aim of the investigation was to find costs and diagnostic accuracy of the two examinations and to compare the consequences of reduced diagnostic accuracy. A cost-effectiveness analysis with the diagnostic accuracy as effectiveness could be achieved. The analysis of costs of increased number of operations can also be classified as a cost-benefit analysis (III).

Screening and radiology

Several screening programs for various diseases and conditions have been undertaken. Contrary to the scarce literature concerning economics in radiology, the literature concerning screening and screening methods is extensive (73-81). Expensive Radiological equipment and skilled personnel makes screening expensive, contrary to most other screening programs, like screening for cervical cancer (smears) (82) or cancer of the colon (blood in stools) (73). Within radiology, mammography screening has been the most discussed (83-90), in Sweden, an issue for argument and controversy (90).

There are several problems:

- the radiological method,
- the costs of the screening program and
- cost-effectiveness and cost-utility of a screening program.

To a lesser extent the same is true for CDH:

- What is the quality and accuracy of the method?
- What are the costs and opportunity costs of allocating personnel and equipment to a screening program?
- What are the gains from the screening program?

In Sweden a screening for breast cancer has been going on for several years and the experiences gained reported (90). The accuracy and opportunity cost of the screening method have been emphasized.

Other radiological examinations have been suggested for screening programs: prostatic carcinomas and comorbid disease in patients with prostatic carcinoma (79), colonic cancer (80) or routine ultrasonographic examinations of the abdomen (91). Such programs have been proposed by physicians eager to «take care of their patients». This an honorable thought, but few analyses of costs have been made. Large screening programs may reveal more diseases, but may prove very costly (73). It is thus important that proper analysis of costs versus improved health are being performed. This in order to make the proper priorities (9,25).

The large costs of most screening programs justifies economic evaluations (73). The investigation of CDH (IV), calculates the cost-effectiveness of screening for a particular condition, CDH. However, it shares the general problems of all screening: both sensitivity and specificity of the examination must be high and the disease must be fairly frequent and a proper treatment must be available (73-77). In order to perform a cost-effectiveness analysis, investigations were performed both at HH and Hagavik Orthopedic Hospital, Bergen, Norway.

Loss of working time, articles V-VI

These articles investigate waiting-times in radiology departments. The basic idea arouse as the radiographers complained upon patients being late. It was a general complaint and a generally accepted problem which no one had ever tried to examine. It gave the idea to the first investigations (V). The results and the comments of validity initiated further investigations (VI). The aim was to find causes of waiting time and possible ways for improvement. An investigation which was performed in order to control the results of the two initial investigations (V,VI) was performed (not yet published, but these results are included in the thesis). This last investigations also aims at looking into other factors influencing on waiting time, outside the department of radiology. One initial finding is that it does not have much effect on nurses at the department of radiology.

The investigations were made of how much time was spent waiting and the reasons for time spent waiting: waiting for patients (68,V) or physicians(VI). The results of the control

study are included in the result section of the articles V and VI. As idle within the department time represents either loss of income and/or prolonged waiting lists for patients, it is important to investigate and quantify it.

The impact of waiting for physicians or patients is that the personnel's control of their working situation is reduced which may reduce the effectiveness of the organization (69). The basis given in the investigations presented here (V,VI and unpublished control), ought to initiate further investigations into organization of radiology departments.

Materials and methods

Cost-analysis at EH

The costs found were based on information from departmental and central hospital accounting concerning general costs of the hospital. The rent was given by Medichus, the municipal housing "company". Time studies on the different examinations were performed by the author, dr. Geitung. Prices of expendable and fixed diagnostic equipment were according to the prices paid by the hospital to the delivering firms. Total costs of the personnel were found both by time studies and a total account of time for the personnel at each diagnostic room.

The time studies were performed by 1) a survey without the personnel's knowledge 2) a personnel self-registration 3) a registration of the physicians on time spent for reporting examinations and for conferences with clinical colleagues. The time found at the survey and at the self registration were compared and found to be approximately the same.

A control with the hospital administration accounting and the radiological department's budget was done to control that the sum of costs found at this analysis was the same as the total costs of the department.

Costs in a department of radiology (article I)

The investigation was based on IVU and US of the kidneys at HH in 1988. Time studies were performed to assess the personnel cost. An appraisal of depreciation, costs, hospital facilities and archiving were based upon departmental and hospital accounting (31). As there were no prices set by the hospital and no rent on hospital areas, these figures were assessed according to textbooks (2,3,4,46).

The principles for performing a cost-analysis have been described (1,2,3,4,46). This article deals with costs for two specific investigations, ultrasonography and IVU of the upper urinary tract.

Cost-benefit of new equipment (article II)

The investment in ADSs were costly, but saved personnel. This cost-benefit analysis of the investment was based upon registrations of the amount of films processed in ADSs at HH during 1989. The personnel resources and the methods for manual processing were calculated. From one remaining, conventional dark-room, estimations were made of the costs for conventional dark-room personnel versus ADSs for the department.

On weekdays throughout 2 weeks registrations of the number of films processed were made immediately before and after working hours, 07.45 and 15.15 o'clock, respectively. In addition registrations were performed on Saturdays at 14.00.

Costs for labor, chemicals and maintenance as well as film consumption were supplied by the Hospital Accounting Department. Studies were performed in the darkroom to assess the minimum time for emptying cassettes, reloading and sending films through the conventional processors.

Cost-effectiveness and clinical usefulness (article III)

The clinical usefulness was used as a basis for a cost-effectiveness analysis of two radiological examination methods in a prospective investigation.

1.During 1991, 53 consecutive patients referred for angiography of the lower extremities were additionally examined with CDS and the diagnostic results of the investigations compared. When the review was performed, 49 records were available. During the same period general costs for performing these investigations were calculated (see cost-analysis), and, in addition more specific costs registered.

The form for registration of clinical efficiency and radiological results included:

1. comparison of the methods' efficacy in detecting occlusions and stenoses
2. evaluation of possible discrepancies between the two methods
3. clinical evaluation of whether or not the methods were adequate for planning surgery.

The clinical evaluation, based on review of the clinical and the surgery records, was the main factor for the assessment of diagnostic accuracy that gave the necessary data for the cost-effectiveness analysis. The following questions were presented to the vascular surgeon:

1) Were both methods sufficient for adequate treatment?
2) If not, was CDS sufficient?
3) Were you able to operate based upon the CDS findings and diagnosis?
4) if you had operated solely on CDS diagnosis (no angiography), what would the consequences have been?
5) Would CDS diagnosis have lead to correct /incorrect treatment?
6) Would CDS diagnosis had any consequences for the operation and its result?
7) Would the hospital stay have been prolonged?
8) Would necessary treatment not have been given because of incorrect diagnosis either by CDS or angiography?
9) Would overtreatment (unnecessary surgery) have been caused by CDS or angiography?

Screening for CDH, article IV

Sensitivity and specificity of ultrasonography for CDH was found according to literature. The cost of ultrasonography was assessed at HH according to the same principles as described in article I. The cost of treating late discovered CDH was based on a survey of 26 late discovered CDH patients, all at HOH. The costs of operations and consultations were also found at HOH. The information is based upon accounting at HOH (92) and interview with the staff at HOH.

The ultrasonographic examinations were performed according to the Graf method (93). The Graf method was routinely used at HH and the time consumption for one examination is based on time studies at HH. The time studies were based on the radiologists performing these examinations. One radiologist was very experienced with the Graf method, two others less experienced.

The effect of waiting-time on the use of a department's resources (articles V-VI)

Waiting-time for patients arriving late or not at all (V), was registered by radiographers in two hospitals, HH and EH. The investigation was performed in three different 3-week periods at HH (during 1987-1988) and two periods, one 3-week and one 1-week, respectively, at EH (1991 and 1993), totally 65 workdays.

The registration was performed 07.45-15.00 at HH and 07.30-16.00 at EH. The radiographers recorded both the amount of waiting-time and the numbers of personnel involved, who could not be occupied elsewhere. Thus the true loss of efficient working time was recorded and not the nominal loss of time.

A control investigation was performed at EH in 1994 (not yet published). It was performed like the previous investigations including waiting time both for radiologists and patients. This part of this investigation is included in the thesis. It was performed during two weeks, totally 10 working days.

Time spent waiting for radiologists was recorded at EH during two periods, one period during 8 working days (1991) and one period during 5 working days (1993), totally 13 workdays. The examinations required a physician's participation: interventional procedures, angiographies, ultrasonographies, fluoroscopies (barium meals and enemas, myelographies, arthrographies, hysterosalpingographies and enteroclyses).

The estimated loss of income was based on the price list of EH (67). The assessment was based upon the hypothesis that time not spent for anything else but waiting, could have been used for performing similar examinations (3,66,94,V,VI).

Results

Cost-analysis, EH

The costs found during a cost analysis was used for the price list at the department of radiology, EH. The results of cost calculation for a specific examination, angiography of the lower limb, is presented in Table 1. Another cost used in the presented thesis was CDS, 1350 SEK (67).

Table 1

Item	Cost
Capital cost	530
Catheters, needles, etc.	520
Contrast media	800
Working time	900
Film	150
Rent	110
Overhead	250
Department's administration	65
Service and maintenance	100
Secr./arch./time scheduling	220
"Waist time"	350
Conferences	15
Common areas like corridors	30
Sum	4040

Table 1: All prices in SEK. Capital costs are based on the instructions of the municipality, 10 % amortization each year, 10 % interest rate. Work time is based on time studies, idle time is the time not used working with the patient, but not necessarily wasted time. Work-time+idle-time=total personnel time for the specific examination room. Rent is set by Medichus. Overhead costs include all costs of all services provided the department from the hospital administration or service departments. Secretarial costs include rent of the secretaries offices and the department's archive.

Cost-analysis and cost-accounting, articles I-IV

The results in articles I and II are based on cost-analysis. In article I, the cost-analyses of IVU and US are performed and the results are as presented in Table 2.

Table 2

	US	IVU
Physician time	65	16
Radiographer time	0	122
Assistant personnel time	19	0
Archive, typing time etc.	33	33
Contrast medium	0	963
Film	35	150
Equipment depreciation	63	95
"Rent" (hospital facilities etc.)	19	19
Hospital depreciation	200	200
Total	434	1598

Table 2: This reflects the costs of US and IVU in 1988. The costs for contrast media has been reduced since then. These presented costs are mostly approximations based on calculations of general information from the hospital's records (I, see materials and methods chapter).

Table 2 reflects 1988 costs at HH (I,31). Article I demonstrates the method for performing a cost analysis. It defines a model for both capital depreciation and cost-analysis of radiological equipment and examinations.

In article II a thorough cost-benefit analysis on investing in ADSs is performed. The depreciation of the equipment is calculated as in article I. The results of the registration of use and throughput of the ADSs are presented in Table 3.

Table 3

Average number of processed films	Processor unit number				
	3	4	5	6	Total
Weekdays 07.45 - 15.15	33	160	124	56	373

Weekdays 15.15 - 20.00	0	2	20	0	22
Weekdays 20.00 - 07.45	1	20	65	4	90
Total weekdays	37	186	214	66	485
Friday 15.15 - Saturday 14.00	9	59	286	0	354
Saturday 14.00 - Monday 07.45	0	32	171	0	203
Average daily processing	23	155	166	58	402

Average number of films processed in ADSs 3-6 at different times of the week. Note the low utilization of ADSs 3 and 6.

In article III, a price list and the accounting of EH, are used as a basis for the cost-analysis (67). The price-list of EH reflects costs, not prices (see:cost-analysis) In addition, the exact costs of the angiographies are calculated, by using the same principles as in article I (see chapter of cost-analysis).

In article IV costs are assessed at HH for performing the ultrasonography examinations and at HOH for the costs of treatment of late discovered CDH (Table 4 and Table 5).

In articles V-VI, total costs are based upon the price list at EH (67).

The cost pro ultrasonographic (US), and clinical (CL) examination, respectively, in NOK:

Table 4

	Ultra-sonography	Clinical examination
Physician time	35	18
Nurse or nurse's aid	20	20
Administrative routines	35	35
Film	10	
Equipment depreciation	20	
Hospital facilities	200	200
Service, maintenance, upgrading	10	
Total	330	273

Cost per ultrasonographic and clinical examination (in NOK).

Table 5

	Extra costs	Costs saved
Ultrasonography with clinical exam	16500000	
(Ultrasonography without clinical exam)[a]	(2850000)[a]	
Overtreatment	400000	
Treatment saved		3155620
Total	16900000	3155620
Total	(3250000)[a]	3155620

Extra costs minus costs saved = approx. NOK 13.75 million

(Extra costs minus costs saved = approx. NOK 0)[a]

[a] Figures in parentheses apply if clinical examinations are abandoned completely.
[b] Calculated as 26xNOK 121 370

Estimated national costs of an ultrasonography screening program: extra costs incurred and treatment costs saved; all costs in NOK at 1993 prices.

Cost-benefit and cost-effectiveness analysis

the daily use of the ADSs (article II,table 1) and are found to be NOK 1.5 millions as presented in Table 6.

Table 6

Year	1	2	3	4	5	6	7	
Costs	936 800	66 800	66 800	66 800	66 800	66 800	66 800	
Benefits	454 200	454 200	454 200	454 200	454 200	454 200	454 200	
Net benefits	-482 600	387 400	387 400	387 400	387 400	387 400	387 400	
Sum DNPV	-482 600	369 000	351 400	334 700	318 700	303 500	289 100	1 483 700

Cost-benefit analysis of the investment for 4 ADSs, in Norwegian kroner (NOK). Interest rate 5%. Costs were initial investment + service and maintenance. Benefits were reductions in personnel. The model according to Mishan (4).

In article II, the cost-effectiveness analysis is based on the clinical utility of color flow Doppler ultrasonography. The diagnostic pathway the analysis is based on is presented in Figure 1.

Figure 1

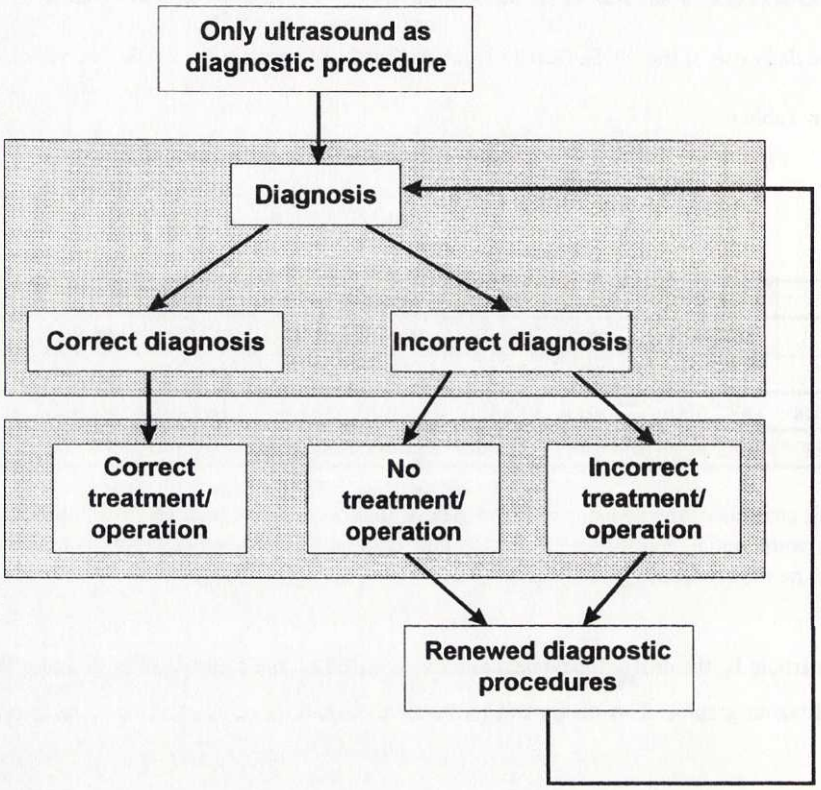

Figure 1: It is a pathway for diagnostic procedures for CDS vs. angiography, if CDS is to be the method of choice.

Table 7

	Occlusions			Stenosis >50%			Stenosis <50%		
Examination	pelv	fem	leg	pelv	fem	leg	pelv	fem	leg
Angio	15	3	3	9	1	0	8	3	2
CDS	12	1	1	1	2	0	2	1	0

Table 7: Reflects the results in 15 patients where CDS was found inadequate for preoperative diagnostics. In addition, CDS overlooked 3 aneurysms and 2 stenoses in the distal aorta of 5 patients requiring aorto-femoral Y-grafts.

A cost-effectiveness analysis is performed based on clinical results (table 7). The effectiveness is calculated in reoperations, delayed operations and overtreatment which would have occurred if only CDS had been used instead of angiography. Nine reoperations, three delayed operations and two unnecessary operations instead of PTA would have been performed, yielding an additional cost of approximately 790 000 SEK (III).

In article IV, the cost-effectiveness study demonstrates that a general ultrasonographic screening program would not be cost-effective. However, if few birth hospitals, and the clinical screening (Ortolani's test) is omitted and only defined risk groups are examined, the screening program may be cost-effective.

Waiting time

One cost-benefit or cost-minimizing analysis (II) and two cost-effectiveness analyses (III,IV) are presented. In Table 6, costs and benefits of investing in ADSs are presented. Benefits are based on

The loss of effective working time due to patients being late or not keeping appointments, was first assessed at HH. Subsequently, a similar investigation was performed at EH (V). The results from the two first investigations at HH are presented (Table 8). These results indicated that waiting-time represented a problem warranting further investigation (42). Similar investigations were later repeated at HH and EH.

The loss of effective working time, as a result of waiting for doctors and patients, was assessed at EH (38). Following cost-minimizing measures in the radiology department, results of the first investigation were controlled.

Table 8

The results from the two first 3-week periods at HH. The first period did to some extent come in conflict with the holidays.

	July-August	November
Non-appearing		
In-patients	13	49
Out-patients	29	54
Total	42	103
Appearing too late		
In-patients	40	122
Out-patients	24	57
Total	64	179
Total loss (in minutes)	1700	3665

The overall results of the loss of working time, due to patients being late or not keeping appointments, are presented in Table 9.

The annual loss of income during 1987-91 according to EH prices would have been 0.4 mill. SEK at EH and 1.3 mill. SEK at HH. The estimated loss at EH in 1993 would have been approximately 2 mill SEK. Income losses because of time spent waiting for radiologists were assessed to approximately 1.3 mill. SEK in 1991 and 0.6 mill. SEK (after cost-minimizing measures) in 1993 (Table 10).

The results of the follow-up investigation in 1994 is presented in tables 11 and 12. This last investigation was probably under best surveillance and thus the most reliable.

Table 9

Minutes lost

	1987-1991				1993	
	HH		EH		EH	
	Total	Per pat.	Total	Per pat.	Total	Per pat.
In-patients	2594	16	240	22	1605	40
Out-pat	3577	16	765	29	650	33
Total	6171		1005		2255	

Working time lost (in minutes) during three 3-week periods at HH and one 3-week period at EH, 1987-1991 caused by patients arriving late, or not keeping appointments. The last figures were based on one 1-week period at EH 1993. At EH 1991, in-patients were usually not scheduled, which they were in 1993.

Table 10

Time spent waiting for physicians, including time spent by residents waiting for help/instruction, was registered during two periods in 1991 and 1993, respectively. In 1991, the investigation was performed during 8 week-days and in 1993 during 5 week-days.

Procedure	Time lost (minutes)	
	1991	1993
Angiography, interventions	227	44
Fluoroscopy	210	35
Ultrasonography	120	90
Total	557	169

Table 11: Control study of time spent waiting, EH 1994 ,for patients being late of not keeping appointments.. Note that EH now had introduced appointment-times for a large group of the in-patients, in order to improve routines.

	No of patients	Minutes lost
In-patients	40	1605
Out-patients	27	650
Total	67	2255

Table 12

Control study of time spent waiting for physicians, including time spent by residents for help/instruction, performed 1994.

Procedure	Time lost	est. income lost
Fluoroscopy	35	1800
Ultrasonography	90	5100
Angiography	44	4800
Total	169	11700

Discussion

Introductory comments

Diminished public spending makes health care economics an important issue. Radiology, is one of the fastest growing medical high-technology specialties. However as Radiology does not involve patient beds, it is regarded as suitable for rationalization. The equipment is an important element of radiology. The technological development of the equipment has widened the diagnostic possibilities as well as given the radiologists improved possibilities to treat patients. However, CT and MRI have, among the public become symbols of medical advances costing society ever more. This despite research evidence that CT is cost-saving (30). Concerning MRI there is not enough research as to say what economic impact it will have. In such a climate, the importance of research into resource allocation and the cost-effectiveness of radiological procedures seems self-evident.

The importance of cost-saving in the two large hospitals and departments is evident. However, cost-saving alone may not be the best way of allocating resources. Quality of the work performed, the cost-effectiveness of procedures, effective utilization of personnel, and time available in the different examination-rooms are factors to be considered (95). We have investigated some of the problems, and proposed solutions.

Even with stagnating or diminishing resources, the expected demand from political authorities, administrators, professionals and the public has been to maintain quality and preferably quantity. A commonly agreed upon definition of quality in health care service is «fully meeting requirements at the lowest cost» (95). The resources for health care in Sweden and Norway have been supplied mainly by public funding since W.W.II. To control costs politically induced rationalization of the services has been applied (22,25,40,42,). Even though attempts to introduce demand-supply systems in a mainly public health sector have been tried (e.g. Sweden and UK), the political community retains the main control (26,27,33,42,96). Accordingly, it is difficult to apply market economic theories on Scandinavian health care as political decisions rely on a diversified basis of interests and considerations (1,9,25,97).

The amount of money spent on health care specifically, and in the public sector in general, are political questions and decisions. The decisions influence the individual and national welfare (40,98,99,100). However, this thesis does not discuss the problems of national welfare systems. It concentrates upon the economy of radiology departments, and factors important for well functioning departments and hospitals.

Cost-, cost-benefit- and cost-effectiveness-analysis

It is essential for assessment of costs to perform cost-benefit and cost-effectiveness analysis, which should be the basis when planning improvement in department economy and management. It is also essential in order to calculate prices in a market system, whether internal or competing externally (29,30,47,66,98). Article I presents a model for assessing costs in radiology. Two defined examinations are being compared regarding costs. It is not surprising that ultrasonography is cheaper than IVU, but it is unexpected that US can be so frequently utilized, as shown in a simultaneously performed investigations (48-54). However, IVU defends its role as primary examination, for ureteral calculi and urothelial tumors (50,51,52,53,101). This shows the need not only for cost-analysis, but for both assessing effectiveness and the examinations ability to detect the pathology in question. Another aspect in is the difference in price relating to the type of contrast media employed at that time. The prices for contrast media are today not that far apart and the non-ionic contrast media have gained an overwhelming share of the market. In the introductory phase it was never-the-less of public interest to evaluate costs versus side effects and complications of contrast media (12).

There was no detailed accounting for individual departments at HH, and thus it was necessary to perform a cost-appraisals. Approximations had to be made, which make the accuracy of the final figures somewhat uncertain. However, considerable work was done, in order to obtain as accurate numbers as possible. At EH, each department was accounted for, which made the cost-analysis easier and the figures more accurate. A detailed cost-analysis is included in the thesis (see results chapter).

In article II is performed a cost-benefit or cost-minimizing analysis of an investment in ADSs, showing the profits to be gained by a particular investment through staff reductions. Further gains were the elimination of uncomfortable (dark room, odeur from developers) work

stations might be eliminated (II). This clear-cut example demonstrates the benefit to the department, with its positive aspects of service, maintenance, and influence on the daily work (102,103).

Other investments may not be as clearly positive for the economy of department or society, even if such investments offer new possibilities for examinations and treatment. Investments in new equipment does not necessarily represent a cost saving, but must be expected to enhance the public good through improved medical diagnosis and medical care (104,105). However, when investing in new equipment economical aspects have to be considered. In a cost-benefit analysis of a company the presented example (II) would turn out as a sound investment. Other aspects to be brought into consideration are evaluation of need, comparing of different equipment and, preferably, evaluation of more global health economic aspects (1,106). The latter referring to investments that will change the present status of a department or hospital or funding (1,25).

In article III, is evaluated the effectiveness and the costs, by comparing an assumedly, less expensive examination with an established and assumed more expensive investigation. The analysis shows that CDS is considerably cheaper to perform than angiography (III). However, the comparison of the clinical results, finds that CDS overlooks essential pathology, especially in the distal aorta and the pelvic arteries(

Table 7). The assessment of clinical utility shows that the sensitivity of CDS is too low to effectively be the sole preoperative investigation, and would ultimately result in increased costs caused secondary to renewed investigations and/or incorrect treatment of several of the patients. For the effectiveness of imaging procedures their sensitivity and specificity are important, when too low, they will have negative effects 107,108). Technical problems prevent CDS from obtaining acceptable results in the pelvis and distal aorta, even though accurate results are rated in the thigh. Thus the less expensive CDS may supplement angiography (III), e.g. in screening graft and endoprosthesis patency (109,110), monitoring balloon angioplasty (106), and diagnosing iatrogenous arteriovenous fistulas (111).

Incorrect use of imaging or therapeutic procedure may increase costs (III,112). This investigation emphasizes the importance of doing cost-effectiveness analyses based on clinical effectiveness. Within radiology more such investigations ought to be performed.

The need to understand the economics of the health sector is increasing (113-118). Globally, the health sector is increasingly analyzed by economists. Hospitals and department will also have to increase their knowledge of hospital economy and relevant analyses.

To define effectiveness and perform analysis according to the definition is a problem when performing cost-effectiveness analyses within medicine (1-3). It is difficult to find two or more methods, in all aspects equal concerning radiological diagnosis, surgical results or survival or whatever is in question. In article III, a thorough comparison was performed in order to see if the cheapest method, ultrasonography, was acceptable as a replacement. In article I, the two methods were compared as to costs. When possible to use, ultrasonography proves to be the most cost-effective. However, as ultrasonography can not always replace e.g. IVU which makes the analysis difficult to perform and to interpret.

Screening, article IV

Performing general screening programs need large resources. Therefore it is difficult to defend in economic terms. Society costs arise as the screening program is evolving. The benefits (or the effectiveness or the utility) of the screening program are not immediate but are expected to appear somewhere in the future. Screening for CDH it is means less late detected babies with CDH. This results in less late detected babies with CDH, consequently less treatment and assumed increased quality of life for the persons in question.

When planning screening it is important to consider 1) the disease and its consequences; 2) the available method for cure; 3) the cost and cost-effectiveness of the screening program; 4) the sensitivity and specificity of the screening method; and 5) the opportunity cost of using skilled personnel for performing screening tasks (1,2,3,73,74,75,76,77,119,120,121).

Screening for CDH (IV) represents all the problems of a screening program. In Norway, with its paucity of radiologists, screening would strain limited resources. The Graf examination technique is used in article IV, as well as in the screening program in Austria (93). and has given good results(119,122,123). Whether this or any other method could be used without radiologists, thereby reducing costs, has not been investigated. Further investigation are necessary to assess the potential cost savings.

CDH is not a frequent anomaly, therefore it is difficult to achieve the necessary sensitivity due to the lack of numbers (76,107). The US examination is not easy to perform, and thus, at least at present, requires skilled physicians(93,119,). These factors make it difficult to achieve a cost-effective screening program (76,108).

The current investigation demonstrates that a general screening program, including all new-borns, is not cost-effective. However, by selecting children for examination from specific risk groups, such a program will be close to cost-effective. By including a quality of life improvement it may be justified as a cost-effective selective screening program, assumed that CDH reduces the quality of life for a life-time. It is also assumed to reduce the amount of coxarthrosis later in life.

In Norway, with mostly small hospitals, the number of newborn children at each hospital will be low. In small units with rare positive results, an acceptable sensitivity rate may be difficult to achieve. It is difficult to imagine an effective program for the entire country(121). Even selective screening programs will be difficult to make cost-effective in small hospitals.

Loss of efficient working time, articles V and VI

Proper utilization of personnel is vital for the efficiency of the department as a whole. Waiting time was investigated (V,VI) as one main efficiency problem. The comments from radiographers, nurses and nurses' aides during these investigations provided ideas for further investigations. Finally a comprehensive overview of waiting time in the EH department of radiology was performed and revealed several problems (94,V,VI).

The initial investigation (V) concentrated on time spent waiting for patients who were either late or not keeping appointments. The next investigation estimated the consequences of waiting for physicians (VI).

The investigation results were heavily dependent on good personnel, compliance (V,VI). It became obvious that the number of registrations were proportionally dependent on how well the authors surveyed the personnel. Non-announced controls revealed low rates of registration with resulting low estimates of working time loss. We anticipated problems in getting high, as has been reported elsewhere (124,125).

The errors in results due to failing compliance were impossible to estimate accurately. However, there is reason to believe that one investigation at HH and two at EH have almost all correct results as these investigations were followed daily by the authors. Based on this, the underregistration has been estimated (see tables).

The rationale for assessing loss of income caused by waiting is to assume that the lost time could have been used for alternative examinations. This is, in practice difficult, but it is never-the-less a way of estimating the magnitude of the problem and its economic consequences. No prior radiological research exists, and little other literature has been published on administrative problems of planning and managing radiological departments (45,126,127). Management of personnel time has received more attention in the private sector (128).

Several interesting results were revealed. Time spent waiting for patients influenced tightly scheduled planning of all the radiological examination rooms (V-VI). The results were remarkable as in the last investigation at EH: after presentation of the previous results attempts were made to improve the situation but paradoxically the loss of effective working-time increased. According to radiographer's comments, later confirmed by comments from the surgical nurses, an important factor contributing to this increasing loss was inadequate transportation capacity. This example emphasizes the importance of both interdepartmental communication and communication between departments and hospital management. With strategic planning, factors that have an influence on the flow of patients between departments must be seriously considered. At EH, during this same time period, a cost-saving plan included a reduction in the number of transporters. This plan probably caused a larger income loss due to the resultant loss of effective work time in service departments, than it saved money.

Residents waiting for assistance from supervisors (VI) caused much lost effective working-time both where the supervising radiologist was expected to be and where the resident was waiting. In the follow-up investigation, the waiting time had shortened because of two factors: the results of the first investigation was known and the investigative registration mechanism may have been recognized. Secondly the residents participating at the follow-up investigation were more experienced than those residents participating in the first investigation. The results indicate the need for having a sufficient staff of experienced radiologists. Other measures to reduce the loss of time would be to improve the management of personnel (especially physicians) and to leave more decisions to radiographers. During the last twenty years, radiology has become increasingly demanding on physician skills. However, the specialty has not received a proportional share of radiologists (129,130,131). The present investigation reveals is most likely a reflection of this lack of radiologists.

The loss of effective working time is worth scrutinizing both regarding time spent waiting for patients and for radiologists. Planning and management expertise, capable of

handling these problems are needed. The results based on V-VI indicate the magnitude of the problem, and the importance of addressing the issue in planning and management departments.

Errors in the investigations and problems with making the results global

It is necessary to have access to all relevant data to perform cost-analysis. As the costs at HH was difficult to differentiate for individual approximations had to be performed (I,III,IV). At EH the costs were more precisely accounted for in each department assumedly with more accurate results (II,III). It should be remembered that evaluations of clinical effectiveness may be biased by the physicians involved (I-IV). Concerning screening, long-term cost utility analyses are desirable.

It turned out to be impossible to have a total compliance in the investigations involving questionnaires (V,VI). However, some of the investigations were performed with a tight surveillance and we consider them a standard.

It is accepted that it is difficult to globalize economic results from one country or one hospital (7). This thesis deals with only two countries, one specialty and large hospitals. The results may thus be representative for larger departments of radiology in Norway and Sweden.

Possible global results are: 1) economic analysis should be performed prior to introduction of less expensive diagnostic method; 2) costs of diagnostic procedures are less expensive than failed/suboptimal treatment because of incorrect diagnoses; 3) it is important to manage waiting time, and to avoid idle time.

Some of the work involved in these articles could be used when making a price list for an internal market at EH. There has been skepticism and discussions concerning internal markets both in Sweden and United Kingdom (132,133). Prices for internal markets may not have a great future, but knowing the costs of procedures will be at least as important in the future as it is today (134). In such a context the works presented in the thesis will have an impact and be of interest to management of radiology..

Another aspect of the thesis is the scrutinizing of comparable radiological examinations. This is important in radiology as well as in many other areas of medicine. There

is a saying that new methods do not exclude older methods. They just make up more work for doing things over and over again. This is to some extent true, but not quite. If we look into the number of angiographies performed at EH and HH from the introduction of the CT and until today, we can see an enormous reduction (31,32). However, it did take its time to exchange older procedures with newer, which in many way were even better.

To present costs as well as clinical usefulness of specific procedures (as in III) will be an important question for planning investments in equipment. To scrutinize problems like waiting time, will be of importance to the planning and management of departments. How to avoid managerial and structural problems which cause time losses. To optimize the future of radiology, the costs and the effectiveness of what is performed must be known.

Comprehensive discussion

The present thesis includes cost-analysis, cost-benefit analysis, cost-effectiveness analysis, investigations of resource allocation, and some quality aspects. All of these factors are within the context of obtaining the optimum use of the available resources in a department of radiology. Depending upon the equipment available, we can choose which modality to utilize to obtain diagnoses. If the selected modality is insufficient, either an additional or a more expensive modality may be required to solve the problem. One such pathway to a proper diagnosis, and the consequences of the choices, is presented (Figure 1). For several diagnoses, the radiologist has different opportunities. Cost-effectiveness analysis defines not only the least expensive method, but also the most effective method. It represents basic knowledge necessary to optimize resource allocation.

During the last twenty years, imaging departments have experienced large technology changes, with increasing total costs. The effects have not been extensively studied, although limited resources require assessment of the economic demands (135,136).

The thesis has also emphasized the need to achieve and apply knowledge of the resources used in radiology on the departmental level. Knowledge is essential in order to obtain the best utilization possible of the radiology resources. Methods and equipment have been looked into by performing cost-effectiveness analyses. The goal has not been to find the absolute "class A" method, but a method providing adequate and sufficient diagnostic information at the lowest cost. By analyzing costs, the need for medical professionals to think

of and regard public spending as a part of their ethical considerations has been discussed, namely: how to provide the best possible public service to as many patients as possible.

The waiting-time found in V-VI represents a problem of patient handling, scheduling and management. Such problems should be considered in department planning. Communications and transportation systems influence the work in the radiology department more than was expected. They also emphasize the importance of cooperation between departments.

Looking into the use of personnel, a field of unknown territory is in the process of being charted. The time-losses found in these current investigations clearly identify a problem. As the two hospitals are large, the problems may be caused by the management difficulties inherent in large institutions as centralization and size may not be the key to success in management.

Conclusions

Radiology and radiology departments represent a more "closed environment" than departments with beds, thus making economic appraisals easier to perform. In the first article of this thesis, instruments and principles of cost-assessment were presented and described. It shows the large differences in costs between two examinations of nearly equivalent diagnostic value.

A well performed cost-appraisal is essential for cost-benefit and cost-effectiveness analysis. Such analyses are essential in order to achieve optimum investment into equipment. They are also necessary to find the most cost-effective algorithm and still achieve correct diagnoses.

Using the cheapest equipment is not necessarily the most cost effective strategy. Ultrasonography is per examination procedure, by far, less expensive than angiography and intravenous urography. However, the sensitivity for vascular structures in the pelvis and distal aorta, and the sensitivity for ureteral calculi, limit the clinical use, and reduce the effectiveness. If only CDS would be used as preoperative examination for vascular ischaemia, total costs would actually rise.

It is difficult to estimate the cost-effectiveness of screening procedures of different conditions in order to detect them earlier. The presented investigation shows that screening for congenital dysplasia of the hip, if given certain conditions, is cost-effective. However, a general screening program for CDH would most likely not be cost-effective, as there are too few positive results in a large population. The effectiveness is, however, limited to the gain in less need for treatment of CDH. It does not include gains in improved quality of life.

Waiting-time represents a major problem for proper use of personnel resources in a radiological department. Decreased transportation capacity may increase costs in a radiology department. Too few specialized radiologists create waiting-time, due to the requirement for supervision and control. In planning and administering departments, adequate personnel resources, adequate transportation and communication between departments must be considered. Improved scheduling routines, improved patient transport capacity, an increase of qualified radiologists, and adequate administrative measures would improve the situation. This

investigation presents a question to the administration of large hospitals and their complexity, "are we coping"?

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