INAHTA Joint Project

The Assessment of Telemedicine

General principles and a systematic review

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Foreword

The International Network of Agencies for Health Technology Assessment (INAHTA) has been formed to exchange information and undertake collaborative activities in health technology assessment. At the INAHTA Annual Meeting in 1997, telemedicine was identified by a number of agencies as appropriate to consider through an INAHTA project.

With recent advances in communication technologies and the increased affordability of equipment, there has been a rapid worldwide increase in telemedicine projects during the 1990s. This report covers issues associated with the introduction, assessment, and use of this information and communication technology. It is intended to provide a basis for discussion and further work in this area.

While the report has been prepared on behalf of INAHTA, the views expressed are those of the authors.

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Contents

Foreword 3

Acknowledgements 4

Summary 6

Introduction 7

Considering the need for telemedicine 9

The need for assessment 15

Assessment of telemedicine 16

Frameworks for assessment 18

Economic evaluation methods 26

A systematic review of telemedicine assessments 31

Appendix A: Methodology used for the report 47

References 48

Tables and Figures:

Table 1: Questions to consider in development of a business case for telemedicine 13

Table 2: Assessment of telemedicine between a remote place Primary Care (PC) unit and Secondary Care (SC) unit (or other special care unit 19

Table 3: Summary of impact for a telepsychiatry application 30

Table 4: Studies evaluating telemedicine applications 34

Figure 1: Breakeven analysis for a telepsychiatry application 28

Summary

- Telemedicine is an information and communications technology which shows promise in improving quality and efficiency of health care. There is increasing use of telemedicine in many countries.
- However, there have been a number of impediments to creation of a fully developed "telemedicine society".
- Those seeking to introduce telemedicine will need to give general consideration to a number of areas, including Population and Services, Personnel and Consumers, Delivery Arrangements, Specifications and Costs, so that a business case can be made for acquiring this technology.
- Assessment of telemedicine applications is needed to assist purchasing and planning decisions, approaches to future health services and health education, and also to monitor and modify the use of the technology when it is in place.
- Several frameworks for assessment have been suggested. An approach is outlined covering the domains of Technical Assessment; Effectiveness; User Assessment of the Technology; Costs of Telemedicine; Trials; Economic Evaluation Methods; and Sensitivity Analysis.
- A systematic review of telemedicine assessments identified 29 studies that met criteria for reporting outcomes and methodological quality.
- The most convincing evidence from the review regarding the effectiveness of telemedicine deals with teleradiology, teleneurosurgery, telepsychiatry, and transmission of echocardiographic images. Promising results have also been obtained for the transmission of electocardiograms. However, even in these applications, most of the available literature refers only to pilot projects and short term outcomes.
- Further scientific assessment studies in the field of telemedicine are needed. Decision makers under public and commercial pressure to start new telemedicine services should link introduction of new, and in many instances costly technology to realistic development of a business case and subsequent data collection and analysis.
- Decision makers should also note that an assessment of a telemedicine application will be strongly influenced by the context in which it is undertaken. Assessments will typically be closely linked to local circumstances and their results may not be generalisable to other situations.

Introduction

Approach used in the report

This report includes two main sections. In the first, a discussion on general principles in the assessment of telemedicine applications is given, together with some background information on the technology. The material presented draws largely on the experience of the author agencies, and literature that they have found to be valuable in developing approaches to assessment of telemedicine.

The second part of the report is a systematic review of assessments that reported the outcomes of telemedicine. Administrative changes, patient outcomes and economic assessment were considered.

In both sections, the emphasis is on the assessment of telemedicine in specific applications.

Definitions

Telemedicine is the use of information and communications technology to provide health care services to persons who are some distance from the provider. It includes technologies such as facsimile, medical data transmission, audio-only format (telephone and radio), still images, and full-motion video (32).

Telemedicine has been defined in different ways. The US Institute of Medicine considers it to be "the use of electronic information and communications technologies to provide and support health care when distance separates the participants" (40). In considering assessment of the technology, we have to emphasize the definition of Wootton (77) who sees telemedicine primarily as a process, rather than a technology. The scope of telemedicine as a technology is considerably wider than the telecommunications equipment and systems that enable exchange of information at a distance. Telemedicine should be regarded in terms of the interaction of the equipment and the information transmitted with the activities of the health care professionals who use them, and the consequences for patients and others who are their clients (33).

These definitions underline the role of the telemedicine as a part of the wider process of care or chain of care, rather than a single technology.

Health technology assessment (HTA) provides a suitable framework to categorize and estimate the various effects resulting from the adoption of telemedicine, and to provide a synthesis of these as input to future decisions. The HTA approach compares alternatives – in this case telemedicine versus what would exist in its absence. A general purpose of HTA is to produce information about the effectiveness, efficiency (cost-effectiveness), and safety of technologies. In addition, it provides information about the ethical and social aspects of their use, and on access and need of services (9). Assessments investigate factors related to the adoption and diffusion of technologies either by producing new information or by analyzing and synthesizing existing information. Assessments provide health technology developers and manufacturers with information that can be used to develop technology and also to advertise and sell their products.

The economic success of health care operations depends on the efficiency of production and the fairness and equality of the distribution of services. Although efficiency is often emphasized in health care assessments, attention should also be paid to the distribution of the services, both between diseases and their treatments (74) and geographically. The accessibility of health services is an important issue when telemedicine services are built up in a new district (40) since telemedicine can both increase the utilization of special care by adding a new way of getting services and decrease the need for secondary care by transferring knowledge to primary care (53).

A new technology has to be proved to be superior to the technology it is intended to replace (for example, more effective or more cost-effective). This is of considerable significance in telemedicine. Telemedicine may have favorable attributes, but the existing system may serve the population well and also be capable of improvement. Comparison should include the present (non-telemedicine) system, the present system when upgraded, and the telemedicine alternative.

The telemedicine alternative should be sufficiently mature for assessment to be meaningful. Prototypes or telemedicine practices that are not fully integrated with the present care and delivery system, can be assessed in pilot studies. However, pilot studies provide mostly interim assessment information, which gives an indication of the feasibility of a telemedicine application.

Telemedicine technology

Telemedicine is not a new concept. For many years, health care information has been sent between persons at different locations using electronic media. Use of older approaches (telephone, fax) is commonplace. However, telemedicine applications increasingly utilize the newest innovations (both in hardware and software) in computer and network technologies. In addition, the technical quality of the other equipment used in telemedicine systems, such as video and document cameras, is progressing rapidly.

The consequence of these developments is that new products are brought into the market every day and equipment will evolve markedly over a period of years. This can be seen in the development of the videoconference (VC) systems, which first used TV technology (76) and then TV with cable or satellite transmission (4). The TV camera has changed to video technology (such as roll'about and desktop cameras) and the transmission modalities have moved to different commercial telephone lines (ISDN or ATM). Also, in the near future, the Internet and radio technologies may prove to be very competitive alternatives to the current networks. This continuing shift in technology places demands on those seeking to introduce and operate telemedicine.

Reid (61) points out that "the life span of most microprocessor-based technologies is no greater than three years. The products themselves last longer, but in that short time they become painfully obsolete. Some telemedicine technologies are more capable than others of being upgraded as improvements become available. 'Face lift' upgrades, where the 'old box' is physically and completely replaced with a 'new box' are to be avoided. This is a very expensive undertaking. Those systems that can be upgraded by loading new software are the most desirable. Expansion capability is a valuable quality, particularly in telecommunication transmission equipment."

In teleradiology, for example, there may be a need to increase the bandwidth of transmission from ISDN lines to frame relay and further to ATM lines. It is essential that the software and hardware of the teleradiology system are capable of accommodating increases in the utilization of services.

Considering the need for telemedicine

Purpose and effects of telemedicine

The implementation of telemedicine is partly aimed at ensuring that health care services are produced at an optimum location from the viewpoint of patients, health care professionals, and funders. For example, visits to hospital outpatient clinics would be unnecessary when the treatment or advice can be provided in a primary health care setting. Telemedicine projects have a bearing on the distribution of specialized health care. However, long distances are not a prerequisite for effective telemedicine applications. On the contrary, telemedicine can be used even over short distances, such as within one hospital or in the same town among different units of health care (11, 23, 77).

However, each case must be considered on its own merits, with appropriate comparison with existing technology and services. The coming of age of telemedicine has instigated public health care programs to include telemedicine in their strategic plans. For example, in Finland, many Health Care Districts have set goals for telemedical services and other information technologies (56). The same kind of strategic work has also been done in many U.S. States, Canada, Australia, and in Northern Norway.

The objectives of telemedicine can be specified as follows (56):

- **to reduce direct costs to the health care sector and patients and to reduce indirect costs (loss of production);**
- **to enhance citizens' equality in the availability of specialized medical services by bringing these services to remote primary health care centres, or equivalent (access of health care services);**
- **to improve cooperation between specialized and primary care by moving services and expertise closer to citizens;**
- **to promote the proficiency of physicians and other health care personnel by means of teleconsultation, and video conference-based training and mentoring;**
- **to provide at least the same level of clinical care to patients as provided by conventional technology;**
- **to reduce waiting lists for specialized health care by providing consultations to remote health centres and educating clinicians to perform some of the most usual examinations in a specialty (e.g., ophthalmology, dermatology, orthopedics);**
- **to improve and expedite consultations among different units of specialized health care in acute special cases (e.g., subspecialites in radiology and pathology, and neurosurgery); and,**
- **to increase delivery of primary and secondary health services to the home and increase access to health care information directly**

There are great expectations for the future of telemedicine. In principle, telemedical projects are considered to benefit all parties: local authorities (cheaper specialized services); hospitals, primary health care centres (improved service, increased supply of expertise); patients (changes in state of health and quality of life, savings in costs and time); health care personnel (increased proficiency); employers (reduced absenteeism from work); and the social insurance system (reduced reimbursements).

In addition, private medicine, teleoperators, and firms developing and producing telemedicine equipment have big expectations about business opportunities with the technology. However, it must be stressed that, for most applications, these remain expectations which require validation from appraisal of appropriate data.

Impediments to the development of a telemedicine systems

There have been a number of impediments to creation of a fully developed "telemedicine society". Consideration of these factors has recently been undertaken in Switzerland. While there are significant geographical and societal differences, it appeared that the Swiss experience had similarities to that in Western Canada, for which the following points appear to be significant (1).

- There still seems some lack of clarity regarding definitions and specifications of telemedicine - what telemedicine is and what is truly needed in various applications.
- Much of the early focus was on hardware and communications details. It is necessary to consider these, but it has taken a while for there to be full appreciation of the need to consult with health care professionals and others and to consider reorganization of services and infrastructure that are consequential to adoption of telemedicine.
- The majority of proposed telemedicine applications have not progressed beyond the pilot project stage. Economic and other evaluation of most applications remains very limited.
- Some potential purchasers and users of telemedicine are not comfortable with the short life time of many equipment components and the speed of change of some technology.
- A major impediment is the lack of resolution as to how physicians (and possibly other health care professionals) should be reimbursed for services they provide using telemedicine. This may be more signficant in private-oriented health care systems.
- Another dilemma is the question of who pays for establishment of infrastructure. There is competition for access to budgets.
- In order for telemedicine to be applied in a fully effective fashion to the whole health care system, there will be a need to ensure interconnectivity between different regions and institutions. Standards are being developed but these have taken some time and will not necessarily be easily implemented. It is not clear all technical issues have been resolved, or that it will be easy to obtain necessary information from suppliers.
- Telecommunications standards are not consistent across the health care system, so there is variation in the transmission costs and capability that apply to various regions.
- There is a concern about inconsistency from equipment suppliers regarding assurance that agreed specifications will be met. Some equipment components may remain in the developmental phase for longer than expected, so that a telemedicine application cannot be established as planned.
- There may also be concern regarding provision of effective routine trouble-shooting support. Operators and users of telemedicine applications require assurance that down time will be minimal.
- Issues relating to licensing of medical staff and other operators are not resolved.
- University-based groups have research interests in the area of telemedicine, but often these do not seem to be closely related to the short term needs of the health care system.
- There are concerns that the introduction of telemedicine might lead to disruption of established referral patterns, linked to a possible lack of control of health care services. These range from individual practices concerned with loss of income to broader considerations of professional bodies regarding the future pattern of health care.
- There is still a need to decide on requirements for real time applications as opposed to store-and-forward, which may be entirely adequate in many situations.
- Questions of availability of specialist referral advice at major centres are not fully resolved, especially for real time applications. Continued negotiations seem needed on scheduling of health care professionals and reasonable funding for the organizations concerned.
- There are various issues related to relationships between different levels of government.
- Health authorities have faced many financial and administrative pressures. In this sort of climate, detailed consideration and implementation of telemedicine systems has tended to be pushed aside by other priorities.
- There is growing acceptance that telemedicine systems require assessment and on-going collection of relevant data for administrative purposes at the local level. However, in most regions, local

resources for these tasks are minimal. There is a real problem in securing resources to gain some understanding of the effectiveness of telemedicine services. The worry is that systems might be acquired but then not be managed efficiently or used effectively.

- Some health authorities, in part because of their proximity to major centres, see no real advantage in proceeding with telemedicine systems at this stage (this may be a legitimate decision; there is little point in acquiring the technology if the business case is poor).

This is a diverse collection of issues. While some may be expected to resolve without too much trouble, others may pose major problems. Overall, users need to have a clearer idea of their requirements, how these can be met technically, and how any new services can be organized and funded on an on-going basis.

Making the case for telemedicine

Prior to any detailed assessment, those seeking to introduce telemedicine will need to give general consideration to a number of points so a business case can be made for acquiring this technology. It will be necessary to specify clinical requirements and the technology being considered for adoption. The specification will include a clear outline of the application and of equipment, staff, and other resources. Introduction of telemedicine will raise some general technical issues. There will be a need to obtain assurance that available hardware and software can provide the performance required, at a realistic cost, and that adequate technical support will be available. Validation of specifications and of performance under local conditions are major issues.

To realize the potential benefits from telemedicine through time-related gains in efficiency, planners and managers will need to put in place changes to organizational structure and administrative procedures. Health care planners and managers should be informed about the possibilities for future use of telemedicine. They can then plan and develop the health care delivery system, where telemedicine is one integrated component, to meet regional conditions and the health services needs of the population. Health care managers and planners must know also the financial resources that can be used for telemedicine in the future (61). Most of the benefits of telemedicine can be realized only when systems are widely used within the organization and/or between organizations. That is, the technology is accepted by patients, health care professionals and managers.

Many of the issues on use of the technology will relate to changes in work practices and routines. Active consultation with all staff who will be affected by introduction of telemedicine, and use of their expertise in developing programs, should be priorities. Availability of a person to take responsibility for coordination of telemedicine applications and their assessment is essential. The coordinator must have a clear understanding of the overall delivery requirements of the health care system and be responsive to the needs of health care professionals and their clients (34).

New technology can also offer a better way of sharing and utilizing information. In psychiatry the use of VC has increased the possibility of having patient care planning negotiations for in-patients before they go back to their remote municipalities (54).

Yellowlees (79) suggests that management and support of telemedicine projects should be from the bottom up rather than from the top down. Clinicians may be more aware about the technical properties of the telemedicine alternative and thus can develop the new system to meet the needs of the local population. However, the experiences from Norway suggest that the importance of the top level in the development of the telemedicine system increases once the pilot project is widened to other sites in a region or to the whole country (58). The telemedicine applications and sites should be selected pragmatically. For example, a state-wide telemedicine system might be built up, even though some regions may not be willing or able to participate in the project (79). If a region does not have required telecommunication facilities, or educated health care staff, the implementation of telemedicine should not be started there.

Consideration of the project specifications should help to determine whether a particular telemedicine application is appropriate or if telemedicine is needed at all. Managers should be seeking strong grounds to presume that the proposed application will be sustainable (capable of providing an effective service continuously, rather than operating only as a demonstration project). Details will be required of the equipment specifications (to eventually be verified under local conditions), the method of data transmission, maintenance provisions, and training arrangements for those who will use the technology. A suggested initial checklist is shown in Table 1.

The management process

Telemedicine, like other forms of information and communication technologies, changes the management process in health care (51). It is important that the telemedicine alternative does not just replace or automate the old practice, but that it renews the whole health care process in question (56). The changes in the processes do not only affect health care costs but also may change the structure of personnel used, legal responsibilities, and the place and nature of the treatments. Assessment studies in telemedicine should describe in detail the health care processes used, assess how well applications worked in practice, and to what extent process and outcomes data can be generalized nationally and to other health systems.

A report by CEDIT has outlined a framework for analysis of telemedicine applications in the context of hospital services (10). Consideration of technical, medical, economic/cost, organizational, and legal aspects is recommended. As suggested in the overview presented here, and elsewhere (31) all these areas will require attention in planning and operating a telemedicine system.

Table 1: Questions to consider in development of a business case for telemedicine

Population and Services	
What applications are being considered?	• By specialty. • By administrative task.
What are the current delivery arrangements for each specialty?	• Approximate level of demand. • Local and remote health care providers. • Referral arrangements.
Personnel and Consumers	
Who is to operate/use the telemedicine application(s)?	• Local health care providers - will there be changes in roles and responsibilities? • Remote health care providers - have changes in relationships to remote providers been identified?
Has there been consultation with all health care staff involved? Is there acceptance?	• Consider views of all staff.
Should there be wider publicity and consultation regarding the telemedicine services?	• Consider: - contact with patient groups, general public. - level of community acceptance.
What training programs need to be put in place?	• Consider qualifications and training needs for all staff who will be involved with the telemedicine application.
Delivery Arrangements	
How many sites will be using telemedicine?	• Specify the applications at each site. • Consider sequency/timing of introduction of telemedicine at each site. There may be advantages in phased introduction.
Has scheduling been addressed, at least at a preliminary stage?	• Consider scheduling of teleconsultation sessions within region/service. • Check/negotiate availability of remote providers.
Is real-time telemedicine essential for local needs, or might store and forward options be adequate?	• Consider if immediate availability of information is important for clinical and administrative needs. • Consider factors which would ensure consistent real time services.
What are the storage requirements for data from use of telemedicine applications?	• Cost and flexibility of storage requirements.
What back-up arrangements will apply should the telemedicine system fail? Have data security and privacy issues been considered?	• Need to develop contingency plans.

Table 1: Questions to consider in development of a business case for telemedicine (cont'd)

Specifications and Costs	
What are the specifications and projected costs for purchasing and maintaining telemedicine equipment? Will they apply fully to the goods that are to be purchased?	• Consider how specifications will relate to the application in question and the needs of those using it. • Ensure availability of desired equipment. • Bear in mind that equipment will need replacement, perhaps after three years. • Clarify cost and details of maintenance arrangements.
What are the mode and costs of communication?	• How do these relate to expected levels of use of the system?
Who is going to invest in telecommunication joint infrastructure?	• Is this to be a responsibility of government or of operators?
Will the telemedicine application cover all use of the service in question?	• If current arrangements are to stay in place for some cases, consider resource and organizational needs, costs.
How will changing delivery arrangements affect cost?	• Changes to personnel and to supplies will have consequences for costs.
Are there other, less expensive telemedicine options?	• Consider potential for Web use, for example, in telemedicine-education applications. • Other telemedicine approaches (e.g. telephone, secure fax, e-mail) may be good options for some applications.
Have issues on funding/reimbursement for use of telemedicine applications been resolved?	• These may involve wider policy matters. • Managers and users will require assurance on reimbursement issues. • Consider that the benefits (e.g. saved travelling costs) may not come to the payer of telemedicine service.

Source: Reference (34)

The need for assessment

Although assessment of new technologies is often time-consuming and expensive, there are a number of reasons for critically scrutinizing telemedicine programs. As noted by Perednia (60) these include the fact that health care resources are limited and data are needed to compare the relative value of telemedicine systems to alternative uses of medical resources. Furthermore, assessment can be used to document the functional utility of telemedicine as a diagnostic and clinical tool. It can help to decide whether remote consultation is equivalent to, better than, or worse than in-person consultation. Assessment can also provide important clues as to why a telemedicine program is successful or unsuccessful, and how it might be made more efficient. Assessment of telemedicine applications is needed to assist purchasing and planning decisions, and also to monitor and modify the use of the technology when it is in place (34).

The example of the heterogeneity of VC technology (4) shows that there is no unique telemedicine technology to be assessed. The soaring demand for telemedical equipment has increased the need for health technology assessment as decision-makers need up-to-date information on the appropriate uses of such equipment within the health service. Older assessments of equipment and networks may not give reliable information about current products in telemedicine.

Most of these technologies (equipment) and their applications are by now sufficiently developed to be suitable for scientific evaluation in their everyday use. However, the activities of purchasers and providers of telemedical services (the health care process) must also correspond to the routine operation of their organisations; otherwise the effects and costs of the telemedicine services cannot be reliably estimated.

The introduction of telemedicine applications will often result in substantial changes to health care practices. The nature of individual telemedicine projects will vary and each case will need to be considered in detail. Investments in telemedicine will be accompanied by changes in patterns of care – in quality of service, time, and availability. There may be consequent changes in health outcomes and patient satisfaction. Some issues will be relatively specific to the health authority or other purchaser, so that local data and circumstances will need to be considered.

Continuous assessment is required to appreciate and respond to changes in the nature of work in the social and health care sectors. Many applications of telemedicine support health care by creating an infrastructure that is conducive to efficient and effective teamwork. Data to assess the function of the technology have to be collected from all user groups.

The implementation of telemedicine requires assessment of advantages, disadvantages, costs (especially transaction and incremental costs), investment schedules, fluency of communication, need and access to services, changes in work processes, and the process and division of work. Since telemedicine changes the conventional division of work and decision making of clinicians, the legal and ethical consequences of telemedicine have also to be assessed (34, 40, 56, 66), though studies on these topics have been slow to emerge. Definitive assessment of a telemedicine application may take a considerable time and be complicated both by changes to the technology and to the health care system in question. This climate of continuing change will often suggest the need for a series of comparatively rapid, less detailed evaluations to provide decision-makers with timely interim advice.

The literature indicates that technology assessment studies dealing with telemedicine are still scarce. The use of telemedicine usually involves significant investments, but decisions on these are often not informed by data and recommendations from assessments. A 1997 review on telemedicine applications was able to identify only one cost-effectiveness study (51). Since then several other economic studies have been published but there is still a major need for high quality evaluation.

Assessment can also produce data on the optimum timing of investments against the background of medium-term structural development in social welfare and health services. Telemedicine offers alternatives to older methods of service delivery. Cooperation and integration of services between the social and health care sectors can make telemedicine projects economically beneficial earlier than when investment is made independently.

Technological change has specific implications for economic research on social welfare and health services. Organizational effectiveness is measured by the momentum of the service system, businesses, and research institutions in regional, national, and international cooperative networks. Effects should be assessed on the basis of the functionality (changes in processes), fluency (savings in time, speed of diagnosis, speed of treatment), and efficiency (cost-effectiveness) of each telemedicine project. In the future, telemedicine applications which may be connected to regional or nation-wide patient registers and smart cards will change the health care organizations and delivery systems. In that environment, assessments of telemedicine should consider more aspects of the information flow (transaction) and what effects this has on the clinical management process and patient outcomes.

Assessment of telemedicine

General considerations

Assessment is targeted at the health care process (clinical management pathway). The flow of information, the price of time used in traveling, waiting time for consultation, and traveling costs are important areas for analysis. It is important to assess how the new technology will change the work processes in health care. In diagnostic applications (e.g., teleradiology) telemedicine can make possible new services to remote centers. However, the measurement of the costs and outcomes of diagnostic technologies can be challenging since they will commonly have an indirect effect on outcomes.

While these are useful guiding principles, telemedicine systems vary considerably in their complexity. The nature of the application may affect the scope of the assessment. For example, there will be differences between assessment of a videoconference facility (VC) and a hospital-wide PACS (Picture Archiving and Communication System). While the assessment of VC can be made even within one sub-group of a specialty (e.g., orthopedics), PACS applications require a much more holistic approach to the whole hospital and to the information flow between wards and other actors within it.

There is a need to consider the assessment of each application in an individual way. The nature of the assessment will depend on the context in which it takes place. Context-specific features may include sources and scope of data, organisation of services, case mix and social values. Economic assessment should account for context variations in issues such as the choice of comparators, values on costs and consequences and the financing perspectives considered.

Special characteristics of telemedicine as a target of assessment

Several publications have discussed telemedicine as a target of assessment (34, 40, 51, 53, 56). One problem that is commonly referred to is the rapid advance of information and telecommunication technologies, which can make the assessments of current telemedicine applications out-of-date even before they are available for decision makers. The choice of telemedicine technology for assessment is then very important, as discussed earlier. Feasibility studies can be used to detect good candidates for fuller assessments.

The prices of telemedicine equipment are high after technologies enter the market, but decrease rapidly once they are widely used. Assessment studies may take several years and the cost structures can change considerably during the assessment period. This effect can partly be controlled by using the latest purchasing prices of the equipment and by presenting sensitivity analysis of the influence of the expected changes in costs.

The size of sites providing the telemedicine link can range significantly between regions and countries. The number and size of clients (e.g., primary health care centres) influence both the way work is organized and costs in the special care site. After a pilot project, there will be an expectation that the service should be made available to other clients without big changes in costs or effectiveness - that is, the results of the feasibility study will be generally useable. Ideally, an assessment study should present information for clients with different levels of service utilization and for service producers with different kinds of clients. In addition, telemedicine may produce changes in health care processes that may have effects on health care organizations in the long run. This can change the outcome and costs of the alternative to telemedicine. Since most studies to date have been made on pilot projects, the assessment results are difficult to interpret for longer term decision making (23).

Telemedicine applications are mostly new and there may not be solid legal and ethical rules for their use in health care. These questions should be discussed and accepted by ethics bodies of the organizations (sometimes even at a national level) before an application is properly assessed. Confidentiality and security of information are common concerns. It should be remembered that in existing systems there is potential for some patient information to fall into the hands of outsiders (79). However, in telemedicine the danger of substantial amounts of information falling into the wrong hands is much bigger without an adequate security system in place. Security and privacy issues should be considered in planning and assessment of telemedicine applications.

Telemedicine applications may be difficult to evaluate, since study designs that will be feasible for some operators may not meet high scientific standards. Randomization and double blinding may not be possible in many studies. However, controlled trials can be made in nearly all telemedicine applications. Although the HTA literature tends to focus on quantitative methods, qualitative methods can produce important information about the meaning in human or organizational transactions and in social and cultural context (51).

According to Ferguson and Keen (21), information and communication technology has a profound impact on the modern health care system; this impact should be evaluated at the level of the entire system. Transaction costs are a frame of reference in evaluating the relationship between information and communication technology and the efficiency of services (21). The core of transaction costs lies in imperfect information. Insufficient or imperfect information increases costs. Transaction costs can be reduced by means of information and communication technology but the important issues are the optimum level of investment and who is to pay for this. At issue are external effects which are positively influenced by fluent communication.

Glandon and Buck (29) showed that economic assessments of information and communication technology have yielded very little information about the real costs and benefits of investments. The same conclusion is frequently made in many fields of telemedicine (4, 53, 68, 79).

Telemedicine can contribute to integrated communication systems that allow information to be disseminated to greater numbers of health care professionals. For example, PACS installations that are used to deliver and store different kind of images, can be connected to telemedicine networks to work interactively between primary and secondary care (63, 68). This is a step towards regional and global networks and patient records that are planned to increase the cost-effectiveness of health care in the future (21). However, the assessment of large information systems in medicine will be a complex undertaking.

Frameworks for assessment

Ideally, assessment should provide a broad description of telemedicine for decision makers, covering technical, clinical, economic, ethical, legal and organizational issues. In practice, assessments have been constrained by availability of data, timing of policy and administrative decisions, shortage of evaluators, and inertia within health care systems. Guidance for assessment has been provided in frameworks formulated by a number of authors (34, 40, 51, 53, 56, 64). These make provision for detailed evaluation of a number of attributes, though to date much more limited assessment has been undertaken in practice. In the discussion presented here, particular reference is made to the framework summarized in Table 2, which draws on work undertaken by FinOHTA (56).

Estimation of the outcomes of telemedicine

The following general hierarchy for evaluation of diagnostic applications of telemedicine, following that of Fineberg et al. (24), gives an indication of stages to be considered in addressing the efficacy and effectiveness of the technology:

1. technical accuracy of the images or other data;
2. diagnostic quality of images or other data (e.g., sensitivity and specificity of the diagnoses, receiver operating characteristic (ROC) analysis);
3. diagnostic effectiveness (changes/confirmations of diagnoses);
4. therapeutic effectiveness (changes in clinical management of patients); and
5. changes in health status of the patients including quality of life (HRQOL).

A complete assessment of, for example, teleradiology services between primary and secondary care, requires discussion of all these questions (39). An analogous list could be formulated for therapeutic applications.

Technical quality: Stage 1 concentrates on the technical quality of the method. This will include the technical quality of the teleradiological images after a transmission, whether the specialist could use different image processing properties, and whether the transfer of all images (or other data) was made successfully. Technical accuracy studies are feasibility studies which show, mostly in laboratory circumstances or in pilot projects, that a certain telematic transmission is technically possible, and that the method fulfills technical quality requirements. Some of these issues may be picked up through routine quality assurance protocols, and in the development of a business case considered earlier.

Table 2: Assessment of telemedicine between a remote place Primary Care (PC) unit and Secondary Care (SC) units (or other special care unit).

Items	Symbols	Measurement topic
Technical Assessment:		
+ technical quality of image (and voice) transfer		time, luminance, resolution
+ reliability, validity and other characteristics		sensitivity, specificity, ROC, rate of successful transmissions
Effectiveness,		
+ diagnostic quality	E	sensitivity and specificity of diagnosis
+ changes in health related quality of life	E, U	e.g., QALY, HRQOL profiles
+ clinical changes in health	E	survival, symptoms
+ changes in management process in hospital		clinical pathway, improved quality of care
+ increasing know-how in PC		decreased utilization of consultations, improved quality of primary care
+ non-health outcomes of a patient		certainty, access of care, equality
User Assessment of the Technology:		
+ doctors		user questionnaire from quality, usability and satisfaction
+ nurses and other staff		user questionnaire from quality, usability and satisfaction
+ patients (if relevant)		user questionnaire from quality, usability and satisfaction
Costs of Telemedicine:		
+ investment costs in PC and SC	FC	direct cost; e.g., equipment and network
+ monthly user charge of equipment in PC and SC	FC	direct cost; rental cost of lines, maintenance (10-15% of capital costs)
+ costs of used communication lines in PC and SC	VC	direct cost; user charge per hour
+ wages of doctors and other staff in PC and SC	VC	direct cost; time used on telemedicine.
+ education of the technology (PC and SC)	VC	direct cost; education of personnel and support services
+ other relevant costs in PC and SC	FC or VC	direct cost; room, energy, administration
+ costs of a patient (and close relatives)		direct cost; travelling and domestic costs, other medical costs
+ lose of working and leisure time of a patient		indirect cost; time away from work
+ intangible costs		indirect; value of death, pain and/or worsened HRQOL
Total Costs (TC)= Fixed Costs (FC) + Variable Costs (VC) + other direct costs (+ possible indirect costs):		

Table 2: Assessment of telemedicine between a remote place Primary Care (PC) unit and Secondary Care (SC) units (or other special care unit) (cont'd).

Items	Symbols	Measurement topic
	Trials:	
+ randomisation		most preferred
+ before and after comparison within hospital		
+ control groups		
(+ experimental or nonexperimental analysis)		
	Economic Evaluation Methods:	
+ cost or effectiveness analysis (CA, CMA, EA)	TC or E	Only TC or E measured
+ cost-benefit analysis (CBA)	TC-E, TC/E	Both TC and E in monetary units
+ cost-effectiveness and -utility analysis (CEA, CUA)	TC/E, TC/U	E in natural units or preferences and U in utilities
	Sensitivity Analysis:	
+ distance		distance between co-operative sites
+ number of patients		patient load in both sites
+ duration of the investment		years of utilization
+ effects of changes in technology in the future		e.g., improved technical quality and shortened duration of transmissions

Source: Reference (56)

CA = Cost analysis
CMA = Cost minimisation analysis
E=Effectiveness
EA=Effectiveness analysis
HRQOL=Health related quality of life
QALY=Quality adjusted life year
ROC analysis=Receiver operating characteristic analysis
TC=Total costs
U=Utility

The technical properties influence the sensitivity and specificity of the telematic diagnostic method compared to a standard method (gold standard, if it exists). One commonly used method to test the diagnostic quality is to perform an ROC analysis where the diagnostic accuracy of telematically transmitted images is compared to that of the same images sent by a conventional method (e.g., plain film sent by post). The use of ROC analysis in telemedicine is explained and reviewed by Taylor (68) and Ruggiero (63). Aspects of technical accuracy and diagnostic quality require evaluation and resolution before consideration is given to assessment of clinical effectiveness.

Clinical effectiveness: The measurement of clinical effectiveness of telemedicine is one of the prime objectives in assessment studies. If information on effectiveness is poor, other types of assessment (e.g., economic or social) are unlikely to give reliable or generalizable results. Clinical health status can be measured with the standard measures used in each specialty. The most commonly available clinical measures are the mortality and morbidity rates (Table 2). Many telemedicine applications aim to produce at least the same clinical outcome as alternative conventional interventions and the differences in mortality or indications of morbidity (e.g. duration of sick leave) are often very small. However, in some applications (such as teleneuromedicine) the aim may be to improve clinical outcomes as a result of the technology, in part through more adequate, faster transfer of the patient.

As with other diagnostic technologies, evaluation data are more readily obtained for levels 3 and 4 of the list given above (diagnostic and therapeutic effectiveness) than for changes in health status. Those taking decisions on telemedicine will commonly have to rely on surrogate measures of effectiveness which may have tenuous links to health status indicators.

Diagnostic effectiveness refers to how much a diagnostic method affects the clinician's thinking about the disease or condition. It can be estimated, for example, by calculating the log likelihood ratio from the diagnosis before and after use of imaging technology (39). Such studies will tend to be most often undertaken at a pilot project stage and could often be regarded as being part of establishing the feasibility of a telemedicine method.

With *therapeutic effectiveness*, appraisal of the influence of telemedicine on patient management will often continue beyond the pilot project stage. Users and funders of telemedicine services may wish to undertake on-going monitoring of patient management, possibly linking such measures to quality assurance programs. In the case of diagnostic imaging technology there will be interest, as with stage 3, in the influence of telemedicine on diagnosis, monitoring/staging and excluding diseases or conditions.

Health outcomes: In stage 5 of the assessment, in principle, the outcome of the whole management process is measured, that is changes in health status of the patients and in their Health-Related Quality of Life (HRQOL) (Table 2).

Measurement of changes to patient outcome poses major challenges to those assessing telemedicine applications, for reasons discussed elsewhere in this report. In general:

- availability of administrative and other data for conventional services may be limited;
- differences in outcomes between the telemedicine and conventional options may be modest, while numbers of subjects may be small and the power of the study low;
- there may be changes to telemedicine technology; and
- there may be changes to the conventional (non-telemedicine) technology and to the structure of the health care systems.

Sisk and Sanders (64) have noted that intermediate outcomes may be acceptable measures of health–related effects.

Study design in telemedicine assessment: The strength of evidence of a telemedicine study depends to a large extent on the study design (Table 2). The starting point is that there should be a comparison between a new and some conventional alternative(s). The study can then be designed according to protocols used widely in clinical and epidemiological studies, with comparative strength of study indicated by classifications such as those of Jovell and Navarro-Rubio (43). Randomized controlled trials (RCTs) with large sample sizes offer the strongest evidence for decision making. However, in telemedicine studies, randomization may be difficult or impossible.

A further limitation on the use of RCTs in telemedicine, as argued by McDonald (52) is that in reality they will be undertaken only during the pilot or early routine use of a telemedicine application. As with other health care technologies, RCTs will be used in telemedicine, if at all, to assess the efficacy of the technology. Such RCTs may not be widely generalisable to other health care systems and will not necessarily be more than a general guide to the effectiveness of the telemedicine application, should it prove to be sustainable and move into long term routine use.

The reality in the evaluation of telemedicine is that weaker study designs may have to be used. As a result, decision makers must be cautious in the degree of inference from the assessment results published in the field. Telemedicine assessments have so far been on stronger ground in considering effects of the technology on time-related consequences of health care services and on organizational issues.

Quality of life measures: Measures of HRQOL in an assessment study in telemedicine will depend on the aim of the study and the disease or condition being considered. For example, if the study assessed the effectiveness of a telepathology system in breast cancer surgery, some cancer-specific instrument can be used to measure QOL outcomes. However, the relatively short-term intervention of most telemedicine applications and the indirect nature in health effects, are impediments to this kind of long-term outcome measurement. In an application such as teleradiology, where many types of conditions are covered, a disease-specific instrument cannot be used. Generic measures developed to be applicable in most diseases may be more useful. At least in the short term, QOL outcomes may be more likely to relate to time-related aspects such as differences in waiting times or travel requirements consequential to use of the new technology. Useful indications of possible effects of QOL may be obtained from preliminary surveys during feasibility studies (17).

The descriptive system of HRQOL can be related to values that a population has from health states (7, 19, 47, 75). The scaling system of the generic measures separates the preference weighted single index measures to their own category, that is, utility measures (U). They can be used in the utility analysis where the outcomes are shown as a combination of time and change in HRQOL, in terms of quality adjusted life years (QALYs). Incorporation of QALY measurements into telemedicine assessments has yet to occur and methodological issues would need to be carefully considered.

Other Outcomes: In addition to process oriented, clinical and HRQOL outcomes, telemedicine may also have substantial educational effects in primary care (Table 2). For example, during videoconference consultations a specialist can guide a GP to make new types of examination on a patient. The GP can hear about new treatments or other medical information. This kind of positive externality benefits both the patient in the consultation and also the future patients of the GP. Although assessment of the educational effect of telemedicine is difficult, it should be included, whenever possible, in the projects where doctors on different levels of the specialty or from different specialties communicate with each other. Bergmo (5) has included educational effects in an economic analysis of teleconsultation in otorhinolaryngology. The educational/ training effects of telemedicine may have an influence on the sustainability and costs of a specific application as it moves from the pilot project phase into routine care (such effects may tend to decrease use of telemedicine). A contrary trend is that establishing of telemedicine may lead to previously unmet demand for services (35).

Telemedicine consultations can also serve as a method of quality assurance for diagnostic procedures. For example, X-ray images can be sent for further examination (or second opinion) and the results compared to the original diagnostic decision and subsequent management decision. The feedback then improves the overall quality of a radiology unit. The increased certainty of diagnostic information is an important outcome, since it reflects the overall patient management process and also the quality of process of care.

The implementation of telemedicine can reduce the time required to get a service (access). Influence on time of transactions may impact on both short and longer term health effects to the patient, and 'non-health' effects connected to increased information such as certainty of diagnosis and the value of time. In principle, the value of these non-health outcomes to patients can be estimated using a willingness to pay method or conjoint analysis (53). However, such assessment approaches have yet to be implemented in telemedicine and their validity and generalisability would need to be established.

Quality and user satisfaction

Quality problems with telemedicine might include:

- overuse of care (e.g. unnecessary use of telemedicine);
- underuse of care (e.g. failure to refer a patient for necessary services); and
- poor technical or interpersonal performance (e.g. failure to get proper voice or image in videoconferencing, and difficulties in interviewing during telesurgical consultation).

Each type of problem is important. The first two are connected to health policy making in a broader sense, since they are closely connected to equity questions and the funding of health care. Technical quality is not only the quality of images or other transmitted information, but also the usability of software and hardware.

Users' satisfaction with the facilities is particularly important when adopting new alternative technologies (9, 34). Staff who are dissatisfied with the equipment will not use it. In addition, satisfaction of patients and their families should be ascertained. Further, it should be noted that patients' satisfaction with telematic services is also influenced by ancillary operations, such as the integration of doctors' appointments and diagnostic tests. User and patient satisfaction will be an important aspect for assessment at the pilot project stage, using survey methodology. Follow-up surveys, as the technology comes into routine use, will also be desirable. Decisions informed by such surveys will commonly be those for the operators as much as for the funders of telemedicine.

Estimation of the costs of telemedicine

From whose viewpoint should costs be examined? This question of perspective is very important in every assessment study, since an item may be a cost from one point of view, but not from another. For example, the travel of a patient to a health facility will be associated with costs from the patient's perspective and from a societal point of view but not from the perspective of the Ministry of Health (19, 33). Usually, costs accrued to each party in the project will be taken into account (producer of the health service, patient, patient's family, other services, the rest of society). If the project is not aimed at a specific perspective, assessment studies utilize the societal point of view, that is, all relevant costs are estimated. If some cost items are common in all compared alternatives, they may be left out of the study.

Table 2 shows the check list of the costs that are applicable in most telemedicine projects. Once the use of resources in natural non-monetary units have been measured, the quantity units of resources are multiplied by their monetary values. The separation of used resources and their monetary values is important for inter-country comparisons, since it enables the re-adjustment of the cost data between different health care systems and price levels (9).

In the valuation, market prices should be used. If some prices are subsidized (e.g. those of laboratory or radiological examinations within a hospital), they should be readjusted to correspond to their market prices. The economic definition of costs also includes the notion that the cost estimates obtained from accounting may not reflect the real opportunity cost of used resources. For example, buildings, land, and equipment may have been written off in the accounting, but will have opportunity cost in the use of other projects (9). To make the comparison between different studies easier, the costs should be valued using standard cost values which reflect the central tendency of cost values of the used resources.

The time horizon of the cost analysis may influence to the cost estimates of project alternatives. The telemedicine application and the alternatives with which it is compared may have different distributions in time of costs and benefits. Higher cost today may reduce costs in the future. In many telemedicine projects, it has been assumed that while current investment costs can be high, the reduction in prices in future together with decreased need for secondary care (by the educational effect on primary care) will significantly decrease the lifetime costs of a project. All future costs are discounted to their present value by using the appropriate social discount rate.

Types of cost: Costs are divided into three general classes: direct, indirect and intangible costs. Costs, estimated as cost flows, are affected by the technology used, the functionality of the health care process, and the changes in the care provided. Most telemedicine projects are aimed at reducing the expenditure related to the transaction of the specialized medical services. In telemedicine, information such as x-ray images travel between primary care (PC) and secondary care (SC) units, as an alternative to travel by the patient or by the specialist between these centres. In the cost assessment, both the conventional and telemedicine alternatives have to be considered in elements that can be determined, for example, from the actual clinical management pathway.

Direct costs can occur either within health care or to the patient. These may include travelling costs, other health care costs and the cost of arranging home help (Table 2). Direct health care costs include those directly due to the application of telemedicine or the conventional alternative. The investment costs of equipment and line charges constitute a great deal of the direct (and total) costs of the telemedicine in many specialties. Both PC and SC units must invest in machinery, software, accommodation, and networking. In economics, these costs are called fixed costs (FC), since they do not vary according to the utilization of a produced service. In addition, fixed costs include the monthly rental cost of the network, some salaries and wages, and possibly administrative expenses of the hospital/centre. Variable costs (VC) include costs that vary according to the level of service such as supplies, drugs, and fees for service. Since in most telemedicine projects health care professionals are working only occasionally in the project, salaries and wages can be counted as variable costs.

The analysis of costs is commonly undertaken using a one year period. The annual fixed costs are calculated by dividing the investment costs by the utilization time of the equipment and adding the other annual fixed costs. The share of fixed costs per patient is calculated on the basis of the annual caseload. If the variable costs do not change according to the number of patients per year, the total direct health care costs per patient (TC) is calculated by adding the fixed cost and variable cost per patient.

Indirect costs are used to denote the time of patients (or their families) consumed or freed by the program (Table 2). The intangible costs include the value of death, pain and HRQOL (19). They are valued either by using monetary values or by using economic and psychometric scaling techniques.

Loss in working time (production) can be estimated on the basis of the average loss in working hours which, in turn, can be valued according to the mean industrial wages to ensure that the cost estimates have not been affected by a few extreme values or by special patient groups. Loss of leisure hours is often estimated on a time basis without monetary valuation, though the question of valuation of non-working time remains a matter of debate. Within health economics there is a fundamental debate on whether indirect costs should be included in analysis of costs. The discussion is centered around how to cope with decreased earnings (losses in productivity). Some are of the opinion that they should be excluded from the agenda altogether (27). Others consider that they should be included insofar as they can be accurately calculated (45, 46).

At this stage in the assessment of telemedicine, consideration of indirect costs has not been a major factor. However, in the study of Halvorsen and Kristiansen (36) indirect costs played an important role when the decision rule for a teleradiology service was made. Because indirect costs may have substantial distributional effects between different subgroups of population, they can be shown separately by natural units or monetary values and the decision maker may include or exclude them from the decision process. If the indirect costs are included in the total costs (TC) of the telemedicine project, there is a need to be aware that there is a danger of double counting, for example, if production losses and change in HRQOL are both valued by monetary values (19). Monetary valuations for HRQOL in telemedicine studies have yet to be undertaken.

The costs of telemedicine are crucially dependent on the degree of utilization of the equipment. For instance, if the primary care centre is able to use video conferencing for many types of consultations, the share of the purchase cost of the equipment (FC) in the total costs will be reduced. In principle, a high degree of equipment utilization (e.g., links with several PC centers or a large number of applications) at an SC unit offering telemedical services reduces the per consultation costs of telemedicine. Much depends, however, on the number of personnel required to produce the service and on the time used for telecommunication, that is, on the variable costs of a project. As a rule of thumb, the shorter the distances between cooperative parties, the higher the utilization of the equipment should be to make the investment beneficial. A good example is PACS where system utilization must be very high to make the investment realistic.

These questions are analyzed in the framework of marginal and incremental costs. The marginal cost (or benefit) is the cost (benefit) borne when one additional unit of product or service is produced. The incremental cost (or benefit) refers to the extra cost when an additional project is established beside the old ones (19). In every investment, the marginal benefits should exceed the marginal costs of the project in the long run (34).

Economic evaluation methods

Table 2 makes reference to Effectiveness Analysis, Cost Minimization Analysis, Cost-Effectiveness Analysis (CEA), Cost-Utility Analysis (CUA) and Cost-Benefit Analysis (CBA). Basically, the costs of a project are evaluated in the same way in all methods. In cost minimization the outcomes are assumed to be equal between the compared alternatives. This method has been the most frequently used approach in the field of telemedicine. Effectiveness analysis assumes that the costs of the alternatives are equal and that they differ only in their effectiveness. In an economic evaluation, at least two alternatives should be compared. If the costs or consequences of a new technology are evaluated without any comparison to some existing alternative, economic interpretation of the results in terms of incremental ratios cannot be made.

CEA is a form of economic evaluation where the costs and effectiveness of alternatives are compared. The effectiveness measures used in the analysis include both natural unit measures (such as life years saved, reduction in sick leave and morbidity) and HRQOL measures other than utility measures. CUA is a special form of CEA where the consequences are measured with utility measures, that is QALY's gained (9, 19).

The results of CEA and CUA are shown as the ratios TC/E and TC/U in Table 2. For meaningful comparison, it is important to analyze the additional costs that one program imposes over another, compared with the additional effects, benefits, or utilities it delivers. Incremental cost-effectiveness ratios are used for such purposes (19).

TC/E ratios are not fully comparable between studies. In principle, the different QALY outcomes are assumed to be comparable, as are also the cost/QALY ratios. However, HRQOL measures and different valuation methods can significantly affect the magnitude of QALY's gained by interventions as well as to the ranking order of the ratios of the interventions (57). The decision rule for the cost/QALY ratios is that the lower the ratio, the more efficient the intervention. The QALYs gained should usually be discounted to their present value.

The outcomes of the CBA are always valued by monetary terms called benefits. The benefits of a health care technology are linked to the resources saved. The estimation of direct benefits (cost savings in the health care sector and individual direct savings) are relatively easy to determine and value. The estimation of indirect (production losses) and intangible (HRQOL) benefits is a more complicated process. In the human capital approach, the value of healthy life is equal to the discounted future earnings. Another method is to ask patients or the general population about their willingness-to-pay for a certain change in HRQOL and the risk of dying over time (for details, see Johansson (41, 42) and Thompson (70).

The main purpose of economic analysis is to give decision makers information on which alternative is superior. The decision-making criteria for CUA and CEA are based on a comparison of incremental C/E ratios of technologies: the lower the C/E ratio, the better its efficiency (9, 19). CBA yields theoretically the best results for resource allocation, if all outcomes can be realistically valued in monetary terms, because the benefits of an intervention show directly the opportunity costs of rejecting it. However, the QALY approach also involves the opportunity cost interpretation: if a certain intervention is chosen, the QALYs in the next best alternative are lost (18).

Implementation of economic analysis to telemedicine

Although the basic theory of economic evaluation is reasonably clear, its implementation to telemedicine is less certain. Difficulties can be found in the estimation of both the effectiveness and the cost side of the analysis.

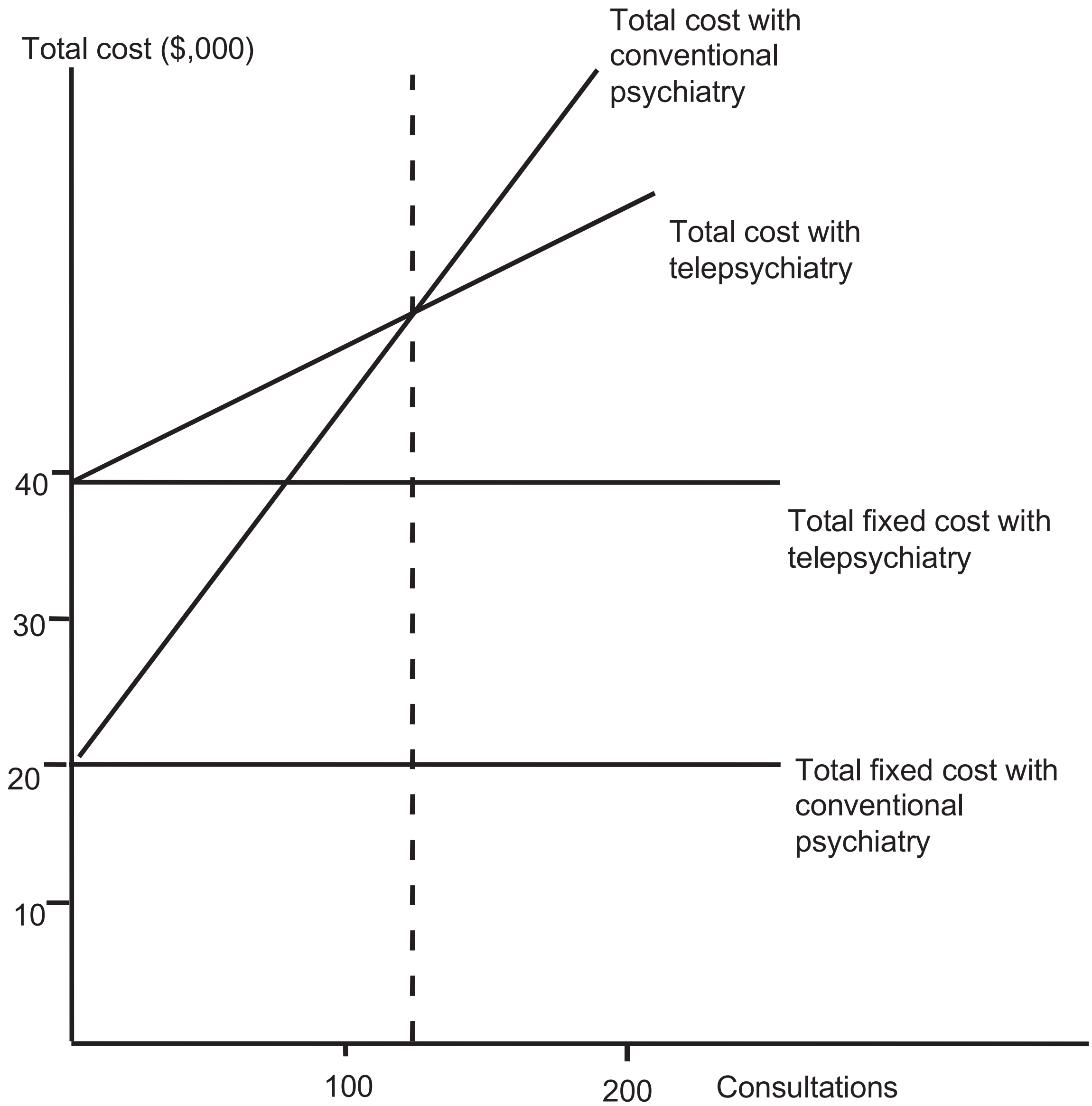
It can be difficult to establish an observable and empirical link between telemedicine and change in patient outcome (53). The implementation of the service may change the quality and process of care and access to care. When new patients who may have a different need for care are treated, the outcomes of the projects will also change both in the conventional alternative to telemedicine, and in the health care unit as a whole. In addition, the valuation of both health and non-health outcomes are always difficult.

In the cost side, the changing technology hinders the estimation of costs, since successive versions of equipment have different, usually decreasing, prices. The same also happens in telecommunication technology. As McIntosh and Cairns (53) have pointed out, changes in access to care, consultation and referral patterns, and number and skill mix of staff, may have significant effects on costs. Since such difficulties are largely connected to the uncertainty of the environment in which telemedicine is used, these questions can partly be addressed by undertaking a sensitivity analysis of study results, which is considered below.

Finally the wide implementation of telemedicine and new information and communication technology will considerably change the health care processes. The so called welfare cluster, that shows the importance of cooperation between different levels of health care together with other related sectors (research and industry), will change the costs and hopefully the outcomes of health care in future (21, 44). Transaction cost theory has yet to be used in an empirical study of telemedicine; guidance on these questions is not yet possible (59).

A useful approach when taking the viewpoint of the health care provider is "breakeven analysis" which considers the volume of consultations needed for the total annual costs of the two types of services (telemedicine and its alternative) to be equal. The telemedicine option will typically have higher fixed costs because of equipment and telecommunication charges. The non-telemedicine option has higher variable costs because of travel and other time-related expenditure. After a certain number of consultations, the costs of telemedicine will be lower than those of providing an alternative type of service. This form of analysis, which is based on a cost minimisation approach, has been used, for example, in assessments of teleradiology (6) and telepsychiatry (17). Figure 1 provides an illustration of this approach.

Figure 1: Breakeven analysis for a telepsychiatry application



Sensitivity analysis

Economic evaluation results reflect the method and data used and thus the environment in which they are derived. Much of the practical interpretation of the results revolves around sensitivity analysis in which cost and outcome factors are simulated under various basic assumptions. In this way, some allowance can be made for future developments. The four broad areas of uncertainty in the analysis relate to variability in sample data; generalizability of results; extrapolation; and analytical methods (53).

In the assessment of telemedicine, difficulties can be found in all of these areas. For example, available data may not be representative of the usual patients who access the service and how well they comply with usual practice throughout a whole health system. Extrapolation is based mostly on assumptions about the possible relationship of the study variables in the real world, for example, the cost structure of the clinic, and the patient and management casemix of the region. In addition, the inclusion (or exclusion) of indirect costs or other cost components can significantly change the result and interpretation of the study.

In telemedicine, sensitivity analyses could be done, for example, by location of primary care unit, number of patients, case mix, useful life of investments, and type (price) of investments. Since telemedicine evolves rapidly, the results will also reflect the effects of this rapid development upon investment decisions. Sensitivity analysis can be helpful in formulating recommendations for the timing of procurement of certain telematic services.

Summaries of monetary and non-monetary factors

Any realistic appraisal of a telemedicine application will need to consider a range of both quantitative and qualitative factors. An approach which has been suggested for assessment of computed radiography applications is social audit analysis (13). With this approach, a matrix of data on monetary items plus information on non-monetary benefits is produced. Monetary and non-monetary factors in different areas of impact can be brought together for comparison, with additional detail and values being included as assessment results become available.

Such analysis could include costs and benefits to specialists, referring physicians, other health care professionals, patients and their families, and to health care administrators and funders. Particular benefits which apply to each group of major participants in the telemedicine application can then be considered, taking care to avoid double-counting of benefits achieved. Consideration can be given to providing appropriate weightings for intangible benefits, in association with those for which monetary valuations are available. Weightings for the various factors would take into account the environment, priorities and values held by policy makers (33). An analogous approach, with more emphasis on monetary factors, is the use of a cost-consequences matrix discussed by McIntosh and Cairns (53). Table 3 illustrates areas of impact for telepsychiatry (33).

Table 3: Summary of impact for a telepsychiatry application. **(see page 30)**

Table 3: Summary of impact for a telepsychiatry application.

Area of impact	Effect on consumer (patients & family)		Effect on psychiatrist		Effect on referring physician/local service provider		Effect on payer (provincial government)	
	Monetary	**Non-monetary**	**Monetary**	**Non-monetary**	**Monetary**	**Non-Monetary**	**Monetary**	**Non-Monetary**
Treatment/ outcomes	Effects through changes in length of treatment	Effect on health status Increased access to care; change in support	Psychiatrist can treat more patients	Intervention before severity of illness increases (identify cases earlier)? Increase in consultation for patients whose conditions would resolve? Effects through decreased travel	More patients can be treated	Assistance/ education in management Ability to clarify information	Increased treatment costs	Improved coverage of population
Travel	Decreased travel expenses and lost work time	Inconvenience and stress of travel		Decreased travel, foregone professional tasks			Decreased travel costs for psychiatrists	
Waiting	Potential decreased costs through lost work time, etc.	Potential for more rapid help/ support, decreased severity of illness	Uncertain	Uncertain	Uncertain	Shorter-term management prior to consultation. Faster decisions on treatment	Possible influence on costs of services	Potential for improved health status

Source: Reference 33

A systematic review of telemedicine assessments

The field of telemedicine is currently under rapid development and in recent years a number of studies have addressed the feasibility of various telemedicine applications. Relatively few studies, however, have been able to collect the data required to provide an unambigious demonstration of the value of applications (68). Furthermore, as far as we are aware, there have so far been no attempts to gather all the relevant information about the effectiveness of telemedicine together in the form of a systematic literature review, though a review of assessments in telemedicine-neuromedicine was included in the report prepared by the TASTE project (31). Therefore, we decided to survey the literature in a systematic manner to clarify the current state of the art. The survey is intended to help decision-makers who are under commercial or public pressure to establish telemedicine services to get an objective view of what is really known at present about the effectiveness and cost-effectiveness of telemedicine.

Literature search and methods for the systematic review

Details of the search strategy are shown in Appendix A. Use of this approach enabled us to identify 784 articles, dealing with telemedicine, that were published between 1966 and November 1998.

Initial screening of the identified articles was based on their abstracts. All abstracts were read by two of the authors (AO and RR). Selection of relevant articles was based on the information obtained from the abstracts and was agreed upon in a consensus meeting between the two reviewers. When an abstract did not give sufficiently precise information about the study or such information was not available at all, the article was obtained for further review.

We looked for articles which reported outcomes of telemedicine in terms of administrative changes, patient outcomes and economic assessment. Articles which were limited to describing the feasibility of a certain system, the technical evaluation of a system (e.g., comparison of transmitted radiological images with plain film images, comparison of transmitted histological images with glass slides) were excluded.

Full-text articles obtained for closer inspection were again evaluated by the two investigators who, in a consensus meeting, made the final decision on whether or not an article should be included in the final review, using the criteria given above.

Methodological quality of the included studies

The strength of evidence in each of the included studies other than those concerned only with economic analysis, was judged according to the classification given by Jovell and Navarro-Rubio (43). In that classification, study design is specified on the following nine levels, in descending order of strength:

I. Meta-analyses of randomized controlled trials.

II. Large sample randomized controlled trials.

III. Small sample randomized controlled trials.

IV. Non-randomized controlled prospective studies.

V. Non-randomized controlled retrospective trials.

VI. Cohort studies.

VII. Case-control studies.

VIII. Non-controlled clinical series, descriptive studies, consensus methods.

IX. Anecdotes or case reports.

Each level is further qualified by conditions of scientific rigor for the study.

For the purposes of the review, the selected assessment studies included comparison between a telemedicine application and a control group. The comparison of telemedicine and some level of conventional alternatives was also required for inclusion of economic analyses in the review. Articles which were duplicates of the same authors' other published studies were excluded - the most representative of the studies was included for further consideration. The chosen articles were described using the following categories: authors and name of the study, strength of evidence according to the nine level classification, objectives of the study, study design, setting and subjects, type of economic analysis, and results and conclusion.

Results

One hundred full-text articles were obtained for closer inspection. Of these, 29 were deemed to fulfill the inclusion criteria of the review and are listed and briefly described in Table 4. Eighteen of the articles assessed at least some clinical outcomes; the remaining 11 were mainly economic analyses. Some kind of economic analysis was included in 19 (66%) of the studies.

The economic analyses in the articles were mostly variants of cost analysis (16 studies) (Table 4). Cost-benefit analysis was said to have been done in two studies. However they were methodologically more like cost analysis studies, since the benefits were estimated as savings (mainly traveling costs) compared to the conventional alternative, that is the costs of conventional care. Except for one study, the analyses measured only direct medical costs and some kind of estimation of transportation costs were included in 14 studies. Indirect costs were assessed in one study. Incremental cost analysis was also performed in one study. Cost-effectiveness ratios were calculated in two studies.

In all of these studies, effectiveness was defined in clinical terms. There were no studies including standardized HRQOL measures or QALY calculations. Some kind of discounting of costs was included in four studies and there were seven studies with some kind of sensitivity analysis of the study results.

Discussion

According to the results of the review, there are still few data on the effectiveness and cost-effectiveness of telemedicine. Of the nearly 800 articles surveyed, most were reports on feasibility of various applications and only a few of the studies reported a controlled comparison of a telemedicine application with conventional means of providing services. More than half of those assessed clinical outcomes; the rest were economic analyses.

The review indicates that at the moment, the most convincing evidence regarding the effectiveness of telemedicine deals with teleradiology, teleneurosurgery, telepsychiatry, and transmission of echocardiographic images. Promising results have also been obtained for the transmission of electocardiograms. However, even in these applications, most of the available literature refers only to pilot projects and short term outcomes. Most other telemedicine applications still lack scientific evidence regarding their effectiveness.

Economic analyses have mostly revealed that teleradiology, especially transmission of CT-images, can be cost-saving, although one of the included studies did not find this to be the case (36). An important contribution to the discussion about the cost-effectiveness of teleradiology is the study by Bergmo (6) which explicitly states the workload that has to be exceeded in order to achieve cost-savings by using teleradiology. A similar study by Bergmo has shown that specialist consultations in the field of otorhinolaryngology can be performed in a cost-saving way when the work-load exceeds a certain number of patients (5). A pilot project on telepsychiatry used a similar approach (17). Such studies that give a clear number needed to treat by the telemedicine option are helpful for decision makers when faced with the question of whether or not to start a new telemedicine service.

Another field in which telemedicine has in several studies been shown to be cost-effective is telepsychiatry. For applications other than those mentioned above, scientific data on effectiveness and cost-effectiveness of telemedicine remains limited.

The quality of the economic analysis in the reviewed papers was relatively low, with few exceptions. The costs included varied significantly between studies, so that comparison of the cost estimates may not be feasible in many cases.

There were also several economic studies that did not give detailed information about empirical background of the cost and/or benefits included in the calculations. These studies were excluded from the review. For example, we excluded one good teleradiology cost-benefit analysis (38) because the theoretically good economic model did not make use of the empirical cost and benefit estimations made at the specific sites by the study group.

Cost-effectiveness studies in telemedicine are still very scarce. A systematic comparison of the costs and more work on the effects of the alternatives should be done in the future. Although the term "cost-effectiveness" was frequently used in the studies, the effectiveness (and sometimes costs) were assumed to be established for telemedicine without any scientific evidence.

More than four years ago an editorial in the Lancet stated that "although much is claimed, the economic benefits of telemedicine have yet to be proved" (3). Although a limited number of telemedicine applications have up to now been shown to be effective and cost-effective, that conclusion still remains valid for the majority of suggested ways to utilize telemedicine. While a number of detailed studies are in progress in several countries, the assessment literature has yet to address aspects of telemedicine applications as they move into routine use, or their longer term impact on health status, costs, and organization. Other dimensions will require consideration when formulating approaches to further economic analysis. These will include sustainability of the telemedicine service, decisions on equipment and telecommunications, impact on the overall use of health program resources, and measurement of outcomes (35).

Consequently, further assessment studies in the field of telemedicine are still clearly needed. Decision makers under public and commercial pressure to start new telemedicine services, should link implementation of new, and in many instances costly technology to realistic development of a business case and subsequent data collection and analysis.

Table 4: Studies evaluating telemedicine applications

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Medical Consultation						
Conrath et al. 1997 (12)	Level IV Patients were examined via telecommunications systems and by conventional means	To compare the diagnostic accuracy, proportion of supporting investigations requested, time taken for diagnostic consultations and the effectiveness of patient management across four communication modes.	Patients were examined via one of four telecommunication systems: two-way color television, two-way black and white television, two-way hands free telephone, two-way still frame television.	1,015 patients with active medical problems seeking medical attention from a clinic in a Canadian province.	No	No significant differences in any of the outcome measures across the four communication modes. The cheapest mode was the most cost-effective
McCue et al. 1997 (50)	Level VI Comparison with a control group who had face-to-face consultation the previous year	To implement a cost/benefit analysis of telemedicine subspecialty care provided between a correctional center and a university clinic.	Treatment of HIV-positive inmates by means of video conferencing.	165 telemedicine consultations over a period of 7 months.	Over the study period transportation and medical savings of $35,640 and $21,123 respectively were achieved. The net benefit was $14,486. Sensitivity analysis.	Telemedicine increased access to care for HIV-positive inmates and generated cost savings in transportation and care delivery.
Hayes et al. 1998 (37)	Level VII Case control study (treatment plan before and after telemedicine consultation)	To assess the effectiveness of telemedicine on the clinical decision-making process for patients with urolithiasis	Consulting urologist recorded treatment options after the "usual" telephone consultation, after the telemedicine consultation, and after examination of the patient if the patient was transferred	Consultation between a referring urologist and Georgetown University Medical Center. 14 patients in the clinical trial group and 18 in a simulated study group.	No	Recommendation of the consulting urologist at the tertiary center was altered in 37.5 % of cases after the telemedicine consultation.

Table 4: Studies evaluating telemedicine applications (cont'd).

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Muller et al. 1977 (55)	Level VI Clinical series with historical controls	To determine the cost-effectiveness of a bidirectional interactive, black and white cable TV in pediatric primary care.	Cost analysis of alternatives.	East Harlem well-baby clinic providing primary care by utilizing pediatric nurse-practitioners. Access to physician consultation via TV. 4000 visits, 500 consultations.	Based on aggregate cost data for two years (a year when the TV link was only partially operational and a year when it was regularly utilized). Medical and transportation costs.	Cost of consultation via TV 2/3 of the cost of a physician providing direct care.
Brecht et al. 1996 (8)	Level VIII Economic and feasibility analysis. No control group	To determine whether telemedicine can save the corrections health system money and whether it adds value to current operations by improving communications between care providers and allowing other applications to take place that had not previously occurred	Four prison delivery models: 1) Inmates are transported to a regional prison medical facility and seen by specialists by telemedicine 2) Inmates only from the immediate surroundings are brought to a regional prison medical facility, 3) Inmates are seen from their home unit equipped with a 17-bed skilled-nursing infirmary, 4) similar to model 3) except that the home unit is equipped only with ambulatory care facilities.	Large department of criminal justice (with a total of 104 units to house 133 000 prison inmates) linked with telemedicine to a university hospital.	Assessing the return of investment on the basis of capital and operational costs in relation to the total cost of transportation, both direct and indirect. Sensitivity analysis	95% of the telemedicine consultations saved one or more trips to outpatient specialty appointments. A high degree of patient, presenter and specialty consult satisfaction. High-volume telemedicine care can be delivered at a cost ranging from $ 40 to $70 per consultation. This is less than the real costs of transporting inmates to specialty clinics (estimated $ 180 to $ 200).

Table 4: Studies evaluating telemedicine applications (cont'd)

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Bergmo 1997 (5)	Economic analysis	To determine the cost differences between three alternative methods of delivering care.	A cost comparison of patient travel, teleconsultation, and visiting specialist in providing consultations for ear, nose and throat (ENT) problems.	Delivery of examination and treatment to a small primary-care center (in Alta, Northern Norway), without an ENT-specialist, from a university clinic 400 km away.	Considering the costs falling on the public health service. Private costs were also included but costs born outside the social and health-care sector excluded. Costs divided into fixed and variable costs. Incremental costs, discounting and sensitivity analysis.	Patient travel cheaper for patient workloads below 56 per year. For patient workloads above 56 and below 325 teleconsultation the cheapest alternative. Above 325 patients per year, the visiting specialist service cost less than either of the alternatives.
Crump & Tessen 1997 (14)	Economic analysis	To determine the actual costs, and costs in an ideal situation, of a video-conferencing system and the savings than can be achieved using the system.	Consultants in otolaryngology, ophthalmology, and dermatology examined patients remotely and provided feedback on effectiveness of the equipment.	A connection between a medical centre and a remote primary care clinic.	Considering costs of the IVT equipment by a 3-year lease/purchase plan, the annual costs of the digital line, and 10% of a technicians time for maintenance of the system.	In optimal use the system would cost about $10 per hour for each site. In the actual lower rates of utilization, the figure was $ 71 per hour. Assuming that a single primary care physician saved an hour round trip of travel per hour of use, the system saved about $ 102 per hour.

Table 4: Studies evaluating telemedicine applications (cont'd).

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Doolittle et al. 1998 (16)	Economic analysis	To examine the cost of providing tele-oncology for patients in a medically underserviced area.	Oncology services provided to a peripheral hospital using three scenarios: conventional clinics, outreach clinics with oncologist flown in periodically, and telemedicine.	University hospital providing services to a peripheral medical center. During 1 year 2,400 patients were seen in conventional clinics, 81 in outreach clinics and 103 in telemedicine clinics.	Measurement of medical costs.	Average costs per patient at the observed workloads $ 149, $ 897 and $ 812 for the three groups, respectively.
Patient monitoring/counselling						
Sparks et al. 1993 (65)	Level III Random allocation of patients to home- or hospital-based exercise program	To determine the effectiveness of a home exercise program using transtelephonic exercise monitoring.	Prospective, two-group experimental, random assignment. Maximal oxygen consumption, blood pressure, pressure-rate product, and workload as outcome measures.	Urban centered hospital and surrounding community. Twenty cardiac rehabilitation patients.	No	Cardiac function improved significantly in both groups. No significant difference between groups before or after training.
Turnin et al. 1995 (73)	Level VIII Before-after study	To determine whether a system for self-monitoring and dietetic education, accessible through minitel, can improve the dietary habits and metabolic balance of diabetic patients.	Clinical examination, tests of dietetic knowledge and biological tests including lipid fractions were carried out before and after six months of use of the system.	155 patients, recruited by six French centres of diabetology used the system from their homes for six months.	No	Dietetic knowledge and some biological parameters (total cholesterol, LDL-cholesterol, Apo A1) improved significantly. Also a small, non-significant decrease in hemoglobin A1C in the total patient population.

Table 4: Studies evaluating telemedicine applications (cont'd).

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Albisser et al. 1996 (2)	Level VIII Clinical series, registered patients who did not use the system as controls.	To determine the effect of an electronic information system (via touch-tone telephone) on diabetes-related crisis and glycated hemoglobin.	Diabetic patients reported blood glucose levels, hypoglycemic symptoms etc. and received immediate advice with respect to medication dosing changes, and other pertinent feedback.	204 patients in two centers (managed care center and private office), registered patients not using the system as controls.	No	Diabetes related crisis (hyperglycemia or hypoglycemia) fell approximately 3-fold. Glycated hemoglobin fell significantly (1.0-1.3%) in patients actively using the system.
Friedman et al. 1996 (26)	Level III Randomized controlled trial	To compare the effect of automated telephone patient monitoring and counseling on patient adherence to antihypertensive medications and on blood pressure control.	Comparison of subjects receiving usual medical care with those using an additional computer-controlled telephone system. Main outcomes: change in medication adherence, systolic and diastolic blood pressure, patient satisfaction, perceived utility for physicians, cost-effectiveness.	267 patients ≥ 60 y., on antihypertensive medication with a systolic blood pressure of ≥ 160 mm Hg and/or a diastolic blood pressure ≥ 90 mm Hg.	Cost-effectiveness ratio $5.42 per 1% improvement in adherence. For diastolic BP, cost-effectiveness ratio $ 7.39 per 1 mm Hg decrease. Direct medical costs included.	Mean medication adherence improved 17.7% for telephone system users and 11.7% for controls (P=0.03). Mean diastolic blood pressure decreased more in users than in controls (5.2 vs. 0.8 mm Hg, P=0.02). The majority of telephone system users were satisfied with the system. Most physicians integrated it into their practices.

Table 4: Studies evaluating telemedicine applications (cont'd)

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Wu et al. 1995 (78)	Level V Controlled retrospective series.	To evaluate the clinical usefulness of transtelephonic arrhythmia monitoring.	Diagnostic yield of transtelephonic arrhythmia monitoring compared to ambulatory ECG recording.	VA Medical Center, Miami, USA. Ambulatory ECG recording and transtelephonic monitoring in 48 consecutive patients and a comparison group of ambulatory ECGs matched for age, sex and indication.	Cost effectiveness analysis. Including medical costs. Sensitivity analysis.	Transtelephonic arrhytmia monitoring appeared more effective than ambulatory ECG for the detection of arrhythmias. Limiting transtelephonic monitoring to patients with primarily cardiac symptoms and to a 1-week time period would have optimized cost-effectiveness.
Radiology						
Fery-Lemonnier et al. 1996 (22)	Level VI Comparison of the situation before and after implementation of telemedicine.	To determine the effect and cost-effectiveness of teleneuroradiology on patient transfer rates from a district hospital to a neurosurgical center.	Three months of observation before and after the implementation of teleneuroradiology. Economic analysis of the costs of implementation of the system and the costs of patient transfer with and without teleneuroradiology.	Seven neurosurgical centers and 180 district hospitals in Paris. Over 10 000 requests for patient transfer to a neurosurgical unit per year.	With the observed usage of image transfer, cost of avoided unnecessary patient transfer was FF 10 800. Even with a 70% usage of the system, cost of avoided unnecessary patient transfer would be FF 3 800. Sensitivity analysis.	Images were transferred in only 25 % of cases. If patients were referred with teleradiologic images, 200 unnecessary transfers would be avoided per year.

Table 4: Studies evaluating telemedicine applications (cont'd)

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Goh et al. 1997 (30)	Level VI Comparison of events before and after implementation of telemedicine.	To examine the role of teleradiology in the management of inter-hospital transfer of neurosurgical patients.	Prospective collection of data from events during the inter-hospital transfer of patients from a district general hospital to a tertiary neurosurgical center.	50 referrals made without teleradiology were compared with 66 referrals after teleradiology installation.	No	For patients referred with teleradiologic images, unnecessary transfers were reduced (21%), more therapeutic measures before transfer were implemented (27% vs 20%), adverse events during transfer were significantly reduced (8% vs 32%, p=0.002), and transfer time was shortened (72 min vs 80 min).
Eljamel et al. 1992 (20)	Level VI Cohort study	To assess the value and reliability of image transmission on management of neurosurgical emergencies.	Comparison of patient management with and without transmission of CT-scans to the neurosurgical unit. Patients with a history suggesting an intracranial hematoma and fit for transport transferred without delay, others scanned in the referring hospital and images transferred to the neurosurgical centre.	Mersey region, U.K. 147 patients scanned in the referring hospital with images transferred to the neurosurgical centre. The outcomes of 51 of these compared with those for 52 patients transferred without image transfer.	Savings in transfer costs of patients.	Image transfer together with clinical history significantly reduced potentially hazardous inter-hospital transfer of patients.

Table 4: Studies evaluating telemedicine applications (cont'd)

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Bergmo 1996 (6)	Economic analysis	To establish whether teleradiology is more or less expensive than a visiting radiologist service.	A public sector cost comparison of the change in resource use when providing a teleradiology service.	A university hospital in Tromsø, Northern Norway providing teleradiology service to a military hospital situated 160 km away. The average workload used for the calculations was 25 patients per day, or 6000 patients (8000 examinations) per year.	Including the fixed and variable costs and travelling costs. Sensitivity analysis (4 and 6 years) and discounting.	For teleradiology to be cheaper, the workload had to exceed 1576 patients per year. Assuming a shorter equipment lifetime, 4 rather than 6 yrs., increased the threshold value to 2320 patients per year.
Halvorsen et al. 1996 (36)	Level V Controlled retrospective trial with economic analysis.	To determine the social costs of providing a rural population with radiology services under three different systems: most exams at remote site, teleradiology, or at the host site.	Cost minimization study assuming that all three options have the same health consequences.	Primary health care in a remote community in Norway, a randomly selected sample (n=597) of all patients (n=1,793) having radiological examinations in 1993.	Including annual direct medical costs, direct non-medical (travel) costs, and indirect (lost production) costs. Sensitivity analysis and discounting.	The teleradiology option did not seem to be cost saving in the study community.
Teslow et al. 1995 (69)	Level VI	To investigate whether the use of a teleradiologic case conference system can improve communication about X-ray images amongst oncologists located at different sites.	Radiation oncology residents and staff reviewed during 8 month cases either by the teleradiologic case conference system or by conferences in person.	83 teleradiology case conference cases, 267 in person conference cases.	No	Case conferences with the teleradiology system influenced changes in treatment planning as effectively as those conducted in person. Treatment outcomes were equivalent

Table 4: Studies evaluating telemedicine applications (cont'd)

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Stoeger et al. 1997 (67)	Economic analysis.	To study the costs of an emergency CT service provided to a remote hospital by the use of teleradiology.	Comparison of teleradiology costs with two alternatives: "non-digital radiology" in which films were sent by taxi to the nearest centre for reporting, and transport of the patient to the nearest central hospital for scanning and subsequent reporting.	A teleradiology link connecting two spiral CT scanners in the University Hospital in Innsbruck and the Regional Hospital in Zwettl 430 km apart. In the 13-month study period 121 emergency examinations of 116 patients were transmitted from Zwettl to Innsbruck.	Cost analysis which did not take the capital costs of CT scanners into account (as they were already installed in each hospital). Annual maintenance costs and expenses for the personnel in the remote hospital were not considered because an equal amount was subtractable at the diagnostic centre where patients were transferred before teleradiology.	The average cost of one emergency CT examination by teleradiology was DM 372. Transporting the films by taxi for reporting elsewhere, was cheaper (estimated cost DM 156), but would have been much slower. Transporting the patient to the nearest central hospital for scanning, was much more expensive: DM 524 by road or DM 4667 by helicopter ambulance.
Davis et al. 1997 (15)	Economic analysis.	To study the feasibility of full-time primary magnetic resonance (MR) image interpretation (using a central diagnostic workstation) of examinations generated at several distant sites.	Economic analysis using three scenarios: High-field MRI unit with traditional film storage and on-site image interpretation; Mid-field MRI unit with film-based storage and a courier service for off-site interpretation; Mid-field MRI unit with filmless digital operation and remote image interpretation by teleradiology.	A private commercial MRI service providing routine and emergency services to two communities in Maryland. In a two-year study period, 8083 teleradiology examinations were performed.	Cost analysis including direct and indirect costs.	At the expected case-load of 2000 per year, a mid-field MR unit was predicted to cost $470 per case using teleradiology and $544 per case using film and courier service.

Table 4: Studies evaluating telemedicine applications (cont'd)

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Lehmann et al. 1997 (48)	Cost-benefit analysis.	To evaluate the cost-effectiveness of a teleradiology system under three different scenarios.	Transmission of CT examinations from one workstation to another. Establishment of a teleconference system in the intensive care unit within the hospital, with an external workstation in a radiology department (6 km away) and with a radiologist on duty (22 km away).	On average, 36 CT slices per patient were transferred.	A break-even analysis with respect to costs of hardware, software, support, use of ISDN and staff, as well as benefits like the decrease in transportation or film documentation cost. Sensitivity analysis.	Two applications (intensive care and external PC) showed a break-even at 1817 and 528 teleconferences/ year, respectively. When all optimisation factors were combined, the break-even decreased to a minimum of 167 and 77 teleconferences/ year, respectively.
Emergency Room						
Trippi et al. 1997 (71)	Level VI Results were compared to those obtained in 3 previous groups of patients during the same study.	To determine the feasibility of dobutamine stress tele-echocardiography (DSTE) in the evaluation of emergency room chest pain patients and the effect of the technology on hospital admission.	Comparison of hospital admission rates between the study groups.	163 emergency room patients with no evidence of myocardial infarction on blood tests or ECG underwent DSTE. In the 3 first phases of the study patients with normal DSTE were admitted to hospital, in the 4th phase of the study they were able to be released.	No	72% of those slated for hospital admission because of cardiac risk factors and chest pain suggesting myocardial ischemia were discharged after normal DSTE results.

Table 4: Studies evaluating telemedicine applications (cont'd)

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Giovas et al. 1998 (28)	Level VI Clinical series with a control group the characteristics of which are not reported.	To determine whether ECG transmission from an ambulance is feasible and to assess time savings.	An ambulance was equipped with an ECG recorder connected to a notebook computer and coupled to a cellular telephone for transmission to a hospital-based station.	ECG recorded in 72 cases en route to hospital. Transmission was successful in 90 % of cases on the first attempt.	No	Paramedics needed 2 min to record the ECG on the move and 34 s to transmit it. The ambulance arrived 15 min. after reception. Pre-hospital ECG diagnosis took place 25 min before in-hospital diagnosis for control group patients.
Psychiatry						
Doze and Simpson 1998 (17)	Level VIII Observational study and cost analysis (break-even analysis).	To identify the impact of video conferencing technology on consumers and service providers and to identify the costs and savings related to the project.	Collection of information through questionnaires, by interviews, site visits, logs and telephone interviews.	Provision of psychiatric consultations through video conferencing technology from the Provincial Mental Health Advisory Board – Central Alberta to five sites at a distance of 80 to 214 km. In total 109 consultations of which 19 were for repeat consumers.	A comparison of a travelling psychiatrist's visit to sites and the telepsychiatry consultation mode using both fixed and variable costs.	The technology was considered easy to use. There was strong acceptance and satisfaction by consumers, service providers, and psychiatric consultants. At eight consultations per week the service would be as cost effective as providing a travelling psychiatrist.

Table 4: Studies evaluating telemedicine applications (cont'd)

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Trott et al. 1998 (72)	Economic analysis.	To compare costs associated with delivering a mental health service by telepsychiatry and by conventional methods.	Telemental Health Service by two general adult psychiatrists, two psychiatry registrars, one child psychiatrist and one psychologist.	Telepsychiatry rural outreach service was delivered to a mining town 900 km from the regional hospital in Townsville, Australia. 50 cases per month seen by telepsychiatry.	Cost comparison. Costs associated with education and other non-clinical activities were not included.	Savings to the health authority were estimated to be $85,380 in the first year and $112,790 in subsequent years, not allowing for maintenance and equipment upgrading. An estimated 40 % reduction in patient transfers due to telemedicine. Considerable savings from reduced travel by patients and health-care workers.
Dermatology						
Loane et al. 1998 (49)	Level IV Prospective study, patients as their own controls.	To determine diagnostic accuracy and management recommendations of real time teledermatology consultations using low-cost telemedicine equipment.	A prospective study involving two hospital dermatology departments and two primary care health centres. Patient outcomes after dermatological consultations by video-link were compared with patient outcomes after hospital outpatient consultations.	A dermatologist first recorded a clinical diagnosis and management plan after seeing a patient over a video-link. Later the same day the patient attended a face-to-face consultation with a dermatologist. A total of 351 patients presenting with 427 diagnoses were seen, management plans were recorded for 214 patients and 252 diagnoses.	No	67 % of diagnoses made over the video link agreed with the face-to-face consultation. In 64 % of cases the same management plan was recommended at both consultations. In 8 % of cases a sub-optimum treatment plan was recommended; and in 9 % of cases the video-link plans were judged to be inappropriate. In 20% of all cases the dermatologist was unable to recommend a suitable plan using video-link

Table 4: Studies evaluating telemedicine applications (cont.d)

Authors and name of the study	Strength of evidence and study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Cardiology						
Rendina et al. 1997 (62)	Level VI Non-randomized study with retrospective controls.	To assess the effects of neonatal echocardiogram transmission on patient management.	Transmission of neonatal echocardiograms for immediate interpretation and availability of videoconferencing for case consultations.	A telemedicine system between a university hospital and a regional medical center in North Carolina. 100 echocardiograms from 48 babies were transmitted. Historical data from 38 babies provided the control.	Cost analysis of medical costs.	Hospital stay decreased by an average of six days in the telemedicine group representing an annual saving of some $ 1.3 million. The differences were, however, not significant in this small sample.
Finley et al. 1997 (25)	Level VII Case-control study and non-controlled, prospective clinical series.	To evaluate the effect of echocardiogram transmission on image quality, diagnostic completeness, diagnosis and patient transfer and to determine the costs associated with the network.	Neonatal echocardiograms and those from older children were transmitted for interpretation by pediatric cardiologists. Transmitted studies were compared with repeat in-person studies in 26 cases	During two years 135 studies were transmitted from six regional hospitals to a tertiary-care hospital in Halifax, Canada.	The cost of the network during the two-year study period was C$ 90000. The cost of transportation avoided was C$100,000-118,000.	A comparison of 26 transmitted studies showed no important discrepancies with repeat, 'in person' studies. Use of telemedicine saved unnecessary patient transfer in 31 cases.

Appendix A: Methodology used for the report

Approaches to assessment of telemedicine

The present study of telemedicine assessment draws on the assessment model developed in the research group of the Health Care District of Northern Finland (56). The project has received financial support and expert assistance from FinOHTA. In addition to the earlier research report, the current study has utilized other frameworks in the assessment of telemedicine that have recently been published (34, 53). The appropriate parts of the CCOHTA guidelines for economic evaluation of pharmaceuticals (9) have been used to update the general assessment framework and the literature in the field.

Literature search and methods for the systematic review

Computerized literature searches were performed using the Medline (1966-November 1998), Health Star (1975-October 1998), Embase (1988-August 1998), and CINALH (1982-August 1998) databases and the search strategy described in Appendix A. In addition the HSTAT-database (Health Services/ Technology Assessment Text , The National Library of Medicine), the Database of Abstracts of Reviews of Effectiveness (DARE, NHS Centre for Reviews and Dissemination), the NHS Economic Evaluation Database and the Cochrane controlled trials register were searched using the search term "telemedicine".

The search strategy used was as follows:

001 exp telemedicine/

002 telemedicine.tw. not 1

003 telepsychiatry.tw. not 1

004 teleradiology.tw. not 1

005 teleconsult$.tw. not 1

006 or/1-5

007 assess$.tw. and 6

008 evaluat$.tw. and 6

009 validat$.tw. and 6

010 feasib$.tw. and 6

011 pilot.tw. and 6

012 or/7-11

013 12

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