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Medical Applications and Technical Standardization of Teleconferencing



ACADEMIC DISSERTATION

To be presented, with the permission of
the Faculty of Medicine of the University of Tampere,
for public discussion in the small auditorium of Building B,
Medical School of the University of Tampere,
Medisiinarinkatu 3, Tampere, on May 25th, 2001, at 12 o'clock.

Acta Universitatis Tamperensis 815
University of Tampere
Tampere 2001

ACADEMIC DISSERTATION
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Cover design by
Juha Siro

Printed dissertation
Acta Universitatis Tamperensis 815
ISBN 951-44-5095-7
ISSN 1455-1616

Electronic dissertation
Acta Electronica Universitatis Tamperensis 106
ISBN 951-44-5096-5
ISSN 1456-954X
<http://acta.uta.fi>

Tampereen yliopistopaino Oy Juvenes Print
Tampere 2001

List of original publications

- I. Lamminen H, Salminen L & Uusitalo H (1999): Teleconsultations between general practitioners and ophthalmologists in Finland. *J Telemed Telecare* 5 (2): 118-121.
- II. Lamminen H, Tuomi M-L, Lamminen J & Uusitalo H (2000): A feasibility study of real-time teledermatology in Finland. *J Telemed Telecare* 6 (2): 102-107.
- III. Aarnio P, Lamminen H, Lepistö J & Alho A.(1999): A prospective study of teleconferencing for orthopaedic consultations. *J Telemed Telecare* 5 (1): 62-66.
- IV. Lamminen H, Lamminen J, Ruohonen K & Uusitalo H (2001): A cost study of teleconsultation for primary care ophthalmology and dermatology. *J Telemed Telecare* (in press).
- V. Lamminen H, Ruohonen K & Uusitalo H (2001): Visual tests for measuring the picture quality of teleconsultations for medical purposes. *Comput Methods Programs Biomed* 65 (2): 95-110.

Abbreviations

<i>ABM</i>	<i>Activity based management</i>
<i>ACR</i>	<i>American college of radiology</i>
<i>ANSI-HISB</i>	<i>American national standard institute, Health care informatics standards board</i>
<i>CEC DG XII</i>	<i>Commission of the European communities, Directorate-General XII</i>
<i>CCD</i>	<i>Charge coupled device</i>
<i>CEN</i>	<i>European committee for standardization</i>
<i>CIF</i>	<i>Common intermediate format</i>
<i>Closed circuit television</i>	<i>A cable-based private local television system</i>
<i>CODEC</i>	<i>An acronym for coder/decoder. This device digitizes and compresses audio and video information before and vice versa after receiving transmission</i>
<i>Compression</i>	<i>The process for reducing the amount of data comprising audio and video signals</i>
<i>Contrast</i>	<i>The ratio between the bright and the dark area in an image</i>
<i>Cost of treatment/illness</i>	<i>The economic impact of a treatment or of an illness/condition , including treatment costs</i>
<i>Cost-benefit analys</i>	<i>The economic study where costs and outcomes are put into monetary units</i>
<i>Cost-effectiveness analys</i>	<i>The economic study where the cost in monetary units involved in producing outcomes are measured in quantitative non monetary units, such as reduced mortality/morbidity, or life-years saved</i>
<i>Cost-minimization analys</i>	<i>The economic study which attempts to determine the least expensive of two or more alternative treatments that produce equivalent outcomes</i>
<i>Cost-utility analys</i>	<i>The economic studies where costs are in monetary units and outcomes in terms of utility or quality of life, for example, using quality- adjusted life years (QALYs)</i>
<i>DICOM</i>	<i>Digital imaging and communication in medicine</i>
<i>DPI</i>	<i>Dots per inch</i>
<i>ECG</i>	<i>Electrocardiogram</i>
<i>EDIFACT</i>	<i>Electronic data interchange for administration, commerce and transport</i>
<i>EEG</i>	<i>Electroencephalogram</i>
<i>FPS</i>	<i>Frames per second</i>
<i>G.711</i>	<i>ITU-T recommendation: Pulse code modulation (PCM) of voice frequencies</i>
<i>G.722</i>	<i>ITU-T recommendation: 7 kHz audio-coding within 64 kbit/s</i>
<i>G.728</i>	<i>ITU-T recommendation: Coding of speech at 16 kbit/s using low-delay code excited linear prediction</i>
<i>HL-7</i>	<i>Health level seven, standard for medical informatics</i>
<i>H.261</i>	<i>ITU-T recommendation: Video codec for audiovisual services at p x 64 kbit/s</i>
<i>H.320</i>	<i>ITU-T recommendation: Narrow-band visual telephone systems and terminal equipment</i>
<i>H.323</i>	<i>ITU-T recommendation: Packet-Based Multimedia Communications Systems</i>

<i>IEEE</i>	<i>Institute of electrical and electronics engineers</i>
<i>Image dynamic range</i>	<i>Also known as pixel depth, defines the number of colors or shades that can be seen in the image. It is defined by the number of bits used to represent each pixel intensity. For example, for an 8-bit representation, the pixel intensity can take values ranging 0-255</i>
<i>ISDN</i>	<i>Integrated services digital network</i>
<i>ISO</i>	<i>International standards organization</i>
<i>ITU-T</i>	<i>International telecommunications union / Telecommunications standardization sector</i>
<i>JPEG</i>	<i>Standard compression of still images that is applicable to nearly all fields of electronic imaging (Joint picture for experts' group)</i>
<i>lp/mm</i>	<i>Line pairs per millimeter</i>
<i>kbit/s</i>	<i>Kilobits per second</i>
<i>Mbit/s</i>	<i>Megabits per second</i>
<i>MEDIX</i>	<i>Medical information for interconnection of intensive care units instruments</i>
<i>Microwave video link</i>	<i>A high frequency radio link for transferring video signal</i>
<i>NASA</i>	<i>The national aeronautic and space administration</i>
<i>NEMA</i>	<i>National electrical manufacturers association</i>
<i>PACS</i>	<i>Picture archiving and communication system</i>
<i>QCIF</i>	<i>Quarter of the common intermediate format (144 x 176 pixels)</i>
<i>SCM</i>	<i>Supply chain management</i>
<i>SF</i>	<i>Store-and-forward</i>
<i>sRGB</i>	<i>Standard red green blue color space definition</i>
<i>T-120</i>	<i>Data standard</i>
<i>TBM</i>	<i>Time based management</i>
<i>TCP/IP</i>	<i>Transmission control protocol / Internet protocol (data transmission protocol used in the internet)</i>
<i>CEN/TC251</i>	<i>Technical committee for health informatics at CEN</i>
<i>TQM</i>	<i>Total quality management</i>
<i>VTC</i>	<i>Real-time videoconferencing, interactive television</i>
<i>VTC</i>	<i>Videoteleconferencing</i>
<i>WE/EB</i>	<i>Western European edifact board</i>
<i>Visual acuity</i>	<i>The ability of the eye to distinguish fine detail</i>

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1. Introduction

Telemedicine is regarded as the delivery of health care and the exchange of health information across distances, including all medical activities: making diagnoses, treatment, prevention, education and research (Craig 1999, p. 6). It is not a new separate discipline of medicine or technology, although it is often classified based on technology or specialty, for example as teleradiology, teleophthalmology etc. The objective of telemedicine is to solve problems related to accessibility of health services and their quality, medical research and education as shown in Figure 1. Medical informatics is a scientific discipline that deals with the storage, retrieval, and optimal use of biomedical information, data, and knowledge for problem solving and decision making (Shortliffe et al. 1990). Medical informatics and telemedicine are seen to be different disciplines, but even though there are some theoretical differences, they cannot always be distinguished in reality.

For the past 30 years the development of telemedicine has followed closely that of general informatics. However, health care services over long distances have a long history. Letters and telegraphs were used to relay casualty lists and to order supplies in the American Civil War (Craig 1999, p. 6). An even earlier example of telemedicine in the Middle Ages was the use of signal fires to transmit information on bubonic plague across Europe (Craig 1999, p. 6). The International Radio Medical Centre in Rome was set up in 1935 and by 1996 it had assisted 42 935 seafaring patients (Amenta et al. 1999). Later the inventions of television, videoconferencing and mobile communication technologies have opened new possibilities for real-time telemedicine. The advent of telephones and wireless communication has also enabled sending biometric signals like ECG and EEG.

The acquisition and maintenance costs per unit in basic computer techniques have fallen after the first inventions of telemedicine and will further decrease, which will increase their application. In the future all the medical specialties will make ever-increasing use of various computer and telecommunication technologies in diagnostic procedures, treatment, education and research. This development seems to be self-penetrating: medical research will progress and with the help of the new communication technologies it is possible to use these research results for the treatment of patients faster and over wider geographical areas. It seems that in many cases the meaning of place and distance will disappear.

Health care systems are facing new challenges as they have done many times before. In the industrialized countries the health care is encountering social changes, changes in age structure, and financial constraints, together with medical and technical advances. It is presumable that some of the existing organisations will not be able to take advantage of the opportunities offered by new technology, which will lead to the development of totally new health care structures.

Many of these new technological opportunities are related to telecommunication and information technology, i.e. telemedicine, where the challenges are often organizational rather than technological. In that respect telemedicine is not only medicine or technology, it involves numerous strategic factors, as well.

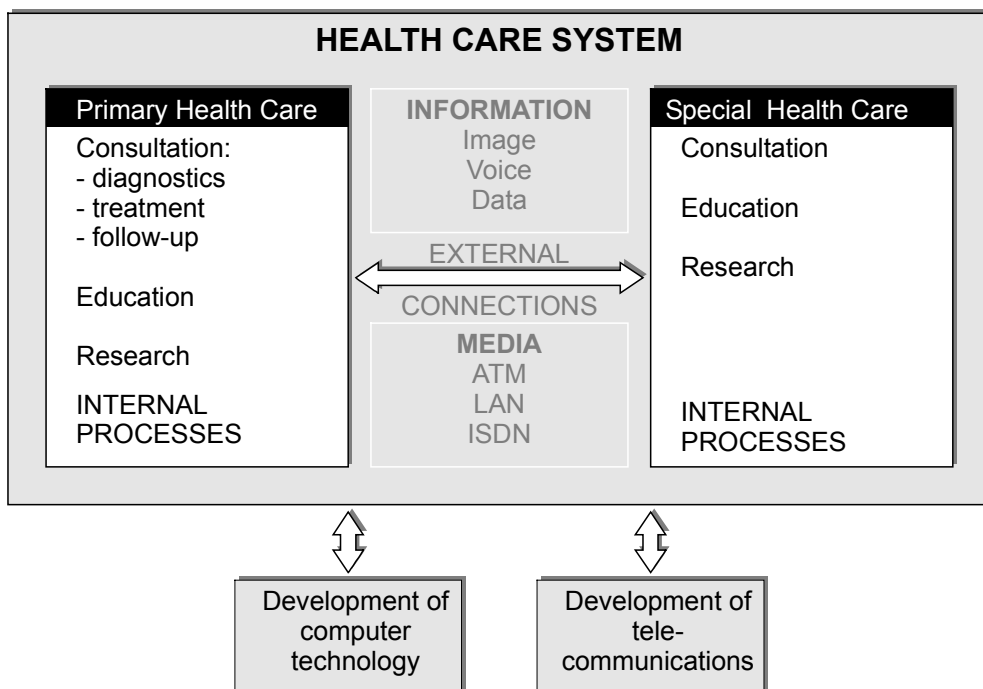


Figure 1. Target area of the research.

2. Review of the literature and basics of telemedicine

2.1. Telemedicine definitions and terminology

Telemedicine has several definitions. In general telemedicine involves the practice of delivering health care over a distance using telecommunication equipment as simple as telephones, fax machines or as complex as personal computers and full motion interactive multimedia. Telemedicine can be broadly defined as the use of telecommunication technologies to provide medical information and services (CEC DG XII Research and technology development on telematics systems in health care, 1993). The definition of the US Institute of Medicine is: “the use of electronic information and communication technologies to provide and support health care when distance separates the participants” (Institute of Medicine, 1996). The American Telemedicine Association defines telemedicine as “the use of medical information exchanged from one site to another via electronic communication for the health and education of the patient or health care provider and for the purpose of improving patient care” (American Telemedicine Association, 2001). Wootton (1996) has considered telemedicine as a process, rather than a technology: telemedicine connects patients and health care professionals in a chain of care.

Telemedicine services in health care should be seen from the viewpoint of patients, health care professionals and funders. It is used either because there is no alternative to telemedicine or it is better than existing conventional services (Craig 1999, p. 12). Telemedicine enhances access to specialists at remote areas (Al-Taei et al. 2000). Telemedicine can also be beneficially used over short distances, such as within one hospital or in the same town among different units of health care (Fery-Lemonnier et al. 1996, Wootton, 1996).

Functionally, telemedicine can be divided into real-time (VTC) and store-and-forward (SF) solutions or combinations of these (Craig, 1999, p 39.) In SF solutions the information is first recorded and thereafter sent to the recipient. Transmitted information can be still images, moving images or combination of the two. Anamnesis is of premium importance in clinical medicine, and this information can be relayed best in real-time consultations. Telemedicine thus creates an opportunity for the patient, his/her physician, and a specialist to communicate in real-time regardless of the distance separating them.

Telemedicine processes are closely linked to local circumstances, which have to be kept in mind when generalizing research findings. The cost-effectiveness of telemedicine also improves considerably when it is an integral part of telecommunications and information technology in the health sector (Mitchell, 2000).

2.2. History of telemedicine

The implementation of new communication technologies to health care has been a continuing process for centuries. Telemedicine has been practised for ages and still is in the form of mailed letters sent for from patients to doctors. According to Craig (1999, p. 6) in the American Civil War telemedicine was used via telegraphy to transmit casualty lists and for ordering medical supplies. Telephone has been used to give treatment instructions since its invention in the late 19th century. The first non-verbal telemedical application was the transfer of amplified stethoscope sounds in 1910 (Brown, 1910, Craig 1999, p.6). Later in the 20th century (1923) medical information was transmitted by radio from Sahlgrens hospital (Gothenburg) to ships sailing on the Baltic Sea. The International radio medical centre in Rome was set up in 1935 to assist seafaring patients (Amenta et al. 1999).

Subsequently, both television and telephone has been used in medicine in many ways (Craig 1999, p.6). In the 1950's radiographs were transmitted via satellites between Nebraska and the National Aeronautic and Space Administration (NASA, USA) (Perednia and Allen, 1995a). The use of closed circuit television at the Nebraska Psychiatric Institute was first demonstrated in 1955 (Benschoter, 1967). Later the first functional telemedicine program was established in 1959 on psychiatric patient care and medical education (Bashsur et al. 1975).

In 1968 rural Vermont and New Hampshire started to provide medical and educational services to 10 sites. It was one of the first projects to establish a network for supporting rural clinics through telemedicine (Park, 1974). Satellite-mediated video consultations have been used since 1971 to improve village health care in Alaska (Foote, 1977). The telestethoscope was successfully used in routine care to bring cardiology to medically disadvantaged areas in the beginning of 1970's (Murphy, 1973).

Transferring medical still images also started very early. In 1929 electrical transfer of dental X-rays started the history of teleradiology (Anonymous, 1929). The first medical television link for routine

use was established between Boston Logan airport and a local hospital. This link was realized with microwave technology. Over 1000 patient examinations were conducted using this telemedical system including radiology, dermatology, and cardiology (Murphy and Bird, 1974).

In 1985 a satellite network was established to provide telemedicine coverage to remote regions of Queensland, Australia (Watson, 1989). In 1986 satellite-based interactive video conferencing between medical facilities in Canada, Kenya, and Uganda enabled formal medical education and lectures, telemedicine consultations and international medical collaboration and research (House, 1987).

First aid solutions have always been in the forefront of telemedicine development. Inter-hospital management of data from neurosurgical patients has shown advantages in terms of safety and early therapeutic interventions, facilitating safer transfers and faster management of neurosurgical emergencies (Goh et al. 1997). Consultations for another emergent event; thrombolytic treatment in acute myocardial infarction is possible via mobile telemedicine nowadays (Karlsten and Sjöqvist, 2000, Mavrogeni et al. 2000). In the future, telemedicine will have more impact on patient treatment and prevention, especially counseling on treatments. A good example of this is antihypertensive medications and blood pressure control counseling (Friedman, 1996).

2.3. Implementation and evaluation of telemedicine

The implementation of telemedicine in health care centers and hospitals is not always accepted without resistance by the health care professionals. It is therefore a process which should be carefully planned and managed. The number of published articles concerning telemedicine has risen exponentially, thus a great number of experiences can already be found in the literature. We also know that telemedicine is an excellent educational tool for medical professionals that is why a good approach to implement telemedicine is to first organize continuing medical education using real-time teleconferencing (Tachakra et al. 2000a).

Telemedicine uses a variety of digital diagnostic equipment. In that respect, health care has its own additional challenges in the development of communication and computer technologies, because of the highly complex world of medicine. Rapid access to shared and remote medical expertise by means of telecommunications and information technologies, no matter where the patient or the relevant information is located, gives value for patient treatment (Stanberry, 1998). Telemedicine

has become more interesting during the last few years because of the

- demand for managed care
- specialisation in medicine
- growing amount of digital patient data
- general increase in the use of computer and telecommunication technology in medicine
- development of mobile communication

The Memorial University of Newfoundland has been involved in telemedicine activities since 1975 (Elford, 1998). In their experience telemedicine projects should meet the following requirements:

- all activities should be based on a legitimate need
- the simplest, least expensive technology should be used to meet the need
- the network should be shared by a variety of users
- users should be given proper training and support

The continuous evaluation of telemedical processes is of great importance because of the rapid technical development (Baer et al. 1997, McDonald et al. 1997), even though in many cases the evaluation of telemedicine applications may be difficult, due to the lacking possibilities for randomization and especially double blinding obstacles. Quantitative methods are essential in telemedicine, but qualitative aspects also produce important information on transactions between professionals and organizations.

Factors to be considered in addressing the efficacy and effectiveness of the technology in telemedicine are the following (Fineberg et al. 1977):

- technical accuracy and diagnostic quality of the information
- sensitivity and specificity of the system used
- diagnostic effectiveness (changes/confirmations of diagnoses)
- therapeutic effectiveness (changes in clinical management of patients)
- changes in health status of the patients including quality of life
- economic aspects

2.3.1. Strategy of telemedicine

Telemedicine has been regarded as a process, rather than a technology as telemedicine connects patients and health care professionals in a chain of care (Wootton, 1996). This approach gives telemedicine a very strategic approach and we can say: telemedicine is at the heart of the unit's strategies.

Most of the needs of patients are globally the same, they want seamless services. Technical development is also driven towards convergence of communication equipment (Forman and Saint, 2000). Simultaneously the time elapsing from the research phase to publicity is constantly shortening. The information systems used in health care have to be flexible enough to support the constant development described above.

The economic aspects of telemedicine are basically a race between alternative methods to use resources (McIntosh and Cairns, 1997). Such ideas are traditionally fairly strange to the public health care sector, but in the future information technology investments will have to be considered more from the point of view of how to allocate spare resources (Hannus, 1994).

The success of health care units depends not only on how well each department performs its work, but also how well the various departmental activities are coordinated. Core medical processes must be identified. These core processes include diagnostic and treatment decisions along patient service process. Generally strategic competence can be divided into three parts (Prahalad and Hamel, 1990):

- Customer (patient, funder) driven strategy
- Product (diagnosis, operation) and service (treatment) driven strategy
- Superior operative power

These strategy classes represent different ways of creating customer/patient value. Thriving units normally have superior competence in one of the three competence areas and good competence in the other two areas.

Strategic aspects must also be measured in order to manage them. There are six different management programs when speaking of process management. These are total quality management (TQM), time based management (TBM), supply chain management (SCM), activity based

management (ABM), lean management and business processes redesign. The key parameters of each of these management style are presented in Table 1.

Table 1. Management styles in process management, where the customer can be a patient or a funder and a product can be a diagnosis, an operation or a treatment (Hannus, 1994).

Management Style	Key Measurement
Total quality management (TQM)	Customer satisfaction, cost of quality
Time based management (TBM)	Production time
Supply chain management (SCM)	Return on investment, costs, equity turnover
Activity based management (ABM)	Costs of product and customers
Lean management	Time, cost of quality
Business process redesign (BPR)	Costs, production time

According to Prahalad and Hamel core competencies mean the ability to bundle skills. This is a result of organizational learning and means the skill to be able to combine different technical and operational skills (Prahalad and Hamel, 1990). Core competence does not wear out in use. Unlike physical assets, which do deteriorate with time, competencies are enhanced when applied and shared. But competencies still need to be nurtured and protected; knowledge fades if it is not used. Competencies are the glue that binds together existing processes. They are also the engine for new development. Patterns of diversification and service entry may also be guided by them, not just by the attractiveness of the existing environment (Prahalad and Hamel, 1990).

The unit's resources can be divided into two different categories: having and competence, capability (Huomo et al. 1995). The unit's "Having –resources" are the unit's assets and intangible resources. The competence can be divided into doing and knowing. Figure 2. shows one way to categorize the unit's resources.

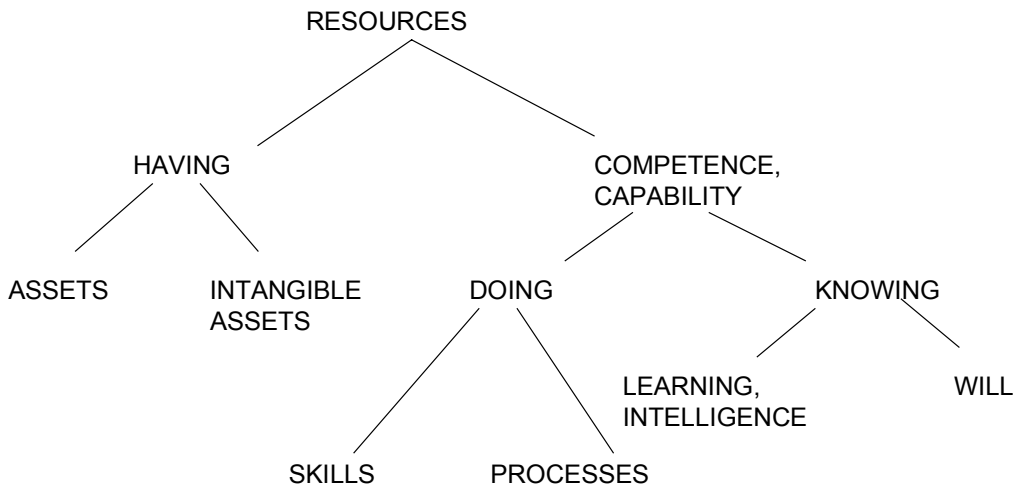


Figure 2. One way to categorize the unit's resources (Huomo et al. 1995).

2.3.2. Legal aspects and standards

The globalization and digitalization of clinical environment has an impact on the legal issues of health care. Most countries have their own regulations on licensing of health care personnel and services to protect the patient and ensure high-quality care. As there may be practitioners from several countries involved in telemedicine medical practice must be standardized to a certain extent. One important aspect of this development is the harmonization of practitioner licensing requirements (Nohr, 2000). On the other hand evolving a contract model that can be used in any country and in any circumstances is naturally impossible to achieve in telemedicine (Stanberry et al. 2000).

Threats in telemedicine services are the same as in conventional services. But the use of telemedicine brings with it the risk that the human factor, i.e. the teleconsultants, will fail to reach a sufficient standard of care as medical professionals. The telemedical equipment or system may also fail at a crucial moment. Public computer networks, such as the Internet, are vulnerable to eavesdropping, which is why securing the data channel from unauthorized access or modification is important (Makris et al. 1997).

Technological risks are present in many medical fields, but international telemedicine raises some additional legal questions. One must consider not only who is liable for failure, but under which country's laws that liability will be determined (Grigsby, 1995a). The proliferation and increasing complexity of medical expert systems also raise ethical and legal concerns about the ability of

practitioners to protect their patients from defective or missused technology or software. User qualifications and educational resources for acquiring the skills necessary to understand and evaluate the system are essential (Geissbuhler and Miller, 1997).

Yet telemedicine does not have special legal provisions in Finland but the existing laws serve quite well in the legal environment described above. The most important laws when implementing telemedicine are listed in Table 2.

Videoconferencing always requires the client's consent as in any other transfer of patient data (Legal protection of patient, 785/1992). Only those people may be present for whom consent has been obtained. Possible recording requires the client's permission. Tapes must be handled and stored as any patient-specific material (Legal protection of patient, 785/1992). The results of the conference may be entered in the patient register.

Table 2. Existing Finnish laws that can be used in telemedicine.

Law	Matter
Legal protection of patient 785/1992	Right to good health care / right to good health care services, preparing and storing of patient's documents
The constitution of Finland, section 19(3)	The public authorities shall guarantee for everyone, as provided in more detail by an act, adequate social, health and medical services and promote the health of the population
Personal data act, section 42	The data protection ombudsman may check if the code of conduct is in conformity with this act and the other provisions relating to the processing of personal data

Telemedicine is likely to adopt rather than create most of its protocols and standards as it becomes an integral part of medical practice. Technical aspects for image resolution and accuracy together with communications protocols are adapted from computer and telecommunication technologies. To optimize this process, it will be necessary to understand how to use existing protocols and standards in storing and viewing images (Klossa et al. 1998). Telemedical solutions should be based on open standards. Table 3, presents compiled standards for the handling and transfer of medical data used in telemedicine.

Table 3. *Standards for handling and transferring medical data.*

ANSI-HISB	American National Standard Institute, Health care informatics standards board
CEN/TC251	Technical committee 251
DICOM	Digital imaging and communication in medicine, adopted from ACR-NEMA, American college of radiology - National electrical manufacturers association
HL-7	Health level seven
IEEE Institute of Electrical and Electronics Engineers	Committee E-31: Medical computing E-31.11: Clinical data transmission E-31.12: Medical informatics E-31.14: Interfaces for laboratory instruments E-31.15: Knowledge-based aspects
ISO	International standards organization, standardization committee of health care informatics
MEDIX (medical data interchange)	Medical information bus (MIB) for interconnection of intensive care units instruments (patient monitoring)
WE/EB MD9	Western european edifact board, message development group of health care

2.3.3. Financial aspects in telemedicine

The basic tasks in all economic evaluation are to identify, measure, evaluate and compare the costs and consequences of the alternatives under consideration, because benefits are not always immediately seen. There is also a broad consensus among health economists that the introduction of new technology increases cost. New technologies have the potential to lead to expanded indications for use. The effects of costs, quality and accessibility are interconnected with patients, professionals and providers as well as with the total health care system (Bashsur, 1978). Also, it is essential to remember for whom cost-effectiveness is intended: society, third-party payers, health care provider or patients and yet to understand that a system cannot cut costs in all sectors.

Telemedicine is expected to bring financial savings to the health care sector. This has not yet been proved. An economic review of information technology applications in health care in the United States suggested that fully automating administrative functions would save \$8 billion per year (Neumann, 1996). However Glandon and Buck (1994) stated 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 drawn in telemedicine (Baer et al. 1997, McIntosh and Cairns, 1997, Yellowlees, 1997, Taylor P, 1998).

Although the basic theory of economic evaluation is reasonably clear, its implementation in telemedicine is less certain, which explains the disagreements. Difficulties can be found in the estimation of both effectiveness and the cost side of the telemedicine analysis. The techniques used and the nature of the transferred data also have a major role in the economic aspects i.e. the size and the number of the data files together with the accessibility of services and technical development. After that the question is whether there is enough volume to justify the existence of telemedicine. Telemedicine costs are closely related to the number of patients (Lobley, 1997). So far the conclusion has been that it is premature for any statements to be made, either positive or negative, regarding the cost-effectiveness of telemedicine in general (Whitten et al. 2000). On the other hand telemedicine should not be evaluated as a whole because a specific application may or may not be found to be cost-effective (Grigsby, 1995b, Field, 1996).

Because the results of the economic evaluation reflect the method and data used and thus the environment in which they are derived, the four broad areas of uncertainty in the analysis are related to the variability of sample data, generalizability of results, extrapolation and analytical methods (McIntosh and Cairns, 1997). According to McIntosh and Cairns (1997) the main challenges for the economic evaluation of telemedicine are:

- Constantly changing technology
- Lack of appropriate study design to manage the frequently inadequate sample sizes
- Inappropriateness of the conventional techniques of economic evaluation
- The valuation of health and non-health outcomes i.e. (length of waiting time, time to diagnosis, improved education and confirmation)

Moore's Law is one of the most important laws describing the development trends in semiconductor industry. The law states that the semiconductor capacity doubles every 18 months (or quadruples every three years). Gordon E. Moore introduced the law in 1965, and it has held true rather accurately up to now. In practice, the law can be interpreted so that the same money will buy twice as powerful computer 18 months from now. As 18 months is a short period of time in medical research, this makes economic evaluation difficult.

Various countries have different implementation environments, which make it difficult to compare telemedicine studies between them (Håkansson and Gavelin, 2000). That is why the breakdown of resources used and their monetary values is important for international comparisons, since it enables the re-adjustment of the cost data between different health care systems and price levels (Canadian coordinating office for health technology assessment, 1997).

Economic evaluation of telemedicine compares the costs and other consequences of delivering specific services through telemedicine vs. alternative means. The cost-effectiveness analysis seen in Table 4. is the most common method used for health care and helps to assess whether the expected health benefits for patients are enough for the investment to be worthwhile. Cost-minimization is often used in telemedicine studies. It is obvious that a breakeven point cannot be achieved when the variable cost of telemedicine exceeds the total cost of face-to-face visits.

Table 4. *Methods to evaluate economics in telemedicine.*

Method	Measurements
Cost-effectiveness	Saved life years or disability days avoided
Cost-minimization	No difference in the nature of consequences
Cost-benefit	Cost achieving a specific goal (allocative aspects), all should be valued in a commensurate unit (money)
Cost-utility	Healthy years (difference to cost-effectiveness is that full health can be converted into healthy years)

Telemedicine presents particular challenges for evaluators: a telemedicine system may have multiple users and joint costs that are difficult to apportion to one service, the existence of a system may lead to expanded indications for use, and technological change may rapidly make an evaluation obsolete (Sisk and Sanders, 1998).

The main purpose of economic analysis is to give information for decision makers considering which alternative is superior. The decision-making criteria for cost-utility analysis and cost-effectiveness analysis are based on a comparison of incremental ratios of technologies (Drummond et al. 1990, 1997, Canadian coordinating office for health technology assessment, 1997).

Theoretically the best results for resource allocation comes, if all outcomes can be realistically valued in monetary terms, because the benefits of an intervention directly show the opportunity costs of rejecting it. Mortality and morbidity are examples which have also been used in measuring

effectiveness in medicine. Types of cost are divided into three general classes: direct, indirect and intangible costs. Cost can also be divided for fixed and variable expenses.

A useful approach for health care providers 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 fixed 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 the cost of 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 (Bergmo, 1996) and telepsychiatry (Doze and Simpson, 1998).

Economic analyses can also be carried out theoretically, the first step is the identification of all of the relevant variables and parameters for modeling. The second step consists of simulating "real world" decision situations involving all relevant variables and parameters. The relation among the variables and parameters is described in terms of mathematical equations. The ability of the researcher to estimate the financial effects of a given telemedicine system is a function of the extent to which the resulting model approximates conditions of the real world; i.e. the fit between model and reality (Cameron et al. 1998). The comparison should be between the telemedical alternative and either the current structure of service provision or some alternative method of improving access to specialist care (Mair et al. 2000a). In radiology there are existing models of cost analysis of a PACS/teleradiology network which can be also used for other specialties (Duerinck et al. 1998).

2.3.4. Quality control

The purpose of quality control is to ensure consistent technical performance of telemedical systems. When the performance is measured with technical criteria, the term 'calibration' may be used. Generally, calibration procedure refers to three separate actions: verifying, adjusting, and reverifying. First, the device must be verified that it is operating within its specifications. If the device does not meet its specifications, it must be adjusted and then reverified.

Physicians have to be aware of the telemedicine systems' diagnostic range. Together with that the systems quality should be checked at least once a month according to the ACR standard (1999) for digital image data management. The diagnostic quality of the whole system in medical imaging can

be tested by phantoms (Phillips and Parker, 1998). In telemedicine the imaging system's color reproduction quality may be verified against standard sRGB color space (Vander Haeghen et al. 2000).

Telemedicine system may include medical devices that are connected to the patients. These devices have special requirements in electrical safety, and they have to fulfill the requirements of the act concerning medical devices (1506/1994). Computer-based instruments must withstand electromagnetic interference (EMI) and supply voltage variations, as well as operate under a wide temperature range.

2.3.5. Digital imaging

Almost all modern teleconsulting systems rely on digital imaging. The digital images may be produced digitally (e.g. CT, MRI), they may be digital photographs, or they may be digitized analog (traditional) images. Digitally produced images can be transferred without loss as digital information (Bemmel and Musen, 1997, p 67). All available information is coded into the image. However, digital photographs or digitized photographs bear considerably less information than there is available for a face-to-face consultant.

Digital images are formed of a finite number of small picture elements of constant color (pixels). In some cases the chrominance (color) and luminance (intensity) information may be separated so that same chrominance information applies to a larger number of pixels than the luminance information. The number of pixels sets the ultimate limit for spatial information in an image (Jain 1989, p. 10). The pixel size dictates the minimum size of any detail visible in the image; if a detail would be smaller than one pixel, it will not show in the image. Resolution is presented by pixels, dots per inch or by line pairs. The relationship between pixels and dots per inch is given by Formula (1),

$$n = D \times L / 25.4 \text{ mm/inch}, \quad (1)$$

where n is the number of pixels in one direction, D is the resolution (in dpi) of the image and L the linear size (in millimeters) of the image in that direction. In addition to dpi, the physical resolution may be specified in line pairs per millimeter. In an ideal system, one line pair per millimeter is equivalent to two pixels per millimeter (i.e. 50.8 dpi). In a non-ideal optical system the resolution is

inferior to the pixel-limited value. However, the number of line pairs can be estimated by in Formula (2),

$$k = \frac{1}{2} D / 25.4 \text{ mm/inch} \quad (2)$$

where k is the number of line pairs per millimeter.

Another important measure of the image is its dynamic range, i.e. the ratio between smallest possible darkness variation to the total intensity of the image. This ratio is often expressed in density units (D). One density unit is equivalent to one order of magnitude, e.g. $D = 2.0$ means 1:100 contrast ratio in the image. In a linear system one bit of color depth is equivalent to 0.3 D. Usually, linear density is used only in scanners; monitors and printers tend to use a curved relation between pixel value and image intensity.

Currently, digital imaging equipment is compared to ordinary photography equipment. High-quality black-and-white photographs (transparencies) may have a resolution equivalent to thirty million pixels and dynamic range of $D > 4$. It should be noted, however, that this kind of performance is very seldom achieved in practice. The practical performance of high-end digital photographing equipment is very close to that of a traditional photograph.

A moving image has one additional parameter to still image; the number of frames per second (fps). The lower limit of continuous movement perception is between 25-30 fps (Jain 1989, p. 479). Increasing the frame rate does not necessarily improve the perception at all. A lower frame rate can be tolerable in some applications, but significantly lower rates give the impression of a series of still images.

To increase the efficiency of digital image transfer pictures are compressed. There are two weaknesses in all common lossy compression methods used with digital images; they may omit important information from the image, or they may add new visual information to the image. The latter are referred to as compression artifacts, and they are often more difficult to cope with than lost information (Sonka et al. 1998, p. 622). It should be noted that most compression methods are designed for photographs, and they may not be very suitable for example X-rays or other artificial images.

2.3.5.1 Digital imaging devices

The actual number of pixels in analog television broadcast is difficult to determine, as the image is not a digital image. However, the resolution used in television production and digital video cameras in PAL television system is 720 (h) x 576 (v) pixels. The actual horizontal resolution in television broadcast is equivalent to approximately 400-500 pixels (i.e. there are approximately 300 000 pixels in the image). The number of pixels in a computer monitor varies between one million pixels of a low-end monitor to three million pixels of a high-end monitor. Digital still cameras may record up to six million pixels in one picture.

Hardcopy equipment (printers) image resolution is usually given in dots per inch (dpi). If a printer is able to produce 300 dpi, the distance between adjacent pixels is $1/300$ " (0.085 mm). Also, the resolution of image scanners is usually given in dpi. This resolution does not tell the total maximum resolution of the device. For example, an A4-size (210 mm x 297 mm = 8.27" x 11.69") scanner with 300 dpi resolution gives 2480 x 3507 pixels, whereas an A3-size scanner of similar resolution has double the number of pixels. Thus considering dpi's is usually relevant only with scanners and hardcopy devices.

Typical physical resolutions of image scanners are 600 to 1200 dpi. Computer monitor resolutions are from 70 to 150 dpi, and printers produce from 200 to 1200 dpi. However, the real printing resolutions are usually considerably lower, as different colors are formed by clustering a larger number of pixels together for a raster. Also, the printing resolution depends much on the print media (paper or film). For visual inspection 300 dpi of real resolution is more than sufficient.

Computer monitors use typically 8 bits per color (in full color picture 24 bits, as there are three color components). Their dynamic range is usually limited by the reflection of ambient light from the screen to approximately $D = 2$. Low-end scanners and digital cameras offer 8 bit dynamic range with $D = 2$, whereas newer equipment gives 12-bit dynamic range ($D = 3.3$). The real D -values do not reach the theoretical values due to image noise. High-end x-ray scanners may have a dynamic range of $D > 4$ with 16 bits per pixel. Printers usually have rather low D -values ($D < 2$) when printing on paper.

2.4. Real-time telemedicine

There are essentially two different approaches to teleconsultation; one is videoteleconferencing (VTC) which employs a two-way real-time video connection and the other is lighter store-and-forward (SF) where data is first captured and then sent forward as an e-mail attachment. The store-and-forward consultation is cheaper, but less clinically efficient, compared with the real-time consultation. But the absence of interaction in a store-and-forward consultation limits the dermatologist's ability to obtain clinically useful information in order to diagnose and manage a patient satisfactorily (Loane et al. 2000a). One of the key issues is whether to use videoteleconferencing or store-and-forward technology, which provides the most efficient, high-quality remote diagnosis (Menn, 1995).

Videoconferencing is the use of two-way video systems as a means of connecting people at different sites. For the reasons described above most video conferencing systems use compressed video. There are several different compression methods, but the aim in all of them is to reduce the number of bits without reducing the visual information content of the image. Already the analog television signal uses a simple compression; the resolution of the chrominance signal is lower than that of the luminance signal.

All modern compression methods are mathematical methods applied on the digital signal. Moving digital image may be compressed in two ways; spatially and temporally. Spatial compression means compressing the image information so that each image takes less time to transfer. In temporal compression the image information is related to the preceding image, i.e. only the changing part of the image is transmitted. This is a very efficient method in, e.g., video conferencing, as usually there are relatively small parts of the image which change.

Compression techniques are continuously improving. Currently, compression methods allow for two-way video to be transmitted over a series of digital telephone lines. As the bandwidth requirement becomes smaller, the cost of interconnecting teleconference sites becomes more affordable.

There are many technical standards that have been developed for videoconferencing. Video standards specify methods of video compression and communication, audio standards specify methods of compression and communication for the sound contained in a video conference, and

data standard allows for collaboration and sharing of data files during a video conference. They can be defined in three broad categories seen in Table 5.

Table 5. *Video conferencing standards (ITU-T).*

Standard	Purpose
<i>Video standards</i>	
H.320	Standard for video communication over ISDN
H.261	Compression component of H.320
H.323	Standard for compressed video over local area networks using internet protocols
<i>Audio standards</i>	
G.711	Provides telephone quality audio (narrow band, 3.4 kHz)
G.722	Provides stereo quality audio (wide band, 7kHz)
G.728	Provides audio for low bandwidth calls (16 kbit/s)
<i>Data standard</i>	
T-120	Data sharing (file exchanges, white boards and annotation, and still image transmission)

Both the acquisition and operating costs of VTC are higher than in SF. The operating costs of an SF system are negligible compared to its acquisition costs. We can conclude that the SF approach is low cost and has better image quality (Table 6.). Image quality is dictated by the camera and the photographer, not even a bad data connection can impair picture quality, only transmission speed may fall. Digital camera technology permits simple, inexpensive telemedicine even for some radiological purposes (Vassallo, 1999, Whitehouse & Moulding, 2000) Limited spatial resolution is still a concern when reading chest images with small pulmonary nodules and infiltrates (Corr et al. 2000). In optimal conditions VTC equipment may have reasonably good image quality (Gilmour et al. 1998, Lowitt et al. 1998). SF system setup requires technical expertise, while a VTC system is often easier to set up. Image quality is also more easily adjusted in VTC, as the specialist can advise the camera operator in real-time. The SF approach has been applied to teledermatology as most of the acute cases can be treated without real-time responses and many dermatological cases are not urgent (Vassallo, 1999, Vidmar, 1999, High et al. 2000). Based on the literature we can not say which solution is better, because surveys have been so case specific. In Studies I, II SF aspects have been added to VTC system.

Table 6. *Store-and-forward and videoteleconferencing comparison*

	Store-and-Forward	Videoteleconferencing
Equipment	PC and a digital camera	Special VTC equipment
Image resolution	1500 x 2000	300 x 400 (CIF)
Image dynamic range	Limited by camera, up to 12 bits	Usually up to 8 bits
Approximate equipment cost	3,000 euro (including PC)	5,000 - 20,000 euro
Diagnoses	Yes	Yes
Continuing education	Yes	Yes
Patient education	Yes	Yes
Early intervention, follow up	Yes	Yes
Real-time interactive consultations	No	Yes
Patient data and information processing at a later time	Yes	No (Yes, if taped)

2.4.1 Theoretical aspects

Medical knowledge is characterised by variability and uncertainty. The phenomenon itself is the individual physiological system, the aetiology of diseases which are to some degree random processes (Bemmel and Musen, 1997, p 233). The theory and the description of the knowledge are many times inexact. Not all medical knowledge can be described exactly or formally (Bemmel and Musen, 1997, p 233). The acquisition process is subjective and may be based on incomplete data elicited from the patient. It may also be objective, especially when acquired directly from the patient. A traditional numerical test result may also be questionable. The test has not been taken correctly or test result depends on secondary factors. Diagnosis between normal and abnormal is not always clear. Additionally, the approach of basic health care differs from that of specialist health care, see Table 7. Communication occurs on the intra-organisational and inter-organisational level. These aspects of the nature of medicine must be born in mind in telemedicine when thinking what is the gold standard in medicine.

Table 7. *The nature of general practitioners' and specialists' work (Grundmeijer 1996).*

	General Practitioner	Specialist
Patient	All age groups, both sexes	Often adults, children or certain age group
Number of diagnoses	All diseases	Often limited
Diagnostic methods	Limited	Good
Symptoms	Various	Specified
Time	Beginning of the disease	Later
Treatment	Various	Specialised
Patient access	Easy	Difficult
Physical, mental and social aspects	All three	All but usually not social ones
Preventive aspect	Major part of the work	Minority
Nature of treatment	Patient oriented	Disease oriented
Time	The time of the symptoms is essential	Technology driven

Video techniques also have their own special aspects. The message should have a familiar structure and clear meaning for the receiver. The receiver of the message is mostly interested in the content of the message and not in the medium used in delivering the message. All these involve technical, medical and human factors. Home health care, remote monitoring of patients at home, patient access to information and between primary care and specialist services are some further examples of communication in health care.

2.4.2. Diagnostic aspects

Information forms the basis of modern medical care. Almost all medical activities involve gathering, analysing, and utilizing data in different decision making situations (Lehman, 1992 p. 116). The quantity and quality of collected data have a very strong impact on the diagnostic accuracy in several ways (Harris, 1981). The patient's current status may depend on earlier situations. To diagnose disease and aetiology, one may need multiple pieces of information, and when two or more diagnoses fit the symptoms, history data may give the additional information required to choose the correct diagnosis. While a computer cannot replace a human practitioner, it can be of valuable help in making diagnoses. In a typical patient case the diagnostic system has to first select the diagnostic features, i.e. the data to be used (Richards et al. 1996). This selection can

also be done from a distance. Computer-aided diagnostic systems are closely related to telemedicine. The availability of well-collected data offers immediate benefits for a single patient. Also, a comprehensive databank makes it easier to find other similar cases and their response to different treatments (Bemmel and Musen 1997, p. 58).

In a typical patient case diagnostic feature selection is done first. This is followed by the selection of the decision strategy or decision model. The more information about patients (symptoms, signs) and the occurrence of diseases in the population is available the better a decision model can be developed (Bemmel and Musen 1997, p. 88). These models may be either quantitative models (selection of features is based on statistical methods), where prior probabilities are incorporated into the model, or qualitative models for features which are selected by experts and based on clinical studies. Both methods use symbolic reasoning methods: logical deduction (Boolean logic) (Bemmel and Musen, 1997, p. 245).

Both quantitative and qualitative models can be combined to give a combination model. For instance, the Bayesian network and the Markov chain are common combination models. Both models assume that the patient is always in one of a finite number of states of health. The Bayesian network is based on quantifying the probabilities of change from one state to another. Markov chains provide a more convenient way to model prognosis for clinical problems with ongoing risk. For example, the Bayesian network, is a probabilistic model that quantifies the strengths of relationships among particular qualitative events (like states or conditions). The Markov model provides a more convenient way to model prognosis for clinical problems with ongoing risk. The model assumes that the patient is always in one of a finite number of states of health (Lehman, 1992 p. 113).

When comparing diagnostic outcomes of teledermatology consultations for example with traditional clinic-based consultations there are two important parameters to assess – diagnostic reliability and diagnostic accuracy. Diagnostic reliability, also known as precision, repeatability, or reproducibility simply refers to agreement. If two examiners agree on a diagnosis (e.g., both examiners believe a skin lesion to be a basal cell carcinoma) then the examiners' diagnoses are said to be reliable. Diagnostic accuracy refers to whether the diagnosis provided by an examiner is correct or incorrect. If an examiner believes a skin lesion represents a basal cell carcinoma, yet a biopsy reveals the lesion to be sebaceous hyperplasia, then the examiner provided an inaccurate diagnosis (Whited, 2001).

Reliability and accuracy are not synonymous and, therefore, it is important to assess both parameters. Two examiners may provide reliable diagnoses (both agree a skin lesion is a basal cell carcinoma), and may be either correct (the skin lesion is, in fact, a basal cell carcinoma) or incorrect (the skin lesion is something other than a basal cell carcinoma). Accuracy of the data can be described by correctness, the ability to perform the task without error or to correctly measure error in data, tendency for measured values to be grouped around a variable's true value. Various errors can be classified for systematic error (methodological), statistical error (repeatability), reading error or conformity (Whited, 2001).

2.4.2.1. Diagnostic studies

A great deal of work is yet to be investigated in videoconferencing diagnostics, but the works accomplished so far in various fields have been very promising. It was noticed very early that the influence of telemedicine is less important than the selection of the therapist or the members of the group (Bashshur et al. 1975). Later studies have focused more on comparing telemedicine against the face-to-face alternative. In a rheumatology outpatient setting the accuracy of videoconferencing was 97%, whereas the accuracy of telephone consultation was 69% compared to face-to-face (FTF) consultation (Graham et al. 2000). A PC-based (bitrate 336 kbit/s) videoconferencing system in child psychiatry assessments compared to independent FTF evaluation showed that in 22 cases out of 23 (96%) the diagnoses and treatment recommendations agreed (Elford et al. 2000). There is also evidence that it is not necessary for patients and neuropsychologists to be present at the same location for cognitive assessments to be carried out (Kirkwood et al. 2000). Comparison of telemedicine (384 kbit/s) with face-to-face consultations for trauma management have shown good diagnostic accuracy (Tachakra et al. 2000b). The real-time echocardiography service by telemedicine from the paediatric cardiology department of a tertiary care hospital in Halifax Canada confirms that broadband echocardiography transmission provides a service comparable in availability and accuracy to that provided in a paediatric cardiology division (Finley et al. 1997). Estimates of the effect of telemedicine on the management of patients with neurological problems have shown that these can be carried out (Craig et al. 2000a, Craig et al. 2000b). Video-capture technology has been proved to be a reliable means of transmitting CT scans and for some radiographics as well (Kroeker et al. 2000). Telemedicine can also be used for various screenings (Trippi et al. 1997, Heaven et al. 1993).

2.4.3. Practical aspects

With videoconferencing large, geographically dispersed groups can be convened and function in real-time. Case-specific discussions can occur with colleagues over great distances (Atlas et al. 2000). Sharing expertise between health-care staff is particularly important in the care of cancer patients, for whom treatment, even at its best, is not always effective, readily obvious or available. Telemedicine increased access to care for HIV-positive inmates and generated cost savings in transportation and care delivery (McCue et al. 1997).

Consultations performed by general and subspecialty medical consultation services showed that physicians commonly requested consultations to obtain advice on diagnosis (56 %) advice on management (37 %) or assistance in arranging or performing a procedure or test (20 %) (Lee et al. 1983). The requesting physician and the consultant completely disagreed on both the reason for the consultation and the principal clinical issue in 22 (14 %) out of 156 consultations. Consultants were twice as likely as the requesting physicians to rate consultations as crucial for management (35 % versus 18 %, $p = 0.001$) because they gave significantly higher ratings when they and the requesting physicians did not agree on the reasons for consultation. Consultations ordered for very specific purposes, such as assistance in arranging or performing a test, were rated significantly higher by the requesting physicians. It was found that breakdowns in communication are not uncommon in the consultation process and may adversely affect patient care, cost effectiveness, and education (Lee et al. 1983).

Proper clinical record keeping is essential in teleconsultations. A clear protocol for telemedical consultations starts with (Tachakra et al. 1997):

- an explanation for the patient of what will happen
- introductions
- relaying the history
- showing of the abnormal part to the specialist
- diagnosis and management
- referral and follow-up discussion

2.4.4. Human aspects

Technological changes in the health-care sector will have effects on the job satisfaction, career satisfaction, relationships and communication activities of health professionals (Hicks et al. 2000). The one-to-one doctor-patient relationship is also being replaced by one in which the patient is managed by a team of health care professionals each specializing in one aspect of care, the information has to be shared easily (Nagle et al. 1992). The results for attitudes to telemedicine are limited but have shown little technology-related anxiety, a positive general attitude to telemedical work, with a perception of the possibility of job satisfaction being improved and the technology being found to be easy to use. The implementation of telemedicine may therefore have a positive effect within organizations (Aas, 2000). Telemedicine has its greatest value in remote sites where the sense of isolation is great and the need to reduce long-distance referrals offsets the costs of the system, allowing more social interaction than the telephone (Moore et al. 1975). The immediate supervision and feedback that is available from the interpreting physician with a telemedicine system represents true potential savings when compared with other methods of remote imaging (Nores et al. 1997, Malone et al. 1998). Telemedicine has been shown to improve the quality of consultations (Watson, 1989).

The requirements of different user sectors, from the primary care physician with a few hundred patients to the large emergency hospital with thousands of patients vary greatly. What they have in common is that the information should always be available and support different views (Grimson et al. 2000). To satisfy user requirements, linking of images, text and data is essential together with the evaluation of telemedicine systems (Houtchens et al. 1991). The views of 26 general practitioners (GPs) on store-and-forward teledermatology were evaluated in a study before its introduction into their practices. There was an overwhelming view that any system needed to be quick, easy to use, efficient and reliable. Concerns were expressed about being part of the clinical trial, using new technology and an increased workload. The future of teledermatology was thought to depend on the clinical adequacy of the system (Collins et al. 2000).

A study on delivering primary health care to remote populations by telecommunication between a doctor and a health aid compared four different telecommunication methods: color television, black and white television, still frame black and white television or hands-free telephone. To obtain comparison information, the patients were examined in the physical presence of a doctor at the clinic. The diagnoses, patient management programs, etc., of the clinic physician were used as the

basis for comparison. The outcome of the study was that there were only small differences between the effectiveness of the four telecommunication modes when used for remote diagnostic consultations between doctor and a health aid (Conrath et al. 1977). Earlier results of the same setup showed that physical presence in consultation was found superior only for detecting secondary medical problems. Significant rank order correlations were found, however, between the years of experience of the consulting physician and both diagnostic accuracy and appropriate patient management. Also, the attitudes of the patients, doctors and nurses alike ranked physical presence over color television over black and white television over hands-free telephone for medical consultations (Conrath et al. 1975). Patient's attitudes to telemedicine have been extremely positive (Elford et al. 2000, Mair et al. 2000b).

The increase of computer related activities in everyday life may positively influence the clinician-monitor display system interactions and improve diagnostic performance, as the clinician is familiar with the use of computer monitor displays, such as recreational video games and computers (Krupinski et al. 1996).

2.4.5. Studies on telemedicine and economics

Economic studies have been conducted mostly in closed systems (prisons, ships and army) and on the basis of individual applications. Prisons and ships are closed units and economic analyses are quite simple to carry out. On the basis of these it has been suggested that telemedicine ultimately becomes cost-effective as the volume of teleconsultations increases (Zollo et al. 1999, Patel et al. 2000). A survey of primary care and consultation providers from four prisons and an academic tertiary care facility in Iowa showed that it would require 275 teleconsultations per year, per site (total of 1,575 consultations a year) for the service to be economically justified. Given the higher equipment investment at the hub, the breakeven point would be around 2,000 teleconsultations annually. The conclusion was that with careful planning, implementing a telemedicine program can be "cost-acceptable" initially (Brunicardi, 1998). Other studies on American prisons have found positive economic results and the inmates were very positive about telemedicine consultations (McCue et al. 1997, Zincone et al. 1998 and Brunicardi 1998).

An economic analysis of the teleradiology service provided by a university hospital to a local hospital without any radiologists showed that teleradiology is cheaper if the patient workload exceeds 1576 patients per year. A sensitivity analysis showed that, assuming a shorter equipment

lifetime, for instance four years rather than six years, the threshold value would be 2320 patients per year (Bergmo et al. 1996). Similarly the results of a survey on a private commercial magnetic resonance imaging service indicated that costs per case in practice were similar to those predicted and in case load 2000 teleradiology was cheaper than using a courier. The system was well received by both referring physicians and patients (Davis 1997). A different conclusion was reached by Halvorsen and Kristiansen (1996) in a retrospective study of a random sample. Teleradiology was not cost effective, but may be justified on the grounds of access and quality of care.

In the USA neurosurgical studies in telemedicine have been found to have positive financial effects, mainly in avoided air transport (Bailes et al. 1997, Chodroff et al. 1999). In Austria 121 emergency examinations of 116 patients were transmitted from Zwettl to Innsbruck. The average cost of one emergency CT examination by teleradiology was more expensive than one possible alternative, transporting the films by taxi for reporting elsewhere, but it would have been much slower. Another alternative, transporting the patient to the nearest central hospital for scanning, was much more expensive by road and yet more expensive by helicopter ambulance than teleradiology (Stoeger et al. 1997).

Teledermatology findings indicate that teledermatology has more benefits for the patient than for the health-care delivery team because consultations were more time-consuming for the general practitioner and dermatologist (Loane et al. 1998a, Loane et al. 1998b). Burgiss et al. (1997) found that teledermatology consultations for new patients referred from rural communities can decrease the cost of care. Wootton et al. (2000) used real-time teledermatology and found it to be clinically feasible but not cost effective compared with conventional dermatological outpatient care. However, if the equipment were purchased at current prices and the travelling distances were greater (75 km), teledermatology would be a cost effective alternative to conventional care (Wootton et al. 2000).

Doze et al. (1999) found in telepsychiatry (Canada) that at least 396 patient video-consultations per year were needed in order to break even. Trott and Blignault (1998) conducted telepsychiatry for a rural town 900 km from the regional hospital in Townsville. The results of the study showed considerable savings from reduced travel by patients and health-care workers. Gammon et al. (1996) estimated that in typical telepsychiatry a mental health institution in northern Norway would have to save 18 trips per year over a distance of 800 km in order to break even, or 34 trips per year over a distance of 300 km. In rural Michigan telepsychiatry it was concluded that telepsychiatry is

technologically feasible, pragmatically difficult and economically not supportable at the time (Werener et al. 1998). Videoconferencing is a crucial part of enhancing psychiatry services in rural areas. However, it is not necessarily cost-effective for all consumers, general practitioners, psychiatrists, or the public mental health service (Kennedy et al. 2000).

In a Norwegian study on telemedicine in ear, nose and throat was found that patient travel was cheaper for a patient workload below 56 per year. At workloads between 56 and 325 patients per year telemedicine was the best alternative. Over 325 patients the visiting specialist cost less than either teleconsultation or patient travel (Bergmo, 1997). In a Minnesota study the costs of offering outpatient care to primarily orthopedic and dermatology patients via live, interactive telemedicine were compared to the estimated costs of direct face-to-face care for the same patients. In that study reductions in patient travel costs and in lost employee productivity were identified. These were the principal benefits of the system. The breakeven point, where total costs equalled total cost savings, was 1,449 consultations annually. Sensitivity analyses indicated that the breakeven point varies from a low of 152 telemedicine consultations for a "best case" scenario to no possible breakeven point for a "worst case" scenario (Stensland et al.1999).

A dynamic robotic telepathology service in Milwaukee provides diagnostic services for routine and frozen section surgical pathology cases at Iron Mountain. A cost minimization analysis of this service was conducted by building a model to compare telepathology and on-site pathology in Iron Mountain and a courier method of transporting specimens from Iron Mountain to Milwaukee for diagnosis. Base case analysis showed the courier method to be the most economical; telepathology was less costly than on-site pathology. If the costs of telepathology equipment and telecommunication are lowered to reflect current cost, then telepathology becomes the favored option (Agha et al. 1999).

The survey of passive sensor telemedical non-stress cardiocography performed at home and the same test performed by traditional equipment in an outpatient clinic in the Budapest area showed that at home performance was less expensive than the same test performed in the traditional way in an outpatient clinic (Torok et al. 2000). In existing home telemedicine studies telemedicine has been stated to be much less expensive than a traditional, personal visit (Doolittle 2000). Other findings are that new solutions especially in home health care, may merely shift rather than save costs.

2.4.6. Picture quality in telemedicine solutions

Picture quality is always a tradeoff in all imaging. Very high-quality pictures require advanced equipment, special studios, and professional personnel (Jain 1989, p. 2). High quality digital pictures are difficult to transfer due to their large size, and they require special equipment to be viewed or hardcopied. Lower-quality pictures are easier and less expensive to produce, but at some point the low quality will interfere with the diagnosing process.

Along with number of pixels and image dynamic range, color reproduction is an important factor (Jain 1989, p. 60). Color reproduction is mostly a calibration and lighting question. There are no simple methods for measuring color rendering, as color perception is a property of the human visual system (Sonka et al. 1998, p. 33). Often, the color rendering is checked by photographing some calibration targets and then adjusting the system so that the visual perception is similar at the receiving end (Gray, 1992).

It should be noted that image quality cannot improve along the information chain. When a traditional photograph is taken of a patient, a lot of information is lost (such as the feel of the skin). This photograph is then developed in a developing process, digitized with a scanner, transferred to the receiver, and finally viewed on a computer screen or a hardcopy is taken. The strength of the digital domain is that no information is necessarily lost in transferring the image from sender to receiver.

To achieve highest possible image quality, the number of steps should be kept down. The final result is as good as is the weakest part of the chain. Usually, a digital photograph is better than a scanned traditional photograph, as developing and scanning are omitted. Also, the loss of information due to sub-standard equipment has to be minimized. A bad component (e.g. monitor) cannot be compensated by using a high-quality component (e.g. camera) in some other part of the chain.

Unfortunately, high quality pictures bear very much digital information. A typical 1600 x 1200 pixel digital color photograph is almost 50 Mbit, and transferring it will take half an hour with a modem. This picture may be compressed with some compression algorithm. There are two types of compression algorithms, lossy and lossless. Lossless compression can always be decompressed to accurately reproduce the original picture (Sonka et al. 1998, p. 621). Lossy compression does not

produce an exact copy of the original file. Photographs are usually compressed with lossy compression schemes, as they are much more efficient; the 50 Mbit picture may be compressed down to 500 kbit without visible differences. In general, the resolution of digital cameras and scanners is good enough for almost all medical applications. The problems with still images are more often related to insufficient dynamic range and poor lighting and color reproduction than low resolution.

2.4.6.1. Picture quality in real-time telemedicine solutions

Face-to-face discussions and educational programs can often operate effectively at lower bandwidths than medical consultations. Medical quality video is the level of quality that provides enough information for specialists to comfortably make medical decisions. This rate is highly subjective to the individual specialists and to some extent the specialty itself.

A video image has a rate of motion known as the frame rate. Standard video, like that seen on television, has a frame rate of 25 frames per second. This rate is sufficient so that the human eye does not perceive any gaps or pauses in the information. When video compression occurs, the frame rate may be decreased due to restrictions in the amount of information that can be transmitted between two sites. This restriction or limitation is known as bandwidth. Depending on the bandwidth available, frame rates are typically 7.5, 10, 15 or 30 frames per second. All of these frame rates are supported by the H.320 standard. The difference is in appearance. Lower frame rates will appear jumpy or jittery. Selecting a higher bandwidth can reduce motion artifact, but bandwidth is directly related to cost. Because of different compression methods, it is not possible to devise an objective test for image quality. Image quality issues are often subjective, and the only way to find a good compromise between cost, speed, and accuracy is by trial and error.

The situation is even worse for full-motion pictures. If one television frame is 720 x 576 pixels, it carries approximately 10 Mbit of information. As there are 25 of these pictures in one second, the total data stream is 250 Mbit/s. There are no practical data transfer channels to handle this amount of information, so the image has to be compressed. Broadcast-quality digital video is compressed down to 25 Mbit/s without any visible difference. Digital television systems use compression schemes down to a few megabits per second. Videoconferencing systems compress even more, down to 128 kbit/s, but their image quality is far inferior to that of an ordinary television.

Motion images suffer from bad image resolution, bad color reproduction, and they are very sensitive to lighting. However, interactivity helps in finding correct settings in real-time. The motion picture quality is expected to improve as consumer-level digital video cameras gain popularity.

2.5. Teleophthalmology

Typical clinical care process are: primary diagnoses, screening, consultation and triage (Flowers et al. 1997). Thus in eye diseases telemedicine can be practised between primary health care and specialist care in real-time through videoconferencing or store and forward by forwarding documents as shown in Table 8.

Table 8. *Telemedical solutions in ophthalmology and main use*

Function	Real-time	Store and forward	Example
Still images		X	Diabetes, CMV retinitis, the optic nerve colour evaluating, glaucoma and teaching file purposes.
Trauma	X	X	Perforations, accidents
Postoperative	X		Cataract, glaucoma
GP's consultations	X	X	Conjunctivitis
Dynamic examination	X		Neurophthalmology, strabismus

Because of its visual nature telemedicine is suitable for eye diseases where the visual information is of great importance. Also, most ophthalmic diseases seen in general practice do not require specialised equipment for diagnosis, and most cases of misdiagnosis have no serious consequences for the patient. The commonest conditions presenting in general practice were infective and allergic conjunctivitis, dry eyes, cataract, blepharitis and chalazion (Sheldrick et al. 1992). Diagnoses most often confused by general practitioners were external eye diseases requiring no specialized diagnostic equipment. On the other hand, compared to other specialties eye examinations require more than usual capability in both equipment and personnel, which to some extent limits the applicability of telemedicine in ophthalmology for general practitioners and health care centers.

While most eye problems are managed solely by general practitioners, there is clearly a need for ophthalmic services that can rapidly provide a specialist opinion. Many general practitioners feel anxious when patients present with eye disease (Sheldrick et al. 1993). Details provided by a simple ophthalmic examination are helpful to ophthalmologists when allocating clinical appointments of an appropriate degree of urgency. Unfortunately such details are often lacking in referral letters (Jones et al. 1990, Gillam et al. 1995).

2.5.1. Teleophthalmology studies

NASA began remote monitoring of astronauts in the early 1960s (Link, 1965, Hunter et al.1993) According to Hunter et al. (1993) in 1987 retinal vessels were monitored during space flights. Digital fluorescein angiography system was developed at this time (Feldman, 1987). Already in the early 1990's digital slit lamp images were transferred from remote places (Garden et al. 1990, 1991). Later patients have been examined by a trained ophthalmic nurse on the first postoperative day after cataract, trabeculectomy and combined operations using video slit lamp images (Murdoch et al. 2000). Similarly images have been successfully transmitted using slit lamp images from a patient in a remote location, with the assistance of a non-ophthalmologist to an ophthalmologist for visualization with relevant clinical information (Shimmura, 1998).

Generally telemedical experiments have been promising in many studies (Pickard, 1998, Shanit et al.1998, Hariprasad et al. 1999). In 1998 Rosengren studied acute ophthalmological conditions via telemedicine consultation. No adverse outcomes were found later. The quality of the transmitted slit lamp image was of sufficiently high quality to allow definite diagnosis in all cases. Successful use of the technology requires skilled practitioners at both ends of the transmission generating and interpreting slit lamp images (Rosengren et al. 1998). Later the 768 kbit/s transmission bandwidth was found to be the minimum speed required for real-time consultations for ophthalmic purposes, producing few motion artefacts and good resolution (Cuzzani et al. 2000).

In Europe there have been several research projects in teleophthalmology. The OPHTEL Project used store-and-forward e-mail systems and real-time videoconferencing for collaborative ophthalmology consultations in diabetes (Mertz et al. 1997, Zahlmann et al. 1988). The EUREKA Project concerned visual electrodiagnosis and transmission of color fundus photographs, pictures of fluorescein angiography, video clips permitting assessment of eye position and mobility, and videoconference facilities for live discussion between experts in cases of diagnostic ambiguity (Papakostopoulos et al. 1997).

Various screenings in ophthalmology (Maldonado et al. 1997, Constable et al. 2000) have been accomplished using telemedicine, for example, in corneal transplants (Shimmura et al. 1998), in macular diseases (Berger and Shin, 1999), in glaucoma (Tang et al. 1977, Tuulonen et al. 1999, Beauregard et al. 2000), in strabismus (Cheung et al. 2000, Jason et al. 2000), in remote refraction (Michelson et al. 2000) and in diabetes (Klein et al. 1985, Yogesan et al. 2000a). Computer assisted diagnoses have also been of interest (Garden et al. 1996, Williamson and Keating, 1998). In the future computer algorithms may allow interesting alternatives especially for screenings (Madjarov and Berger, 2000). The lessons that have been learned are that people involved in telemedicine have to be aware of the technologies used (Jennett et al. 1995, Nitzkin et al. 1997).

2.5.2. Fundus imaging

All photographing in ophthalmology is a rewarding task (Hansell, 1978). Still, fundus imaging and photokeratography are valuable diagnostic aids in ophthalmology. Optical aids, such as microscopes, are in wide use in patient examinations and operations. But retinal photography development has been the most valuable and exciting field in ophthalmic photography. Approximately 100 years ago Gerloff recorded the first tiny photographic image of the retina and optic nerve-head using a modified eye-bath and a paraffin lamp. Since then the development has been remarkable, and the ophthalmic photography has become an everyday diagnostic and documenting tool.

Digitalization of traditional fundus imaging offers new opportunities to make the imaging less time consuming and prone to observer errors. Electronic images may be stored with other clinical patient data, and transferring images between doctors is fast. It is also possible to store the images in a computerized database for follow-ups. Electronic imaging systems represent a potential major advance for the improvement of diabetic retinopathy screening (Ryder et al. 1998). It is also possible to use digital image enhancement methods and even automatic diagnostics systems (Shin et al. 1999).

The digital fundus camera system comprises optics, camera, workstation, and application software. For flexibility, the front of the eye can also be photographed with the same equipment in eye diseases. The quality of digital images is acceptable for diagnostic purposes although the resolution is limited. Other advantages and developing technologies will make it increasingly attractive in the future (Prasad et al. 1999). Compression aspects need more standardizing in medicine (Iyriboz et al.

1999) though generally experiences in ophthalmology compressions have been good (Yogesana, 1998). Fundus images can be digitized and stored with significant compression while preserving stereopsis and image quality suitable for quantitative image analysis and semiquantitative grading. Low-compression (30:1) JPEG images may be suitable for archiving and telemedical applications (Lee et al. 2000).

Telemedical direct ophthalmoscopic, real-time fundus imaging may provide a valuable means for providing ophthalmic consultation to the primary care physician in younger patients without lens or media opacity, but is inadequate for eyes with any degree of lens or media opacity (Marcus et al. 1998). Teleophthalmic consultations were conducted between a hospital in East Java, Indonesia, and an ophthalmology centre in Perth, Western Australia. Twenty-two eyes of 14 subjects were screened for glaucoma using a hand-held fundus camera. Optic disc images comprised 267x234 pixels at 24 bit/pixel (187 kByte). The images received in Perth were considered to be of excellent quality and readily interpreted by ophthalmologists in terms of the likely presence of glaucoma (Yogesana et al. 2000b).

2.6. Tele dermatology

The digital imaging revolution is beginning to find new and important roles in dermatology. This technology has a wide range of educational, clinical, and research applications. General practitioners have reported the teleconsultations to have educational benefit. Knowledge of basic concepts about images and imaging techniques must be known in order to take advantage of progress in this field and eventually apply it to research and clinical practice (Perednia, 1991, Lowitt, 1998). A survey made for dermatologists demonstrated that a high proportion of dermatologists in private practice would use a tele dermatology service (Glaesse et al. 2000). Optimum use of medical assistants at the remote site will be necessary to increase the likelihood of complete agreement on diagnoses among dermatologists using interactive television (Leshner et al. 1998). Teledermoscopy can be a reliable technique for the diagnosis of pigmented skin lesions but one that will depend on the expertise of the observer (Piccolo et al. 2000).

Telemedicine has potential to diagnose and manage dermatology cases referred from primary care (Gilmour et al. 1998). Even though the tele dermatology system increased the number of patients referred for specialist evaluation the number of in-person visits to specialists fell. Tele dermatology also has positive effects on recommended treatment plans. Telemedicine technology can also have

positive effects in reversing conditions that had been poorly controlled for a number of years prior to teleconsultation (Perednia et al. 1998). Primary care physicians' diagnoses made from color slides compared to dermatologists from black and white televised image showed that the dermatologists were able to diagnose the images with greater accuracy than primary care physicians (Murphy et al. 1972).

No differences were found in clinical outcomes of real-time teledermatology (128 kbit/s) and conventional dermatology (Loane et al. 2000a). Digital image consultations also result in reliable and accurate diagnostic outcomes when compared with traditional clinic-based consultations (Whited et al. 1999, Krupinski et al. 1999). No specific disease category appeared to be more or less amenable to diagnosis based on still digital imagery. The concern about the malignancy of a particular skin lesion and the recommendation whether to do a biopsy were not significantly affected by telemedicine technology (Phillips et al. 1998). Still digital images can substitute for the dermatological physical examination in up to 83% of cases (Kvedar et al. 1997). However, diagnostic correlations have varied (57-92 %) in videoconference and store and forward teledermatology studies (Kvedar 1997, Oakley 1997, Gilmour 1998, Loane 1998a, Lowitt 1998, Whited 1999 et al.). Appropriate clinical management is possible in approximately two-thirds of dermatology consultations via the video-link (Loane et al. 1998c). Generally videoconferencing can be used with a reasonable degree of accuracy for the diagnosis of dermatological disease (Oakley et al. 1997, Loane et al. 1998a, Lowitt et al. 1998). Physicians and patients have been found to be satisfied with teledermatology examinations.

Interphysician variability will also account for a proportion of disagreements in telemedicine. The essential question is how much disagreement may be attributed to the technology itself (Lowitt, 1998). Findings support the theory that a substantial proportion of the differences found in the teledermatology trial reflects differences between dermatologists rather than problems with the videoconsultation itself (Loane et al. 1998b). Limitations in teledermatology studies are when comparing face-to-face situations, which is the true gold standard, whether it should be based on pathology or something else. There is no accepted or widely adopted diagnostic rating scale for dermatological disease (Whited et al. 1999).

Digital images appear to be as informative as slides for specific dermatological diagnoses. Images at a resolution of 768 x 512 x 24 were perceived as equivalent to higher resolutions, whereas a clear difference was visible between 768 x 512 x 24 and 384 x 256 x 24 (Bittorf et al. 1997). It is quite

probable that many clinically important conditions cannot be reliably diagnosed more than 75 % to 85 % of the time based on clinical appearance alone. It is useful to know that 'easy' and 'hard' clinical cases can be reliably differentiated by a clinician moderately familiar with the clinical appearance of the diagnoses in question (Perednia, 1995b). Despite the relatively high degree of concordance the teledermatologist had a significantly lower degree of confidence in his diagnoses (Phillips et al. 1997).

Even highly trained dermatologists also appear to differ significantly in their initial interpretations of skin images, both from observer to observer and within observers from session to session. These findings have important implications for determining where errors may occur in dermatological screening and for automating the process of detecting changes in skin lesions over time (Perednia et al. 1992).

2.7. Orthopaedics

There exist very few teleorthopaedic studies in the literature. Surgical patients have been satisfied with the videoconsultations (Aarnio et al. 2000) and videoconferencing has been successfully used for the examination of orthopaedic outpatients (Haukipuro et al. 2000). A study incorporating 410 consultations suggested that telemedicine may be an avenue for the delivery of orthopaedic care to patients residing in areas where orthopaedic specialists are not available (Lambrecht et al. 1998). Teleconsulting between orthopaedic surgeons and elderly patients appeared also to be possible (Couturier et al. 1998).

A wide range of scopes and diagnostic equipment can be used for emergency situations (Nordberg, 1996). The largest number of trauma teleconsultations concerns orthopaedic surgeons. The clinical effectiveness of telemedicine technology in the evaluation and treatment of extremity and pelvic injuries have been good (Lambrecht, 1997). There were no findings described by the radiologist not previously reported by the orthopaedic surgeon. So in no case did the radiology interpretation influence clinical management decisions (Parmar et al. 1999).

3. Aims of the present study

This Ph.D study focuses on feasibility, diagnostic accuracy, picture quality and economic aspects of telemedicine between the central and remote places in real-time telemedicine. The aims of this Ph.D. study are to investigate:

- The feasibility of real-time teleconsultations in ophthalmology, dermatology and orthopaedics from the point of view of health care professionals and patients.
- The technical reliability and diagnostic accuracy of the equipment and communication lines.
- The overall costs of real-time consultations.
- The picture quality of teleconsultations in medical applications.

4. Material and Methods

4.1. Teleconsultation and Financial Studies

Ophthalmology and dermatology teleconsultation studies were carried out between the GPs in Ikaalinen (Table 9.) and the specialists in Tampere (I and II). In the orthopaedic study the enquiring surgeon was located in Pori (Figure 3.) and the consultative specialist was in Helsinki (Orton Orthopaedic Hospital) (III). Detailed demographic information on the patients is presented in Table 10. The present dissertation includes one more patient in ophthalmology and two more in dermatology than in the previous studies in the original articles (I, II). These three additions do not have statistical significance for the results.

Table 9. *Teleconsultation Studies.*

Specialty	Study period	Number of patients	Study methods	Diagnoses checked	Connection (ISDN)
Ophthalmology	10 months	25	Questionnaires (physician and patients)	Not confirmed	128 kbit/s
Dermatology	8 months	27	Questionnaires (physician and patients)	After 16 months by follow up	128 kbit/s
Orthopaedics	3 months	29	Questionnaires (physician and patients)	In two weeks face-to-face	384 kbit/s

Table 10. *Patients' demographic distribution.*

Specialty	Male	Female	Average age and range
Ophthalmology	11	14	61 (6-90)
Dermatology	6	21	45 (2-95)
Orthopaedics	15	14	30 (9-79)

All ophthalmological and dermatological patients completed the questionnaires right after the consultation. The economic observations are based on ophthalmological and dermatological consultations. Orthopaedic patients answered at their home after the consultation and mailed their responses. Of the orthopaedic patients 24 (83%) responded. Of these 7 were working and 17 were not.

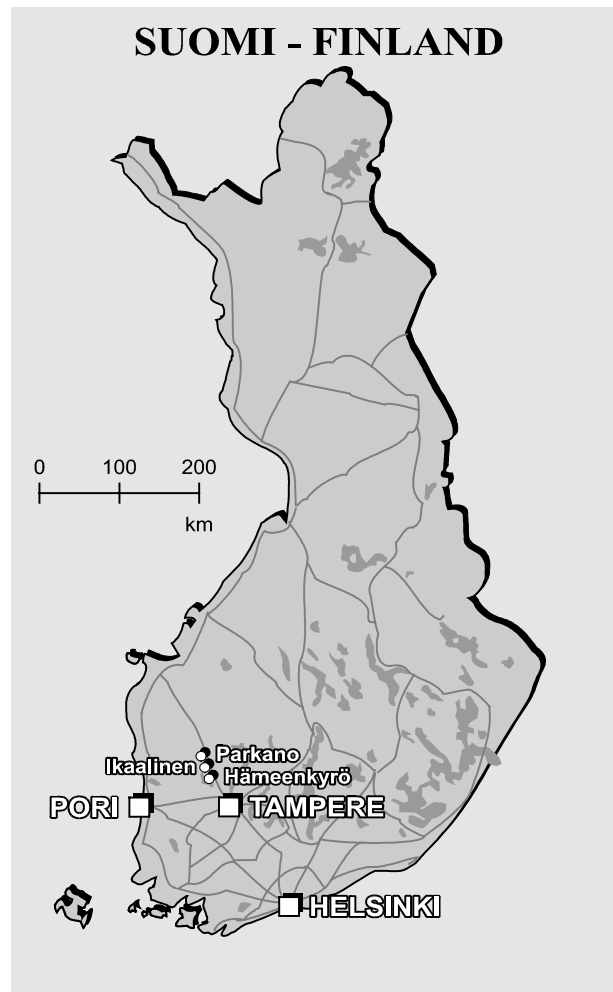


Figure 3. Geographical locations of the cities involved in the teleconsultations and two neighboring municipalities of Ikaalinen.

4.1.1. Primary Health Care Consultations

Ikaalinen belongs to the Pirkanmaa Health Care District and TAUH is its referral hospital. The Primary Health Care Centre of Ikaalinen has 5 GPs (one resident) and the total number of employees is 97. There are no dermatological or ophthalmological services in Ikaalinen. Patients have unlimited access to the Ikaalinen Health Care Centre for a nominal fee of 16.7 Euro per annum (2000). Access to TAUH is by doctor's referral, except in emergency.

Ophthalmological and dermatological consultations were carried out at the Primary Health Care Centre in Ikaalinen and the Tampere University Hospital (TAUH) during the period August 1997 - June 1998. All the patients needing non-emergency specialist consultations were included in the

teleconsultation in the order of appointments available, no other criteria were used for selection. Consultation times were scheduled for fixed hours. The patient's history and the clinical problem were faxed to TAUH a day before the consultation. All the health care centre doctors referred patients to consultations. During the consultations all the doctors working at Ikaalinen health care center had also a chance to follow the teleconsultation and ask questions. Consultation for the health care centre doctors was given by the same ophthalmologist and dermatologist in all cases and eight different orthopaedists (I, II, III).

The Primary Health Care Centre was in charge of collecting the data. Immediately after each consultation session a questionnaire was given to the patient. The consulting GP in Ikaalinen also completed a questionnaire immediately after the consultation. Likewise, following the consultation, the specialist answered the questions. All the questions were multiple choices where answers were either yes or no or on a scale 1-5 (1 = really poor, 2 = poor, 3 = satisfactory, 4 = good, 5 = extremely good and N/A = No answer).

The teleconferencing equipment used at the Health Care Centre of Ikaalinen consisted of a PictureTel Swift teleconferencing unit, a Panasonic TV and Panasonic Video Imager document camera model WE-160/G. The room settings in Ikaalinen are shown in Appendix 1. The GPs also had an opportunity to use a dermatoscope model Welch Allyn IPX 7 (528CE/1510) to magnify the selected skin area during the teleconsultation. At TAUH the specialist had PictureTel Venue 2000 videoconference equipment. From the Venue the snapshot picture was captured using PictureTel's proprietary technology onto an SVGA monitor. The snapshot picture resolution was 2 x FCIF Annex D: 704 x 576 pixels.

4.1.2. Specialist Consultation

Orthopaedic consultations were carried out with the aid of videoconference for the patients who needed an orthopaedic consultation at the Satakunta Central Hospital in Pori. The specialist was 240 km away in Helsinki and the patients were examined by the same surgeon at a distance and later in two weeks traditionally face-to-face. These results were then compared to each other.

The system used was Concorde 4500 Picture Tel, using 3 x ISDN (384 kbit/s) both in Pori and Helsinki. In Pori an additional Canon VC-C1 camera for image transfer of the room was used and also a document camera Sony VID-P100 for still image transfer (e.g. radiographs). ATM based

radiograph transmissions were also evaluated and used occasionally.

4.2. Picture Quality Study

Picture quality tests (Table 11) were carried out in precisely the same environment where the Primary Health Care consultations took place. The color temperature in the Ikaalinen VTC room was 4350 K when the document camera sidelights were on and 3330 K when they were off. The measurements were carried out with Minolta Color Meter II. The test subjects first took the normal test (gold standard) and then after a month they took the tests again using various camera, lighting and screen combinations. The purpose of the time lag was to prevent the test persons from remembering the test. Test persons' (N=5) vision was with or without glasses 1.0 or better. One test person's reading vision was 0.6. at a distance of 40 cm and for the others it was 1.0. The mean age was 38 years and the ages ranged from 21 to 47 (V).

Table 11. *Picture quality tests used.*

Focus of the study	Tests used
Resolution	-Test chart TE 107 -RMA -Near vision tests (text, numbers and Landolt's C-rings)
Contrast sensitivity	-Vision contrast test system -Grayscale TE 153 (contrast range scale 63:1) -11 logarithmically graduated gray scales
Colour tests	-Colorscale TE 106 -Ishihara 24 platecharts -The Standard pseudoisochromatic plates test Part 2 -Boström-Kugelberg -Farnsworth Panel 15 -Farnsworth Panel D (desaturated) 15 -Farnsworth-Munsell 100 hue test

The statistical significance of the results was assessed using the standard 2-way variance analysis (ANOVA) and Student's t-test.

5. Results

All the results presented below include the above mentioned three additional patients, who were not in Studies I and II. These patients do not change the results significantly, but increase the number of measurement points and the reliability of the statistical data.

In order to gain an overall picture as to whether the activities of the Ikaalinen Health Care Centre differed from those of neighboring municipalities information was compiled (Appendix 2.) on the populations, distance from TAUH, references and treatments of three neighboring towns of the same size: Ikaalinen, Parkano and Hämeenkyrö during the years 1996-1998. According to a 3-way ANOVA test, references reported to the number of inhabitants in each city no differences were found between the different years (1996–1998). Significant differences between the towns, especially, Parkano compared to Ikaalinen and Hämeenkyrö ($p < 1\%$) were found. There were also significant differences between ophthalmology and dermatology ($p < 1\%$). The number of referrals through doctors on call was smaller for skin diseases. Fewest referrals to TAUH were from Parkano, which also had fewest case days in TAUH.

5.1. Results of the Teleconsultations

The majority of patients could be transferred to the hospital by public transport. After all (N=81) consultations, in 73% cases the patient did not need to go to the TAUH or Orton. Most consultations took 10-20 minutes (Figure 4) and did not require any specific advance arrangements.

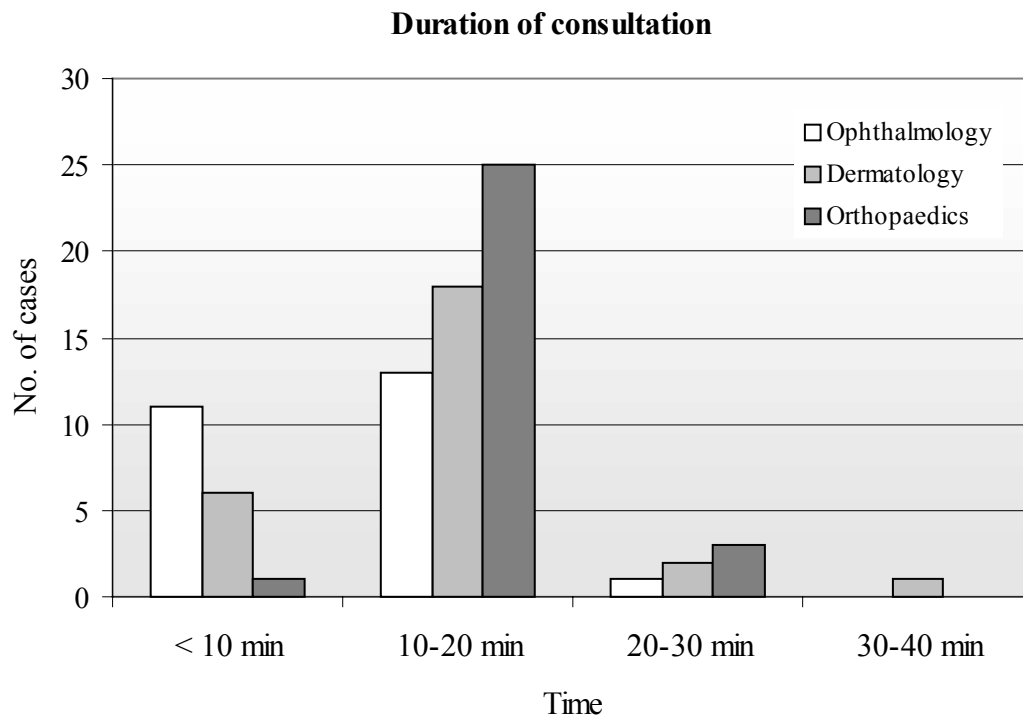


Figure 4. Time taken for one teleconsultation.

5.1.1. Answers of the consultative physicians

Assessed in advance, most ophthalmological, i.e. 88 % (22/25), and dermatological consultations, i.e. 93 % (25/27), would have been referred to a specialist. All orthopaedic patients 100 % (29/29) would also have been referred to a specialist if there had not been the teleconsultation opportunity (III). In a significant part of patient cases the patient would not have needed to be sent to a specialist for consultation after the teleconsultation (I, II, III).

Diagnoses changed in most cases; 68 % in ophthalmology and 56 % of cases in dermatology (Figure 5). Treatments also changed often in all specialties; ophthalmology (60%), dermatology (78%) and orthopaedics (83%) (Figure 6). On average the treatment received by the patient changed in the ophthalmological, dermatological, and orthopaedic consultations together in 74 % (60/81). Treatment changes in consultations were also valued high for the patient treatment (I, II). The answers of the consultative physicians are gathered in Appendix 3.

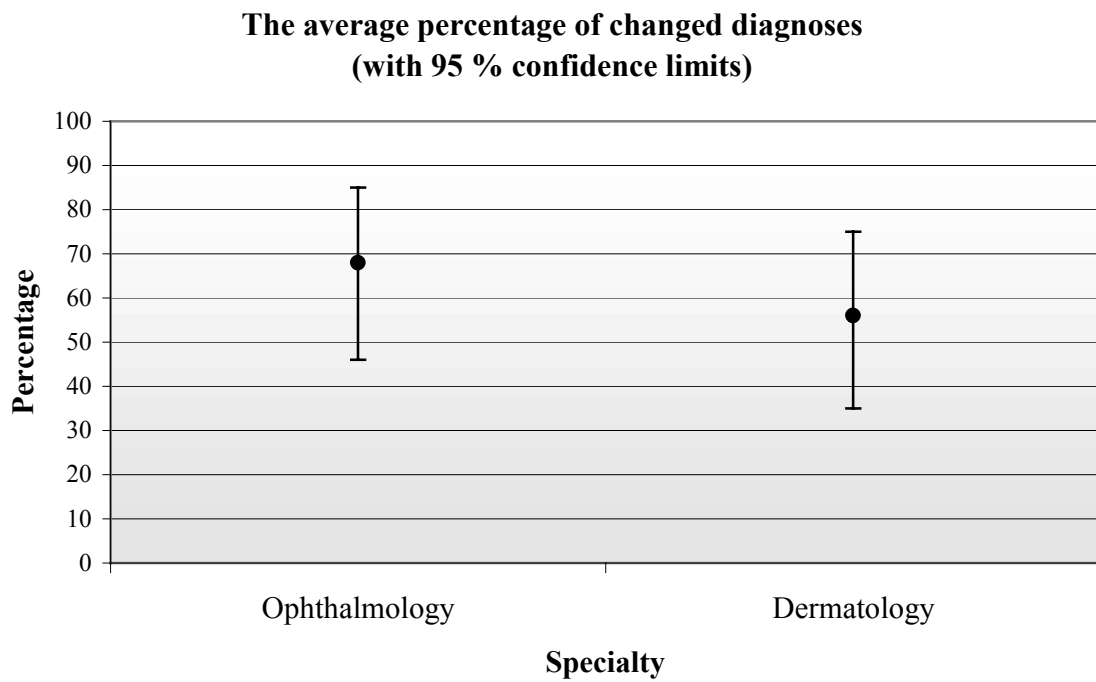


Figure 5. Percent of diagnoses changed after teleophthalmology and teledermatology consultations.

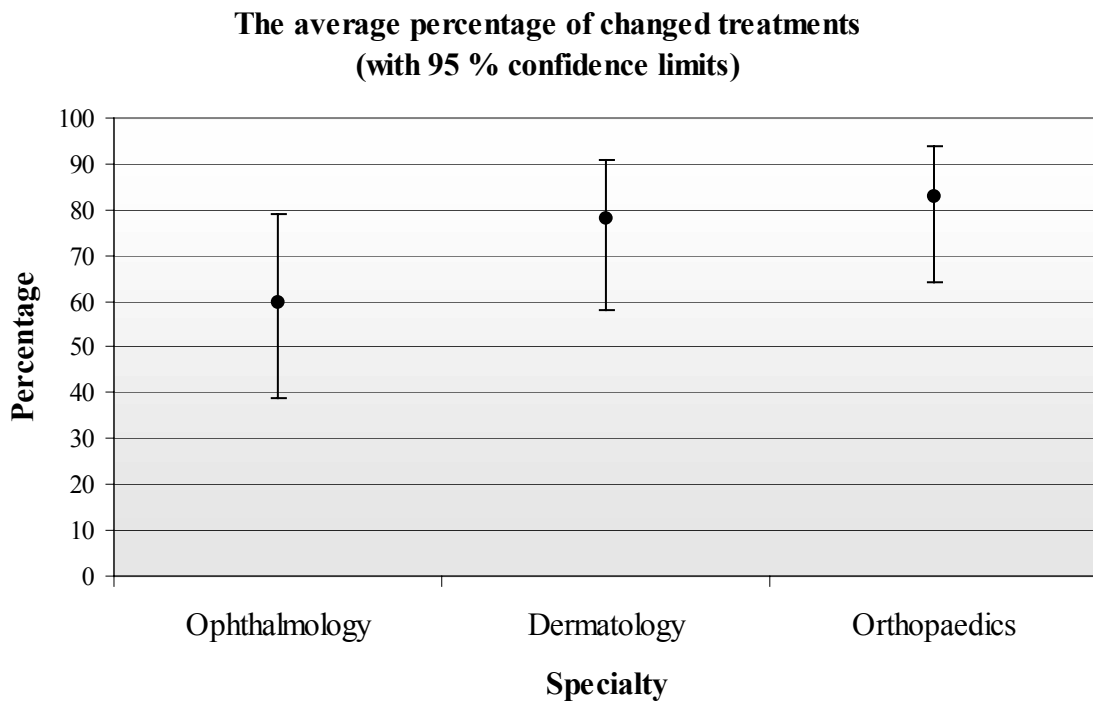


Figure 6. Percentage of treatments changed after teleophthalmology, teledermatology and tele-orthopaedics consultations.

Reliability and level of utilization of equipment were good. In a total of 93 % of cases their properties were sufficient for the consultation. The difference between 128 kbit/s and 384 kbit/s connections clinical results were small. The technical reliability was good or extremely good in 83 % of all consultations and none was it really poor. Shortcomings in the equipment were related to mobility and lighting (I, II, III).

The consultation's educational significance was very considerable. On average in the ophthalmological, dermatological and orthopaedic consultations together consultative physicians evaluated it in 84 % cases it to be good or extremely good, though the greatest benefits had to do with diagnostics and decisions on treatments (I, II, III).

5.1.2. Consultants' answers

No emergency patients participated in the examinations and most cases had an urgency classification of 30 days. No significant change occurred in the urgency classification due to the consultation. Not all orthopaedic patients went to Orton, as it would have been ethically questionable to send all the patients, as the diagnoses were evident in the videoconference (III). Consultants' answers are presented in Appendix 4.

5.1.3. Patients' answers

Most of the patients had not been in a videoconferencing situation before the consultation (96%) and their attitudes to the teleconsultation were very positive. In most cases they felt that they had got their views across very well (96%) and most of them were willing to participate again in the same type of teleconsultation (95%). They also felt that this activity would suit other visits to doctors. Videoconferencing was seen as a reliable aid to the doctor (I, II, III). The patients saved an average of 1.14 hours in the Ikaalinen consultation because they did not need to go to Tampere.

The dermatology patients reported saved time (N=5), the presence of an expert (N=10) or convenience (N=3) an important advantage in the consultation. Likewise for eye patients the certainty of the disease was important for eight and saving time for eight respondents. The orthopaedic patients were also asked about teleconsultation before and after (III). "After" responses were more positive than before the consultation, which indicates some prejudices against teleconsultation.

5.2. Results of the Economic Evaluation

We found cost savings to occur when the yearly consultation rate was at least 110 in ophthalmology (IV). Also, in the case of dermatology consultations savings would occur with 92 consultations annually (IV). The cost of the videoconsultations for the 18 patients in dermatology who avoided a journey to TAUH was 18 627 FIM and the total costs for the 18 conventional consultations in the TAUH would have been 18 034 FIM (II). Economic studies varied depending on methods.

The main economic savings from medical videoconferencing are attributable to the reduced traveling and hospital costs. The major difference between the two specialities was in the traveling cost. In dermatology consultations some patients needed an ambulance to take them to TAUH (IV). The economic benefits from medical education are more difficult to quantify.

In the use of teleconsultations, situations may arise in which patients should be sent to TAUH immediately and video consultation does not provide any benefit (II). This same effect may also occur in normal treatment processes, where a patient is sent to the referral unit unnecessarily.

5.3. Results of the Picture Quality Study

In the earlier studies the other aspects of quality, e.g. the combined effects of service performance, which determine the degree of satisfaction of the user of the service were evaluated (I, II and III). Subjective tests were also carried out for the different telesystem used between Ikaalinen and TAUH (V). Teleconsultation conditions succeeded poorly in resolution tests compared to direct viewing (V). Various lighting and screen combinations yielded only slight differences in resolution tests, and only slight differences were detected between test persons (V).

Frequencies arranged in the center of the test chart were seen slightly better than the raster frequencies arranged in the corners. The Grayscale test was seen fairly well, but the Contrast Sensitivity Tests were seen in all videoconference test conditions significantly weaker than in the normal situation. Between both bandwidths 1-3 and systems 1-6 there are highly significant differences ($p \approx 1\%$). The test was also run with only system alternatives 2-6, then between bandwidths 1-3 and systems 2-6 and there were highly significant differences ($p < 1\%$).

Teleconsultation proved to be fairly efficient in discriminating colors. The Standard Pseudoisochromatic and Ishihara plates together with the colour scale 106 test all were seen well with all systems (Figure 7). The Boström-Kugelberg test on the other hand showed quite considerable difference between the normal situation and test conditions. The Boström–Kugelberg test results were also tested in system alternatives 2-6 (i.e. normal situation 1. was omitted) with 2-way ANOVA test. No differences were detected between the system alternatives, while there were highly significant differences between people ($p = 1\%$).

The Farnsworth-Munsell test was applied to system alternatives 1 – 3 and between subjects 1 – 5 using two-way ANOVA. The test parameters chosen were the averages of overall error, red-green error, and blue-yellow error. Both overall error and red-green error showed significant differences between system alternatives ($p = 5\%$). For blue-yellow errors the differences were only symptomatic ($p = 10\%$). Between subjects, however, there were no perceptible differences regarding test parameters. Since the differences were apparently due to the inclusion of system alternative 1 (normal situation) the test was rerun with only systems alternatives 2 and 3. For both overall error and red-green errors no differences could be detected between system alternatives 2 and 3. On the other hand for the blue-yellow errors there was a significant difference between these alternatives ($p = 5\%$). Again, no differences between subjects were found.

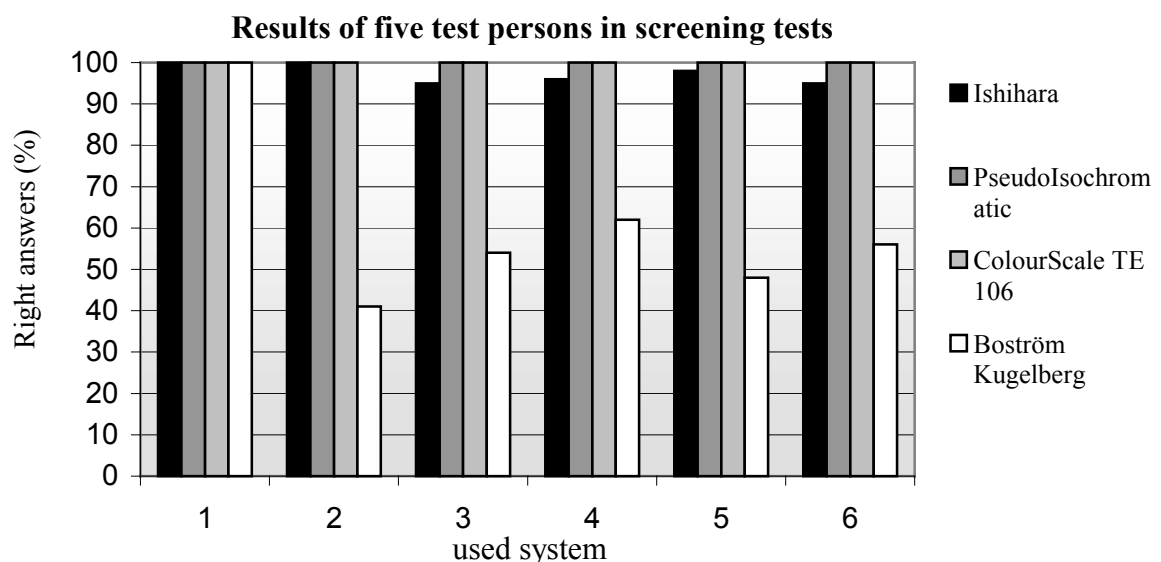


Figure 7. Five test persons' results in screening tests.

The system can be calibrated subjectively by using three separate tests (see Table 12.), where one is for resolution, one for contrast sensitivity and two for colours. Separating tests for various plates is least confusing and convenient to run.

Table 12. *Image quality tests*

Test number	Parts of the test
Test 1	Horizontal and vertical resolution tests (line pairs) one positioned to the center of the screen and four to the corners of the screen. Line pairs scale is from 0.1 to 5 line pair/mm (0.1, 0.5, 1, 2, 3, 4 & 5).
Test 2	Contrast sensitivity i.e. the Vision contrast test system for visual acuity. Vision contrast test system plates background pure white (color).
Test 3a	Ishihara test plates (N=6) numbers: 1, 3, 7, 9, 13 &15, i.e. the simplified Ishihara test.
Test 3b	Boström-Kugelberg test.

6. Discussion

The concept of telemedicine is not new, but during the last 30 years the technical development has made it possible to construct light telemedicine solutions – both in weight and cost (Craig 1999, p. 6, I, II, III). In general, telemedicine is used because there is no alternative or it is the best existing alternative for a certain purpose (Allen 1996, Allen 1998, Craig 1999, p. 12, I, II, III). The objective in telemedicine is to create added value in a cost-effective way (Taylor D, 1998, IV).

Information is a production factor and an appropriate way to manage this should be clarified (Prahalad and Hamel, 1990, IV). After that the essential question is what segments virtual organisations really need. Handling of information flows along social and technical systems are interdependent, influencing each other (IV). Values influence our behavior, which is why organizations should have clear strategies (IV) to maximize the benefits that telemedicine enables. Yet, all action in telemedicine should be based on real need and proven knowledge (Elford, 1998).

Telemedicine offers an interface between various health care sectors. Because of this the following aspects need to be taken into account (IV, Grundmeijer, 1996).

- the existing functional action models within health care organizations
- the goals of public organizations and private sector have differences
- the working of general practitioners' and specialists' have differences

After implementation telemedicine should be followed by continuous evaluation (Grigsby, 1995b, Field, 1996). When evaluating the cost-effectiveness of telemedicine - or any new technology - it should be kept in mind that overall savings do not necessarily mean cost savings to all participating units (IV). The increasing costs of some unit are acceptable if there are net savings for the whole system (Grigsby, 1995b). This is obviously a great challenge for the health care authorities and management system itself.

Nowadays telemedicine is divided into real-time (VTC) and to store-and-forward (SF) solutions or combinations of these (Craig, 1999, p. 39., I, II, III). Based on the literature, it is not possible to say which one of the two systems is better (Grimson et al. 2000). However, the immediate supervision and feedback available from the interpreting physician in a VTC consultation represents potential savings compared to SF consultations (Nores et al. 1997, Malone et al. 1998, I, II). This presented (I, II, III, IV, V) study concerns VTC systems evaluation.

6.1. Methodological considerations

Evaluation of telemedicine is a continuous and challenging process. The literature describes some protocols for telemedical assessments (Houtchens et al. 1995, Hailey et al. 1999). One of the core questions is how to measure the improvement of the health care provided, because it is difficult to predict the influences of the telemedicine systems on human and organizational behavior and education (Perednia et al. 1998, I, II, III, IV). Another example of evaluation difficulties is that telemedicine can increase the number of patients referred to specialist but decrease the number of face-to-face visits and thus have positive effects on the patients' treatments (Perednia et al. 1998, I, II, III, IV). Evaluation should include the entire health care system, not only certain specific solutions (Perednia et al. 1998, IV). So far studies presented in the literature have concentrated on evaluating only specific solutions (McCue et al. 1997, Zincone et al. 1998, Patel et al. 2000, IV). This is one explanation for the fact that different telemedicine studies give contradictory results, which makes it generalization difficult (Houtchens et al. 1995, Hailey et al. 1999). It also means that the telemedical solutions in their specific environment should be analyzed and evaluated not only clinically, technically but also economically, before large implementations (Baer et al. 1997, I, II, III, IV, V).

The continuous evaluation of individual telemedicine systems is essential to recognize all occurred hazards, to prevent their reappearance in the future (McDonald et al. 1997, IV). In all cases proper clinical record keeping is essential. This also means standardized protocols for teleconsultations (Tachakra et al. 1997, V). One limitation to telemedicine is frequently seen in the state of the legislation and the lack of standards (Huston, 1997). However, it is often possible to apply existing laws and technical standards to telemedicine as in Finland. The Finnish legislation gives basic rules for telemedicine (Legal protection of patient 785/1992, Personal data act, section 42, the constitution of Finland, section 19 (3), Medical devices act 1506/1994). But certain specifications are needed for practise (V). The standardized medical protocols for teleconsultations are still

immature (V). The identification, licensure and qualifications of medical professionals' are also detail, which have to be agreed on a broad international basis.

Basically, the idea behind the VTC studies has been to compare telemedicine system against the reference, gold standard (I, II, III, Wootton, 2000), which may not be easy to specify (I). Also, the outcome of the system is often difficult to measure in quantity (I). A quantitative, objective, approach is based on the assumption that systems have real measurable parameters like diagnostic accuracy (II, Whited 2001). Unfortunately, not all clinical situations have exact results (I) nor is there any clear agreement, whether the telemedical study outcome should be compared to a specialist's or consultant's face-to-face diagnosis or treatment decision. In certain cases patients symptoms also diminish and change quite a lot even in a few days (II). Waiting for the next consultation may thus prevent accurate diagnosis and appropriate treatment in such cases (II). A videorecording of the signs at the acute stages in addition to the patient history is helpful in those situations. During the teleconsultation it is also possible to show pre-recorded material from the acute stage of the disease (II). This fact may increase the value of store-and-forward teleconsultation in this type of situation, as the photographs of the acute phase may be taken by, e.g., a trained nurse (II).

Still one of the disadvantages of teleconsultation for example for the dermatologist is that it does not allow the consulting specialist to touch the skin of the patient. Diagnostic and treatment aspects are related also to patient history and time factors including the possibility to perform follow-ups like for hip prosthesis patients (Haukipuro et al. 2000, III). All these aspects set various requirements depending on specialties and diseases together with the available professional skills (I, II, III).

6.2. Human factors

When new technologies are implemented, it often appears that the technology itself represents less of a problem than sociological aspects do (Vazir et al.1998). Yet, at an individual level, it is often stated that the technology itself represents the entire problem. In the studies presented (I, II, III) the time used for one consultation was in most cases 10-20 minutes, which is comparable to the face-to-face visits. This was true even we started the study right after implementation (I, II). This is an encouraging finding remembering that new systems are usually in the beginning much slower than traditional, already well trained ways to work (Vazir et al.1998).

The data concerning health care professionals' attitudes to telemedicine is still limited (I, II, III), but showed no technology-related anxiety along positive general attitude to telemedical work. The technology was found to be easy to use (I,II,III). Implementation of VTC systems and adaption of new software versions in SF-solutions raised an interesting question concerning the optimization time for new processes. We do know that the use of VTC systems needs very little if any previous education (I, II, III) if the user has had previous experience of technical equipment, such as TV and video recorder. The computer-based SF-solutions are usually more complicated to use and they evolve more rapidly. The evaluation of SF systems in the beginning easily measures the learning ability of the users rather than the properties of the telemedical system. The increase of computer related activities in everyday life may positively influence the clinician-monitor display system interactions and even improve diagnostic performance, as the clinician is familiar with the use of computer monitor displays and SF solutions (Krupinski et al. 1996).

The implementation of telemedicine may therefore have a positive effect within organizations (I, II,III). This is accordance with other studies where technological changes in the health-care sector have demonstrated positive effects on the job satisfaction, career satisfaction, relationships and communication activities of health professionals (Moore et al. 1975, Nagle et al. 1992, Aas, 2000, Hicks et al. 2000). However, concerns have been expressed about being part of the clinical telemedicine trial, about the new technology itself, and about an increased workload because of telemedicine (Collins et al. 2000, Glaesse et al. 2000). The attitudes of the patients have been positive in practically all studies (Elford et al. 2000, Mair et al. 2000b, I, II, III).

6.3. Medical factors

Based on the present studies (I, II, III) and a previous study by Wootton (2000) we can say that the videoconferencing technology is mature enough for many applications in clinical medicine including clinical processes like: diagnosing, screening, consultation, treatment and triage. The consultative physicians estimated that the system's capabilities were sufficient to carry out the consultation in ophthalmology 96% (CI 86–100%), dermatology 89% (CI 71–98%) and orthopaedics 93% (CI 77–99%) (I, II, III). However, it is not suitable for every cases and face-to-face visits have to be considered still superior in their clinical accuracy (II, III, Wootton, 1996). This is also in accordance with other studies (Flowers et al. 1997, Pickard, 1998, Shanit et al.1998, Hariprasad et al. 1999).

Videoconferencing facilitates live discussion between experts in cases of diagnostic ambiguity (Papakostopoulos et al. 1997, I, II, III). Also, the educational value of the teleconsultation (I, II, III) was rated to be good or extremely good by all doctors. Similar conclusions have been drawn in other studies (Perednia, 1991, Lowitt, 1998, Gilmour et al. 1998, Al-Taei et al. 2000). Consultation's value for the treatment of the patient was evaluated to be good or extremely good in most of the cases in the study (I, II, III). Consultations were performed most commonly to obtain advice on diagnosis or management on diseases, this finding is obvious and not new (Lee et al. 1983). The patient's diagnosis changed in 68% of the cases in ophthalmology (IC 46%–85%) and dermatology 44% (IC 35%–75%). These numbers have to be reflected on the background that these consultations have been made to get advice and help to cases where GP's have had difficulties. After teleconsultation the patient would have to go to the specialized place in ophthalmology 24% (IC 7%–41%), dermatology 26% (IC 11%–46%) and orthopaedics 31% (IC 15%–51%). Similar result was obtained in dermatology by Wootton (2000).

Changes made in diagnoses and treatments during this study by the consultant together with the saved transportations showed the value of the teleconsultations (I, II, III). There was one specialist in ophthalmology and dermatology but eight different in orthopaedics in our study (I, II, III). The teleconsultation showed the physical examination compared well or very well in 84% of the cases to the face-to-face consultation in orthopaedics (III). Based on this we can estimate that the reliability (interspecialist concordance) of the VTC was good in orthopaedics. Also, the accuracy of diagnosis was estimated good in dermatology (II). These findings are concur with previous studies (Haukipuro, 2000, Wootton 2000).

Based on our experiences, telemedicine seems to be promising in ophthalmology (I). We could not find any notions of an identical system to that presented in (I). However, there are some telemedicine system descriptions for ophthalmology in the literature, especially for various screenings (Tang et al. 1977, Klein et al. 1985, Maldonado et al. 1997, Shimmura et al. 1998, Berger and Shin, 1999, Tuulonen et al. 1999, Beauregard et al. 2000, Cheung et al. 2000, Constable et al. 2000, Jason et al. 2000, Michelson et al. 2000, Yogesan et al. 2000a). We can conclude that very little is known about diagnostics in teleophthalmology, but trials carried out this far have been promising (Shimmura et al. 1998, I).

The VTC system offered good still image resolution for teledermatology (II). This is in accordance with earlier SF studies (Bittorf et al. 1997, Kvedar et al. 1997, Krupinski et al. 1999, Whited et al. 1999). We have to remember that even highly trained dermatologists also appear to differ somewhat in their initial interpretations of skin images, both from observer to observer and within observers from session to session (Perednia et al. 1992). A substantial proportion of the differences found in the teledermatology trial also reflect differences between dermatologists rather than problems with the videoconsultation itself (Loane et al. 1998b). It is quite probable that many clinically important dermatological conditions cannot be reliably diagnosed more than 75 % to 85 % of the time based on clinical appearance alone (Perednia et al. 1992). But it is useful to know that 'easy' and 'hard' clinical cases can be reliably differentiated by a clinician moderately familiar with the clinical appearance of the diagnoses in question (Perednia, 1995b, II). However, we know that primary care physicians' diagnoses made from colour slides compared to dermatologists from black and white images showed that the dermatologists were able to diagnose the images with greater accuracy than primary care physicians (Murphy et al. 1972). An interesting new question is what is the best way to improve the quality of general practitioner services': education, teleconferencing or specialists visits. The best method of improvement may change over time even for the same service (Watson, 1989).

There are very few teleorthopaedic studies in the literature and all of them have had positive findings concerning diagnostics, treatments and patients attitudes (Nordberg, 1996, Couturier et al. 1998, Lambrecht, 1997, Lambrecht et al. 1998, Parmar et al. 1999, Haukipuro et al. 2000). This is in good accordance with our study (III).

Statistically significant differences in the accuracy and reliability of the use of telemedicine were not found between specialties (I, II, III), this is supported by studies made in other specialties previously in rheumatology (97%) and child psychiatry (96%) (Graham et al. 2000, Elford et al. 2000). Promising results have been gained from neuropsychology (Kirkwood et al. 2000) and trauma management (Tachakra et al. 2000b) as well as in the real-time echocardiography service in paediatric cardiology (Finley et al. 1997) and neurology for adults (Craig et al. 2000a, Craig et al. 2000b).

Patients' opinions about the telemedical consultation were extremely positive (I, II, III). Patients found videoconferencing to be suitable for consultations in other medical specialties in ophthalmology 96% (IC 80%-100%), dermatology 96% (IC 79%-100%) and orthopaedics 96% (IC

79%-100%). Patients estimated videoconsultations generally to be either good or extremely good (I, II, III). Physicians and patients have been found to be satisfied with teledermatology examinations, also in previous studies (Loane et al. 1998c, Lowitt et al. 1998).

6.4. Economic factors

The videoconferencing system seems to be an economically justifiable investment for a health care unit which is in the same size range as Ikaalinen Health Care Center, if the system is used by several specialties and also for educational purposes (II, IV). The same kind of results have been obtained by other authors as well (Bergmo, 1997, Gammon et al. 1996, Trott and Blignault 1998). However, the cost analysis has also shown that realtime teledermatology is clinically feasible but more expensive than conventional care (Loane et al. 2000b, Oakley et al. 2000). We have to remember that a great variety of break-evens has been found earlier (Brunicardi, 1998, Stensland et al. 1999, Doze et al. 1999, Wootton et al. 2000, II, IV). The differences could be explained by differences in equipment costs, salaries, cost of telecommunication, and also in the way how the expenses have been calculated. Also the cost-effectiveness of telemedicine improves considerably when it is an integral part of telecommunications and information technology in the health sector (Mitchell, 2000, II) and telemedicine in closed systems becomes cost-effective as the volume of teleconsultations increases (McCue et al. 1997, Zincone et al. 1998, Brunicardi 1998, Zollo et al. 1999, Patel et al. 2000, IV).

The calculated breakeven in dermatology was lower than in ophthalmology (IV). The number of ambulance services needed was higher in dermatology due to the general condition of the patients (II). Teleconsultation in dermatological consultation might have been available to patients who would not otherwise have been sent to a dermatologist due to their need of ambulance transportation (II, IV). The transportation has a huge effect for economic calculations (IV), this has been confirmed also in other studies (Bailes et al. 1997, Stoeger et al. 1997, Chodroff et al. 1999). Because of this it would be recommendable to use videoconference before ambulance transportation, if the situation allows it.

The secondary effects of the implementation of new technologies like telemedicine are difficult to detect and even more difficult to accurately evaluate in terms of money (IV). Information technology itself does not always bring savings, as it dictates process changes (Davenport and Thomas, 1993). Previously it was found that the implementation of the service may change the

quality and process of care and access to care (Muller et al. 1977). That is why the accurate cost savings in public health care are virtually impossible to measure on a large scale. Reviewing costs too early is also a mistake, as all technological activity requires a learning period during which the activity is refined into a more useful form.

Different specialties require different quality standards and therefore we need more specific recommendations on the equipment and line speeds of videoconsultation (V). Only after careful evaluation of technical needs it will be possible to produce reliable cost-benefit analyses of these consultations (Fineberg et al. 1977, Glandon G & Buck T, 1994, II, IV).

Considerable amounts of money are put into IT investments, some 40% of all investments in business life go into computers and telecommunications (Economist, 1997). As public health care belongs to the public sector, all costs to the national economy should be taken into account. An extra delay in receiving the best possible treatment may be either very expensive or almost negligible cost to the society depending on the patient. When a working patient has to be one extra day off, it is a fairly significant cost to his/her employer (and that way to the economy), and possibly also to the social security system. The same delay with a patient living on social security does not cause any extra costs to the community, as there are no monetary measures for human suffering. Due to these difficult secondary factors, it is advisable to build the strategy with the idea of offering better care with the same money and personnel rather than thinking of offering the same care with fewer resources.

6.5. Technical factors

These studies (I, II) demonstrated that teleconsultations can be carried out using relatively simple, inexpensive equipments and with little technical training (I, II, III). Also, health care staff could perform consultations without the need for technicians (I, II, III). These findings are similar to previous studies (Wootton, 2001). The technical reliability of the equipment was rated as good or extremely good (I,II, III). Their usability was also mainly good or extremely good (I, II,III) as found in literature previously (Loane, 1999). However, we do not know the reliability of the system in emergency situations (I, II, III). This is an important aspect knowing that in the earlier studies there have been technical difficulties. For example, it was found that breakdowns in communication were not uncommon in the consultation process and that they may adversely affect patient care, cost effectiveness, and education (Lee et al. 1983).

No differences was found in consultations between ISDN lines 128 k/bits and 384 k/bits (I, II, III). Same kind of finding has been made in very early studies where the influence of telemedicine or used technologies was estimated to be less important than the selection of the professionals (Bashshur et al. 1975, Conrath et al. 1975, Conrath et al. 1977).

Real-time videoteleconsultation has several advantages over SF consultation. Eavesdropping on telephone lines is usually very difficult, and identification of each participant is easy (I, II, III). Interactivity also helps in finding the best camera positions and settings (I, II, III). However, the resolution of a standard VTC system is rather limited (Gilmour et al. 1998, Lowitt et al. 1998, V). This limitation may be partially overcome by using a document camera to relay still images of better quality (I, II, III, V). This way some SF properties may be brought into VTC (I, II).

In theory, accurate color calibration is very difficult because even small changes in the lighting of either end of the connection may change color perception significantly (II, V). It is good to remember that different compression methods used in image transmission may lose either temporal or spatial data. Objective measurements of image quality in VTC systems is difficult (V). Due to the numerous parameters, the final evaluation of a VTC system has to be made subjectively (V). Our study (V), however, gave results which indicated that the color rendering of a VTC system is good enough for most uses with a simple calibration procedure and that the calibration is possible by using relative simple tests (V). There are some practical measures which make the use of a VTC system easier and improves the image quality (III). The color and depth perception may be improved if the camera is rotated around the scene before starting the actual consultation session (III). Clear position marks on the floor may also help creating better image quality and decrease the time required in setting the cameras (III).

In the future digital convergence may pull VTC to the Internet. This together with the advent of high-quality low-cost digital videocameras promises large improvements both in image resolution and movement quality. Another significant change in the future may be the advent of automatic diagnostic aids which analyses certain features directly from digital images taken from the patient.

7. Summary

The focus in this PhD study has been to develop a practical videoconferencing system that would serve the consultation needs of the Finnish health care center, especially from the perspective of the GP's clinical work and continuing medical education. This research has shown that teleconferencing is medically, economically and technically feasible for purposes of consultations (I, II, III, IV, V).

Based on the present Study (I, II, III) videoconsultations with standard equipment can be used for primary health care and specialist consultations. Videoconference works reliably (I, II, III). It can improve the general practitioners' diagnostic accuracy (I, II). However, clinical decision-making is never 100% accurate, and it must be kept in mind that teleconsultation is at its best only equal to face-to-face examination. Still, teleconsultation is in most cases good enough to be useful (I, II, III).

Progress in telemedicine should be iterative, beginning with an identification of the needs of the users (task and user analyses) (IV) then with continuous assessment of the products in use (safety and risk analyses, usability testing, gathering of feedback) (V). The overall evaluation of a teleconsultation system is difficult due to several soft factors (IV), e.g. education, medication and the changes in treatment pattern due to availability of teleconsultation (I, II, III).

Before large-scale implementations, it is essential to have organization strategy (IV). After this it will be possible to take the most suitable technical and medical solution for the health care units (I, II, III). In this process the data on the quantity of the equipments technical qualifications (V) along the economical evaluation (IV) of the used system is valuable. In order to choose the best possible system, several so-called soft factors factors also have to be taken into account (IV). The number of patients, the traveling costs, the accessibility of the services of specialists all influence the evaluation (IV).

8. Acknowledgements

This Ph.D. study has had numerous supporters, and I wish to thank them all. I would like to acknowledge late Prof. Antti Alho, Docent Kaj Tallroth, Dr. Juha Nevalainen, Prof. Pekka Loula, Prof. Pertti Aarnio and my colleagues Markku Lampinen, Jaakko Niinimäki, Pentti Rantanen and Marja-Leena Tuomi for their invaluable help with the practical arrangements in the beginning of these studies. I would like to thank Prof. Lotta Salminen and Docent Hannu Uusitalo for the possibility to carry out my Ph.D. study in the department of ophthalmology and for the support and instructions they have given me during the study.

Professor Keijo Ruohonen has helped me in analyzing the material collected during the study. I want to thank him for this help and especially for the interesting discussions we have had on the data. For the practical realization of technical details and for some interesting interpretations I want to thank my good friend M.Sc. Ville Voipio. This work along with Ville's comments has opened me many secrets of the visual world. My sister Johanna Lamminen earns a warm thank you for patiently explaining economic factors so that even an engineer-physician has understood them. I wish also to thank Virginia Mattila, for revising the English language of the manuscript.

I would like to thank my godparents Maj-Lis and Helge (the diver) for the good example they have set to me. A big thank you to my father and mother for the everyday life. And finally, a huge thank you for Sanna and Reetta for giving a purpose to the work and for their unlimited love.

Furthermore, I thank the Yrjö Jahnsson Foundation for the financial support and the Medical Research Fund of Tampere University Hospital. This study was also supported by a grant from the Finnish Cultural Foundation.

9. References

- Aarnio P, Rudenberg H, Ellonen M & Jaatinen P (2000): User satisfaction with teleconsultations for surgery. *J Telemed Telecare* 6(4): 237-41.
- Aas IHM (2000): Working with telemedicine: user characteristics and attitudes. *J Telemed Telecare* 6(Suppl 1): 66-68.
- ACR STANDARD FOR DIGITAL IMAGE DATA MANAGEMENT (1998) Effective 1/1/99. http://www.acr.org/cgi-bin/fr?tmpl:standards00.pdf:pdf/digital_image.pdf (1.2.2001).
- Agha Z, Weinstein RS & Dunn BE (1999): Cost minimization analysis of telepathology. *Am J Clin Path* 112(4):470-8.
- Allen A, Scarbrough & ML (1996): 3rd Annual program review. *Telemed Today*. 4(4):10-17.
- Allen A & Grigsby B (1998): 5th Annual program survey. *Telemed Today*. 6(5):18-19.
- Al-Taei MK, Pan Y & Lu DM (2000): An Internet-based telediagnosis system for Chinese medicine. *J Telemed Telecare* 6(Suppl 1): 63-65.
- Amenta F & Rizzo N (1999): Maritime radiomedical services. In: Wootton R (ed). *European telemedicine*. Kensington Publ., London: pp. 125-126.
- American Telemedicine Association (2001): <http://www.atmeda.org/>(1.1.2001).
- Anonymous: Sending dental X-rays by telegraph (1929). *Dental Radiography and Photography* (2): 16-19.
- Anonymous (1997): Answering the critics. *Economist* 342(8010): 22.
- Atlas I, Granai CO, Gajewski W, Steinhoff MM, Stellar M, Falkenberry SS, Legare R, Szvalb S, Prober A, Zafir H & Farbstein J (2000): Videoconferencing for gynecological cancer care: An international tumor board. *J Telemed Telecare* 6(4) : 242-4.
- Baer L, Elford R & Cukor P (1997): Telepsychiatry at forty: What have we learned? *Harv Rev Psychiatry* 5:7-17.
- Bailes JE, Poole CC, Hutchison W, Maroon JC & Fakushima T (1997): Utilization and cost savings of a widearea computer network for neurosurgical consultation. *Telemed J* 3: 135-9.
- Bashshur RL, Armstrong PA & Youssef ZI (1975): *Telemedicine: Explorations in the use of telecommunications in health care*. Charles C. Thomas, Springfield, Ill. p. 354.
- Bashsur R (1978): Public acceptance of telemedicine in a rural community. *Biosci Commun* 4: 17.
- Beauregard D, Lewis J, Piccolo M & Bedell H (2000): Diagnosis of glaucoma using telemedicine - the effect of compression on the evaluation of optic nerve head cup-disc ratio. *J Telemed Telecare* 6(Suppl 1): 123-125.

- Bemmel van JH, Musen MA, ed.(1997): Methods for decision support. In: Handbook of Medical Informatics, Bohn Stafley Van Loghum, Houten.
- Benschoter RA (1967): Multi-purpose television. *Ann N Y Acad Sci* 142(2): 471-478.
- Berger JW & Shin DS (1999): Computer-vision-enabled augmented reality fundus biomicroscopy. *Ophthalmology* 106(10): 1935-41.
- Bergmo TS (1996): An economic analysis of teleradiology versus a visiting radiologist service. *J Telemed Telecare* 2 (2):136-142.
- Bergmo TS (1997): An economic analysis of teleconsultation in otorhinolaryngology. *J Telemed Telecare* 3(4):194-9.
- Bittorf A, Fartasch M, Schuler G & Diepgen TL (1997): Resolution requirements for digital images in dermatology. *J Am Acad Dermatol* 37(2):195-8.
- Brown SG (1910): A telephone relay. *J Inst Electrical Engineers* 5: 590-619.
- Brunicardi BO (1998): Financial analysis of savings from telemedicine in Ohio's prison system. *Telemed J* 4: 49-54.
- Burgiss SG, Julius CE, Watson HW, Haynes BK, Buonocore E & Smith GT (1997): Telemedicine for dermatology care in rural patients. *Telemed J* 3: 227-33.
- Cameron AE, Bashshur RL, Halbritter K, Johnson EM & Cameron JW (1998): Simulation methodology for estimating financial effects of telemedicine in West Virginia. *Telemed J* 4: 142-4.
- Canadian Coordinating Office for Health Technology Assessment (1997): Guidelines for economic evaluation of pharmaceuticals. 2nd Edition. CCOHTA , Ottawa.
- CEC DG XII.(1993): Research and Technology Development on Telematics Systems in Health Care. AIM 1993. Annual technical Report on RTD: Health Care. Brussels.
- Cheung JC, Dick PT, Kraft SP, Yamada J & McArthur C (2000): Strabismus examination by telemedicine. *Ophthalmology* 107(11): 1999-2005.
- Chodroff PH. (1999): A three-year review of telemedicine at the community level – clinical and fiscal results. *J Telemed Telecare* 5 (suppl:1): 28-30.
- Collins K, Nicolson P, Bowns I & Walters S (2000): General practitioners' perceptions of store-and-forward teledermatology. *J Telemed Telecare* 6(1): 50-53.
- Conrath DW, Buckingham P, Dunn EV & Swanson JN (1975): An experimental evaluation of alternative communication systems as used for medical diagnosis. *Behav Sci* 20(5): 296-305.
- Conrath DW, Dunn EV, Bloor WG & Tranquada B (1977): A clinical evaluation of four alternative telemedicine systems . *Behav Sci* 22(1):12-21.

- Constable IJ, Yogesan K, Eikelboom R, Barry C & Cuypers M (2000): Fred Hollows lecture: digital screening for eye disease. *Clin Exp Ophthalmol* 28(3):129-32.
- Corr P, Couper I, Beningfield SJ & Mars M (2000): A simple telemedicine system using a digital camera. *J Telemed Telecare* 6(4): 233-6.
- Couturier P, Tyrrell J, Tonetti J, Rhul C & Franco A (1998): Feasibility of orthopaedic teleconsulting in a geriatric rehabilitation service. *J Telemed Telecare* 4(Suppl 1) : 85-7.
- Craig J (1999): History of telemedicine. In: *Introduction to telemedicine*, p. 6. Eds. R Wootton, J Craig, Royal Society of Medical Press, London.
- Craig J (1999): Why is telemedicine being done. In: *Introduction to telemedicine*, p. 12. Eds. R Wootton, J Craig, Royal Society of Medical Press, London.
- Craig J, Chua R, Russell C, Patterson V & Wootton R (2000 a): The cost-effectiveness of teleneurology consultations for patients admitted to hospitals without neurologists on site. 1: A retrospective comparison of the case-mix and management at two rural hospitals. *J Telemed Telecare* 6 (Suppl 1): 46-9.
- Craig JJ, McConville JP, Patterson VH & Wootton R (2000b): Neurological examination is possible using telemedicine. *J Telemed Telecare* 6 (2): 291-294.
- Cuzzani O, Bromwich M, Penno E & Gimbel H (2000): The effect of transmission bandwidth on the quality of ophthalmological still and video images. *J Telemed Telecare* 6(Suppl 2): 11-3.
- Davenport T & Thomas H (1993): *Process Innovation Reengineering Work through Information Technology*, Harvard Business School Press, Boston, Massachusetts.
- Davis MC (1997): Teleradiology in rural imaging centres. *J Telemed Telecare* 3(3):146-53.
- Doolittle GC (2000): A cost measurement study for a home-based telehospice service. *J Telemed Telecare* (6 Suppl 1): 193-5.
- Doze S & Simpson J (1998): Evaluation of a telepsychiatry pilot project. Alberta Heritage Foundation for Medical Research, Edmonton.
- Doze S, Simpson J, Hailey D & Jacobs P (1999): Evaluation of a telepsychiatry pilot project. *J Telemed Telecare* 5: 38-46.
- Drummond M (1990): Allocating resources. *Int J Technol Assess Health Care* 6(1):77-92.
- Drummond M, Cooke J & Walley T (1997): Economic evaluation under managed competition: evidence from the U.K. *Soc Sci Medicine* 45(4):583-95.
- Duerinck AJ, Kenagy JJ & Grant EG (1998): Planning and cost analysis of digital radiography services for a network of hospitals (the Veterans Integrated Service Network). *J Telemed Telecare* 4(3):172-8.

- Dyer AM & Kirk AH (2000): A fully automated remote refraction system. *J Telemed Telecare* 6(Suppl 2): 16-8.
- Elford R (1998): Telemedicine activities at memorial University of Newfoundland: a historical review, 1975-1997. *Telemed J* 4(3): 207-24.
- Elford R, White H, Bowering R, Ghandi A, Maddigan B, St John K, House M, Harnett J, West R & Battcock A (2000): A randomized, controlled trial of child psychiatric assessments conducted using videoconferencing. *J Telemed Telecare* 6(2) : 73-82.
- Feldman EL (1987). Digital fluorescein tele-angiography. *Am J Ophthalmol* 104: 91-3.
- Fery-Lemonnier E, Charpentier E & David P (1996): Impact of inter-hospital transmission of radiological images in the context of neurosurgical emergencies. In: Lemke H (ed). *Proceedings of CAR '96*. Elsevier Science, Amsterdam: pp. 558-564.
- Field MJ editor (1996): *Telemedicine: A Guide to Assessing Telecommunications for Health Care*; Committee on Evaluating Clinical Applications of Telemedicine, Institute of Medicine. National Academy Press, Washington.
- Fineberg HV, Bauman R & Sosman M (1977): Computerized cranial tomography: effect on diagnostic and therapeutic plans. *JAMA* 238: 224-227.
- Finley JP, Sharratt GP, Nanton MA, Chen RP, Bryan P, Wolstenholme J & MacDonald C (1997): Paediatric echocardiography by telemedicine--nine years' experience. *J Telemed Telecare* 3(4): 200-204.
- Finnish legislation, 785/1992: Legal protection of patient.
- Finnish legislation, 523/1999: Personal data act, section 42.
- Finnish legislation, 731/1999: The constitution of Finland, section 19 (3).
- Finnish legislation, 1506/1994: Medical devices act.
- Flowers CW, Baker RS., Khanna S, Ali B, March GA., Scott C & Murrillo S (1997): Teleophthalmology: Rationale, Current Issues, Future Directions. *Telemed J* 1: 43-52.
- Friedman RH, Kazis LE, Jette A, Smith MB, Stollerman J, Torgerson J & Carey KA (1996): telecommunications system for monitoring and counseling patients with hypertension. Impact on medication adherence and blood pressure control. *Am J Hypertens* 1996 9(4 Pt 1):285-92.
- Formman P & Saint RW (2000): The future of digital entertainment. *Scientific American* 11: 31-64.
- Foote DR (1977). Satellite communication for rural health care in Alaska. *J Commun* 27(4):173-82.
- Gammon D, Bergvik S, Bergmo T & Pedersen S (1996): Videoconferencing in psychiatry: a survey of use in northern Norway. *J Telemed Telecare* 2: 192-8.

Garden JW, Knapp CF & Sanders JH (1990): Biomicroscopic electronic imaging and data transfer. *Arch Ophthalmol* 108: 637-8.

Garden JW, Knapp CF & Saunders JH (1991): Ophthalmologic electronic imaging and data transfer. *J Ky Med Assoc* 89(3):115-7.

Garden G, Keating D, Williamson TH & Elliot AT (1996): Automatic detection of diabetic retinopathy using an artificial neural network: screening tool. *Br J Ophthalmol* 80:940-4.

Geissbuhler A & Miller RA (1997): Desiderata for product labeling of medical expert systems. *Int J Med Inf* 47(3):153-63.

Gillam SJ, Ball M, Prasad M, Dunne H, Cohen S & Vafidis G (1995): Investigation of benefits and costs of an ophthalmic outreach clinic in general practice. *Br J Gen Pract* 45: 649-652.

Gilmour E, Campbell SM, Loane MA, Esmail A, Griffiths CE, Roland MO, Parry EJ, Corbett RO, Eedy D, Gore HE, Mathews C, Steel K & Wootton R. (1998): Comparison of Teleconsultations and face-to-face consultations: preliminary results of a United Kingdom multicentre teledermatology study. *Br J Dermatol* 139:81-7.

Glaesse A, Schiffner R, Walther T, Landthaler M & Stolz W (2000): Teledermatology: The requirements of dermatologists in private practice. *J Telemed Telecare* 6(3) : 138-141.

Glandon G & Buck T (1994): Cost-benefit analysis of medical information systems: a critique. In: Anderson J, Aydin C, Jay S (eds.) *Evaluating health care information systems*. Sage, Newbury Park, CA.

Goh KY, Lam CK & Poon WS (1997): The impact of teleradiology on the inter-hospital transfer of neurosurgical patients. *Br J Neurosurg* 11(1):52-6.

Graham LE, Leggett P, Steele K, Gilliland A, O'Reilly D, Stevenson M, Wootton R & Taggart AJ (2000): Do all outpatients need a face-to-face consultation in rheumatology? *J Telemed Telecare* 6(Suppl 1) : 198.

Gray J.E. (1992): Use of the SMPTE Test Pattern in Picture Archiving and Communication Systems. *J Digit Imaging* 5 (1): 54-58.

Grimson J, Grimson W & Hasselbring W (2000): The SI challenge in health care. *Communicat ACM* (43) 6: 49-55.

Grisby J, Schlenker R & Kaehny M (1995a): Analytic framework for evaluation of telemedicine. *Telemed Journal* 1: 31-39.

Grigsby J, Kaehmy MM & Sandberg EJ (1995b): Effects and effectiveness of telemedicine. *Heath Care Financ Rev* 17: 115.

Grundmeijer H (1996): General practitioner and specialist: why do they communicate so badly? *Eur J Gen Pract* 2: 53-54.

- Hailey D, Jacobs P, Simpson J & Doze S (1999): An assessment framework for telemedicine applications. *Journal of Telemedicine and Telecare* 5: 162-170.
- Håkansson S & Gavelin C (2000): What do we really know about the cost-effectiveness of telemedicine? *J Telemed Telecare* 6 (Suppl 1):133-6.
- Halvorsen PA & Kristiansen IS (1996): Radiology services for remote communities: cost minimisation study for telemedicine. *BMJ* 312: 1333-6.
- Hannus, J (1994). *Process management – restructuring the core business processes and competence performance*. Fourth Edition. Jyväskylä, Gummerus.
- Hansell P (1978): Photography in ophthalmology. *J Audiov Media Med* 1(4): 184-5.
- Hariprasad R, Shin DS & Berger JW (1999): An intelligent, interactive platform for ophthalmic teaching, telemedicine, and telecollaboration: design considerations and prototype construction. *Stud Health Technol Inform* 62:124-9.
- Haukipuro K, Ohinmaa A, Winblad I, Linden T, Vuolio S (2000): The feasibility of telemedicine for orthopedic outpatient clinics: A randomized controlled trial. *J Telemed Telecare* 6(4): 193-8.
- Heaven CJ, Cansfield J & Shaw KM (1993): The quality of photographs produced by the non-mydratric fundus camera in a screening programme for diabetic retinopathy: a 1 year prospective study. *Eye* 7: 787-90.
- Hicks LL, Boles KE, Hudson ST, Koenig SE, Madsen R, Kling BW, Tracy J, Mitchell J & Webb W (2000): An evaluation of satisfaction with telemedicine among health-care professionals. *J Telemed Telecare* 6(4) : 209-15.
- Harris JM (1981) The hazards of bedside Bayes. *JAMA* 22:2602-5.
- High WA, Houston MS, Calobrisi SD, Drage LA & McEvoy MT.(2000): Assessment of the accuracy of low-cost store-and-forward teledermatology consultation. *J Am Acad Dermatol.* 42(5): 226-83.
- House M, Keough E, Hillman D, Hillman E, Bwibo N, Meme J, Wafula E, MacLeod S & McCullough N (1987): Into Africa: The telemedicine links between Canada, Kenya and Uganda. *CMAJ* 136:398-400.
- Houtchens BA., Clemmer TP & Holloway HC (1991): Telemedicine and international disaster response: Medical consultation to Armenia and Russia via a telemedicine spacebridge. In: *International/Disaster Medicine Conference*. Bethesda, MD: pp. 1-22.
- Houtchens BA, Allen A, Clemmer TP, Lindberg DA & Pedersen S (1995): Telemedicine protocols and standards: development and implementation. *J Med Syst* 19(2):93-119.
- Hunter N, Caputo M & Billica R (1993): Portable dynamic fundus instrument: uses in telemedicine and research. *Seventh annual workshop on Space Operations and Research (SOAR)* 2: 555-6.
- Huomo T, Mäkelin M & Vuoria A (1995): *Visio 2000* p. 170. Espoo. HM&V Research Oy.

Huston JL (1997): A telemedical record model. *J Telemed Telecare* 3 (Suppl 1):86-8.

Institute of Medicine. Committee on evaluating clinical applications of telemedicine. In: Field MF (ed.). *Telemedicine: a guide to assessing telecommunications in health*. National Academy Press, Washington, DC.

Iyriboz TA, Zukoski MJ, Hopper KD & Stagg PL (1999): A comparison of wavelet and Joint Photographic Experts Group lossy compression methods applied to medical images. *J Digit Imaging* 12(2 Suppl 1):14-7.

Jain AK (1989). *Fundamentals of digital image processing*. Prentice-Hall International (UK) Limited, London.

Jason C, Cheung M, Dick P, Stephen P, Kraft, Yamada J & Macarthur C (2000): Strabismus examination by telemedicine *Ophthalmology* 107: 1999-2005.

Jennett PA, Hall WG, Morin JE & Watanabe M (1995): Evaluation of a distance consulting service based on interactive video and integrated computerized technology. *J Telemed Telecare* 1(2):69-78.

Jones NP, Lloyd IC & Kwartz J (1990): General practitioner referrals to an eye hospital: a standard referral letter. *J R Soc Med* 83: 770-2.

Karlsten R & Sjoqvist BA (2000): Telemedicine and decision support in emergency ambulances in Ups *J Telemed Telecare* 6(1) : 1-7.

Kennedy C & Yellowlees P (2000): A community-based approach to evaluation of health outcomes and costs for telepsychiatry in a rural population: preliminary results. *J Telemed Telecare* 6 (Suppl 1): 155-7.

Kirkwood KT, Peck DF & Bennie L (2000): The consistency of neuropsychological assessments performed via telecommunication and face to face. *J Telemed Telecare* 6(3) : 147-151.

Klein R, Klein BE, Neider MW, Hubbard LD, Meuer SM & Brothers RJ (1985): Diabetic retinopathy as detected using ophthalmoscopy, a nonmydriatic camera and standard fundus camera. *Ophthalmology* 92: 485-91.

Klossa J, Cordier JC, Flandrin G, Got C & Hemet J (1998): A European de facto standard for image folders applied to telepathology and teaching. *Int J Med Inf* 48(1-3):207-16..

Kroeker KI, Diamond R, Jennett PA & Johnston RV (2000): Video-capture teleradiology for the after-hours reading of computerized tomography scans. *J Telemed Telecare* 6(4) : 229-232.

Krupinski EA, Weinstein RS & Rozek LS (1996): Experience-related differences in diagnosis from medical images displayed on monitors. *Telemed J* 2(2):101-8.

Krupinski EA, LeSueur B, Ellsworth L, Levine N, Hansen R, Silvis N, Sarantopoulos P, Hite P, Wurzel J, Weinstein RS & Lopez AM (1999): Diagnostic accuracy and image quality using a digital camera for teledermatology. *Telemed J* 5(3):257-63.

- Kvedar JC, Edwards RA, Menn ER, Mofid M, Gonzalez E, Dover J & Parrish JA (1997): The substitution of digital images for dermatologic physical examination. *Arch Dermatol* 133(2):161-7.
- Lambrecht CJ (1997): Telemedicine in trauma care: Description of 100 trauma teleconsults. *Telemed J* 3(4) : 265-8.
- Lambrecht CJ, Canham WD, Gattey PH & McKenzie GM (1998): Telemedicine and orthopaedic care. A review of 2 years of experience. *Clinical Orthopaedics and Related Research* 348 : 228-32.
- Lee MS, Shin DS & Berger JW (2000): Grading, image analysis, and stereopsis of digitally compressed fundus images. *Retina* 20(3):275-81.
- Lee T, Pappius EM & Goldman L (1983): Impact of inter-physician communication on the effectiveness of medical consultations. *Am J Med* 74(1):106-12.
- Lehman HP (1992). A Bayesian computer-based approach to the physicians' use of the clinical research literature. Stanford.
- Leshner JL Jr, Davis LS, Gourdin FW, English D & Thompson WO (1998): Telemedicine evaluation of cutaneous diseases: a blinded comparative study. *J Am Acad Dermatol* 38(1):27-31.
- Link MM (1965): Space medicine in project mercury. NASA Publication SP-4003. National aeronautics and space administration, Washington DC.
- Loane MA, Gore HE, Bloomer SE, Corbett R, Eedy DJ, Mathews C, Steele K & Wootton R (1998a): Preliminary results from the Northern Ireland arms of the UK Multicentre Teledermatology Trial: is clinical management by realtime teledermatology possible? *J Telemed Telecare* 4 (Suppl 1):3-5.
- Loane MA, Corbett R, Bloomer SE, Eedy DJ, Gore HE, Mathews C, Steele K & Wootton R (1998b): Diagnostic accuracy and clinical management by realtime teledermatology. Results from the Northern Ireland arms of the UK Multicentre Teledermatology Trial. *J Telemed Telecare* 4(2):95-100.
- Loane MA, Bloomer SE, Corbett R, Eedy DJ, Gore HE, Mathews C, Steele K & Wootton R (1998c): Patient satisfaction with realtime teledermatology in Northern Ireland. *J Telemed Telecare* 4(1):36-40.
- Loane MA, Bloomer SE, Corbett R, Eedy DJ, Gore HE, Hicks N, Mathews C, Paisley J, Steele K & Wootton R (1999): Patient cost-benefit analysis of teledermatology measured in a randomized control trial. *J Telemed Telecare* 5 (Suppl 1): 1-3.
- Loane MA, Bloomer SE, Corbett R, Eedy DJ, Hicks N, Lotery HE, Mathews C, Paisley J, Steele K, & Wootton R (2000a): A randomized controlled trial to assess the clinical effectiveness of both realtime and store-and-forward teledermatology compared with conventional care. *J Telemed Telecare* 6(Suppl 1) : 1-3.

- Loane MA, Bloomer SE, Corbett R, Eedy DJ, Hicks N, Lotery HE, Mathews C, Paisley J, Steele K, Wootton R (2000b): A comparison of real-time and store-and-forward teledermatology: a cost-benefit study. *Br J Dermatol* 6:1241-7.
- Lobley D (1997): The economics of telemedicine. *J Telemed Telecare* 3(3):117-25.
- Lowitt MH, Kessler II, Kauffman CL, Hooper FJ, Siegel E & Burnett JW (1998): Teledermatology and In-Person Examinations. *Arch Dermatol* 134:471-476.
- Madjarov BD & Berger JW (2000): Automated, real time extraction of fundus images from slit lamp fundus biomicroscope video image sequences. *Br J Ophthalmol* 84(6):645-7.
- Mair FS, Haycox A, May C & Williams T (2000a): A review of telemedicine cost-effectiveness studies. *J Telemed Telecare* 6 (Suppl 1): 38-40.
- Mair F, Whitten P, May C & Doolittle GC (2000b): Patients' perceptions of a telemedicine specialty clinic. *J Telemed Telecare* 6(1) : 36-40.
- Makris L, Argiriou N & Strintzis MG (1997): Network and data security design for telemedicine applications. *Med Inform* 22(2):133-42.
- Maldonado MJ, Arnau V, Martinez-Costa R, Navea A, Mico FM, Cisneros AL & Menezo JL (1997): Reproducibility of digital image analysis for measuring corneal haze after myopic photorefractive keratectomy. *Am J Ophthalmol* 123(1):31-41.
- Malone FD, Athanassiou A, Craigo SD, Simpson LL & D'Alton ME (1998): Cost issues surrounding the use of computerized telemedicine for obstetric ultrasonography. *Ultrasound Obstet Gynecol* 12(2):120-4.
- Marcus DM, Brooks SE, Ulrich LD, Bassi FH, Laird M, Johnson M & Newman C (1998): Telemedicine diagnosis of eye disorders by direct ophthalmoscopy. A pilot study. *Ophthalmology* 105(10):1907-14.
- Mavrogeni SI, Tsirintani M, Kleanthous C, Vranakis K, Secheta E, Mihelakis D, Sotiriou D, Gatzonis M, Tsolas C, Kontaratos AN & Cokkinos DV (2000): Supervision of thrombolysis of acute myocardial infarction using telemedicine. *J Telemed Telecare* 6(1) : 54-58.
- McCue MJ, Mazmanian PE & Hampton C (1997): The case of Powhatan correctional center/Virginia department of corrections and Virginia commonwealth university/ Medical college of Virginia. *Telemed J* 3:11-7.
- McDonald I, Hill S, Daly J & Crowe B (1997): Evaluating telemedicine in Victoria: A generic framework. Center for the Study of Clinical Practice, St. Vincent's Hospital, Melbourne.
- McIntosh E & Cairns J (1997): A framework for the economic evaluation of telemedicine. *J Telemed Telecare* 3:132-139.
- Menn ER & Kvedar JC (1995). Teledermatology in a changing health care environment. *Telemed J* 1995 1:303-8.

- Mertz M, Mann G, Zahlmann G & Obermaier M (1997): Scientific role of German ophthalmology in the European telecommunication project OPHTEL. *Ophthalmologie* 94: 523-8.
- Michelson G, Striebel W, Prihoda W & Schmidt V (2000): Telemedicine in the control of intra-ocular pressure. *J Telemed Telecare* 6(Suppl 1) : 126-128.
- Mitchell J (2000): Increasing the cost-effectiveness of telemedicine by embracing e-health. *J Telemed Telecare* 6(Suppl 1) : 16-19.
- Moore GT, Willemain TR, Bonanno R, Clark WD, Martin AR & Mogielnicki RP (1975): Comparison of television and telephone for remote medical consultation. *N Engl J Med* 292(14):729-32.
- Muller C, Marshall CL, Krasner M, Cunningham N, Wallerstein E & Thomstad B (1977): Cost factors in urban telemedicine. *Med Care* 15(3):251-9.
- Murdoch I, Bainbridge J, Taylor P, Smith L, Burns J & Rendall J (2000): Postoperative evaluation of patients following ophthalmic surgery. *J Telemed Telecare* 6(Suppl 1) : 84-86.
- Murphy RL Jr, Fitzpatrick TB, Haynes HA, Bird KT & Sheridan TB (1972): Accuracy of dermatologic diagnosis by television. *Arch Dermatol* 105(6):833-5.
- Murphy RL, Block P & Bird KT (1973): Accuracy of cardiac auscultation by microwave. *Chest* 63(4): 578-581.
- Murphy RL & Bird KT (1974): Telediagnosis: A new community health resource: Observations on the feasibility of telediagnosis-based on 1000 patient transactions. *Am J Public Health* 64(2):113-119.
- Nagle JP, McMahon K, Barbour M & Allen D (1992): Evaluation of the use and usefulness of telephone consultations in one general practice. *Br J Gen Pract* 42(358): 190-193.
- Neumann PJ, Parente ST & Paramore LC (1996): Potential savings from using information technology applications in health care in the United States. *Int J Technol Assess Health Care* 12(3):425-35.
- Nitzkin JL, Zhu N & Marier RL (1997): Reliability of telemedicine examination. *Telemed J* 3(2):141-57.
- Nohr LE (2000): Global medicine and licensing. *J Telemed Telecare* 6(Suppl 1) : 170-172.
- Nordberg M (1996): Remote control. Telemedicine revolutionizes EMS in rural America. *Emerg Med Serv* 25(8) : 39-45.
- Nores J, Athanassiou A, Malone FD & D'Alton ME (1997): Technical dependability of obstetric ultrasound transmission via ISDN. *Telemed J* 3(3):191-5.

Oakley AM, Astwood DR, Loane M, Duffill MB, Rademaker M & Wootton R (1997): Diagnostic accuracy of teledermatology: results of a preliminary study in New Zealand. *N Z Med J* 110(1038):51-3.

Oakley AM, Kerr P, Duffill M, Rademaker M, Fleischl P, Bradford N & Mills C (2000): Patient cost-benefits of realtime teledermatology-a comparison of data from Northern Ireland and New Zealand. *J Telemed Telecare* 2:97-101.

Papakostopoulos D, Everingham M, Gogolitsyn Y, Dodson K, Papakostopoulos S & Dean-Hart JC (1997): Comprehensive standardized ophthalmic telemedicine. *J Telemed Telecare*; 3 (Suppl 1):49-52.

Park. B (1974): An introduction to telemedicine. The Alternative Media Center at the School of the Arts New York University, New York, NY:pp. 129-135.

Parmar VS, Stanitski DF & Stanitski CL (1999): Interpretation of radiographs in a pediatric limb deformity practice: do radiologists contribute? *J Pediatr Orthop* 19(6):732-4.

Patel T (2000): A cost-benefit analysis of the effect of shipboard telemedicine in a selected oceanic region. *J Telemed Telecare* 6 (Suppl 1) : 165-7.

Perednia DA (1991): What dermatologists should know about digital imaging. *J Am Acad Dermatol* 25(1 Pt 1):89-108.

Perednia DA, Gaines JA & Rossum AC (1992): Variability in physician assessment of lesions in cutaneous images and its implications for skin screening and computer-assisted diagnosis. *Arch Dermatol* 128(3):357-64.

Perednia DA & Allen A (1995a): Telemedicine Technology and Clinical Applications. *JAMA* 273(6): 483-488.

Perednia DA, Gaines JA & Butruille TW (1995b): Comparison of the clinical informativeness of photographs and digital imaging media with multiple-choice receiver operating characteristic analysis. *Arch Dermatol* 131(3):292-7.

Perednia DA, Wallace J, Morrisey M, Bartlett M, Marchionda L, Gibson A & Campbell E (1998): The effect of a teledermatology program on rural referral patterns to dermatologists and the management of skin disease. *Medinfo* 9 Pt 1:290-3.

Phillips CM, Burke WA, Shechter A, Stone D, Balch D & Gustke S (1997): Reliability of dermatology teleconsultations with the use of teleconferencing technology. *J Am Acad Dermatol* 37(3 Pt 1):398-402.

Phillips CM, Burke WA, Allen MH, Stone D & Wilson JL (1998): Reliability of telemedicine in evaluating skin tumors. *Telemed J* 4(1):5-9.

Phillips D & Parker KJ (1998): A new imaging science test object for performance measurements of ultrasonic imaging systems. *Phys Med Biol* 43(2):455-65.

- Piccolo D, Smolle J, Argenziano G, Wolf IH, Braun R, Cerroni L, Ferrari A, Hofmann-Wellenhof R, Kenet R, Magrini F, Mazzocchetti G, Pizzichetta MA, Schaeppi H, Stolz W, Tanaka M, Kerl H, Chimenti S & Soyer HP (2000): Teledermoscopy: Results of a multicenter study on 43 pigmented skin lesions. *J Telemed Telecare* 6(3) : 132-7.
- Pickard JA (1998): Instrumentation available for remote diagnosis and consultation in eye care. *Int J Circumpolar Health* 57 (Suppl 1):694-6.
- Prahalad, CK & Hamel, G (1990): The Core Competence of the Corporation. *Harv Business Rev* May-June: 79-91.
- Prasad S, Bannon P, Clearkin LG & Phillips RP (1999): Digital fundus imaging: a quality and cost comparison with 35-mm film. *Acta Ophthalmol Scand* 77(1):79-82.
- Researches to test teleophthalmology on the reservation (1997): *Telemed Virtual Real*. 2(11): 121-131.
- Richards RJ, Hammitt JK & Tsevat J (1996): Finding the optimal multiple-test strategy using a method analogous to logistic regression: the diagnosis of hepatolenticular degeneration (Wilson's disease). *Med Decis Making* 4:367-75.
- Rosengren D, Blackwell N, Kelly G, Lenton L & Glastonbury J (1998): The use of telemedicine to treat ophthalmological emergencies in rural Australia. *J Telemed Telecare* 4 (Suppl 1):97-9.
- Ryder RE, Kong N, Bates AS, Sim J, Welch J & Kritzinger EE (1998): Instant electronic imaging systems are superior to Polaroid at detecting sight-threatening diabetic retinopathy. *Diabet Med* 15(3):254-8.
- Shanit D, Lifshitz T, Giladi R & Peterburg Y (1998): A pilot study of tele-ophthalmology outreach services to primary care. *J Telemed Telecare* 4 (Suppl 1):1-2.
- Sheldrick JH, Vernon SA & Wilson A (1992): Study of diagnostic accord between general practitioners and an ophthalmologist. *BMJ* 304(6834):1096-8.
- Sheldrick JH, Wilson AD, Vernon SA & Sheldrick CM (1993): Management of ophthalmic disease in general practice. *Br J Gen Pract* 43(376):459-62.
- Shimmura S, Shinozaki N, Fukagawa K, Shimazaki J & Tsubota K (1998): Real-time telemedicine in the clinical assessment of the ocular surface. *Am J Ophthalmol* 125(3):388-90.
- Shin DS, Javornik NB & Berger JW (1999): Computer-assisted, interactive fundus image processing for macular drusen quantitation. *Ophthalmology* 106(6):1119-25.
- Shortliffe EH & Perreault LE (1990): *Computer applications in health care*. Addison Wesley, New York.
- Sisk JE & Sanders JH (1998): A proposed framework for economic evaluation of telemedicine. *Telemed J* 4(1): 31-7.

Sonka M, Hlavac V & Boyle R ed.(1998): Image data compression. In: Image processing, analysis, and machine vision, An international Thomson publishing company, London.

Stanberry B (1998): The legal and ethical aspects of telemedicine. 4: Product liability and jurisdictional problems. *J Telemed Telecare*. 4(3):132-9.

Stanberry B, Rossignol G & Menke P (2000): Contracting with health-care customers and specialists for the provision of telemedicine services across European borders: The TEN-Telemed legal project. *J Telemed Telecare* 2000 6(Suppl 1) : 104-106.

Stensland J, Speedie SM, Ideker M, House J & Thompson T (1999): The relative cost of outpatient telemedicine services. *Telemed J* 5(3):245-56.

Stoeger A, Strohmayer W, Giacomuzzi SM, Dessl A, Buchberger W & Jaschke W (1997): A cost analysis of an emergency computerized tomography teleradiology system. *J Telemed Telecare* 3(1):35-9.

Suzuki J., Furukawa I., Sadayasu O, Masayuki K & Ando Y (1997): Contrast Mapping and Evaluation for Electronic X-Ray Images on CRT Display Monitor. *IEEE Trans Med Imaging* 16(6): 772-784.

Tachakra S, Sivakumar A, Hayes J & Dawood M (1997): A protocol for telemedical consultation. *J Telemed Telecare* 3(3): 163-8.

Tachakra S, Lynch M, Newson R, Stinson A, Sivakumar A, Hayes J & Bak J (2000a): A comparison of telemedicine with face-to-face consultations for trauma management. *J Telemed Telecare* 6(Suppl 1): 178-181.

Tachakra S, Dutton D, Newson R, Hayes J, Sivakumar A, Jaye P & Bak J (2000b): How do teleconsultations for remote trauma management change over a period of time? *J Telemed Telecare* 6(Suppl 1) : 12-15.

Tang R, Li H & Schiffman, J (1977): Screening for open-angle glaucoma through telemedicine in a rural family practise setting. *American Academy of Ophthalmology Annual Meeting Final Program* p. 180.

Taylor D (1998): *Global cases in logistics and supply chain management*. Alden Press, Oxford.

Taylor P (1998): A survey of research in telemedicine. 1: Telemedicine systems. *J Telemed Telecare* 4:1-17.

Torok M, Kovacs F & Doszpod J (2000): Cost-effectiveness of home telemedical cardiocography compared with traditional outpatient monitoring. *J Telemed Telecare* 6 (Suppl 1):69-70.

Trippi JA, Lee KS, Kopp G, Nelson DR, Yee KG & Cordell WH (1997): Dobutamine stress tele-echocardiography for evaluation of emergency department patients with chest pain. *J Am Coll Cardiol* 30(3):627-32.

Trott P & Blignault I (1998): Cost evaluation of a telepsychiatry service in northern Queensland. *J Telemed Telecare* 4 (Suppl 1):66-8.

- Tuulonen A, Ohinmaa T, Alanko HI, Hyytinen P, Juutinen A & Toppinen E (1999): The application of teleophthalmology in examining patients with glaucoma: a pilot study. *J Glaucoma* 8(6):367-73.
- Vander Haeghen Y, Naeyaert JM, Lemahieu I & Philips W (2000): An imaging system with calibrated color image acquisition for use in dermatology. *IEEE Trans Med Imaging* 19(7):722-30.
- Vassallo DJ (1999): Twelve months' experience with telemedicine for the British armed forces. *J Telemed Telecare*. 5 (Suppl 1):117-8.
- Watson DS (1989): Telemedicine. *Med J Aust*. 151:62-71.
- Vazir MH, Loane MA & Wootton R (1998): A pilot study of low-cost dynamic telepathology using the public telephone network. *J Telemed Telecare* (3):168-71.
- Werner A & Andersson LE (1998): Rural telepsychiatry is economically unsupportable: the Concorde crashes in a cornfield. *Psychiatr Serv* 49 : 1287-90.
- Whited JD, Hall RP, Simel DL, Foy ME, Stechuchak KM, Drugge RJ, Grichnik JM, Myers SA & Horner RD (1999): Reliability and accuracy of dermatologists' clinic-based and digital image consultations. *J Am Acad Dermatol* 41(5 Pt 1):693-702.
- Whited JD: Teledermatology (2001): Current Status and Future Directions. *Am J Clin Dermatol* (in press).
- Whitehouse R & Moulding F (2000): Latitude and noise comparisons between digital cameras and a radiographic film scanner. *J Telemed Telecare* 6(Suppl1):41-42.
- Whitten P, Kingsley C & Grigsby J (2000): Results of a meta-analysis of cost-benefit research: is this a question worth asking? *J Telemed Telecare* 6 (Suppl 1):4-6.
- Vidmar DA (1999): The history of teledermatology in the Department of Defense. *Dermatol Clin* 17(1):113-24.
- Williamson TH & Keating D (1998): Telemedicine and computers in diabetic retinopathy screening. *Br J Ophthalmol* 82: 5-6.
- Wootton R (1996): Telemedicine: a cautious welcome. *BMJ* 313:1375-1377.
- Wootton R, Bloomer SE, Corbett R, Eedy DJ, Hicks N, Lotery HE, Mathews C, Paisley J, Steele K, Loane MA. (2000) Multicentre randomised control trial comparing real time teledermatology with conventional outpatient dermatological care: societal cost-benefit analysis. *BMJ* 6 (7244):1252-6.
- Yellowlees P (1997): Successful development of telemedicine systems - seven core principles. *J Telemed Telecare* 3:215-222.
- Yogesani K, Constable IJ, Eikelboom RH & van Saarloos P (1998): Tele-ophthalmic screening using digital imaging devices. *Aust N Z J Ophthalmol* 26 (Suppl 1):9-11.

Yogesana K, Cuypers M, Barry CJ, Constable IJ & Jitskaia L (2000a): Tele-ophthalmology screening for retinal and anterior segment diseases. *J Telemed Telecare* 6(Suppl 1) : 96-98.

Yogesana K, Constable IJ, Morgan W & Soebadi DY (2000b): International transmission of tele-ophthalmology images. *J Telemed Telecare* 6(1) : 41-44.

Zahlmann G, Walther HD & Liesenfeld B (1988): Teleconsultation network for ophthalmology: experience and results. *Klin Monatsbl Augenheilkd* 212: 111-5.

Zincone LH (Jr), Doty E & Balch DC (1998): Financial analysis of telemedicine in a prison system. *Telemed J* 4:49-54.

Zollo S, Kienzle M, Loeffelholz P & Sebille S (1999): Telemedicine to Iowa's correctional facilities: initial clinical experience and assessment of program costs. *Telemed J* 5(3):291-301.

10. Original communications