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Assessments of telemedicine applications - an update

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FOREWORD

This report brings together details of an update to a systematic review of the telemedicine evaluation literature that was undertaken by FinOHTA and AHFMR on behalf of the International Network of Agencies for Health Technology Assessment (INAHTA) and published in 1999. The present review is based on results of further literature searches undertaken between February and December 2000 and covers studies published since the earlier report was prepared.

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SUMMARY

- A systematic review of telemedicine assessments based on searches of the electronic data bases between November 1998 and December 2000 identified 38 scientifically credible studies that included comparison with a non-telemedicine alternative and which reported administrative changes, patient outcomes or results of economic assessment.
- Nine of the studies were considered to be of good quality. Only some of these corresponded to the nine papers that described work based on randomized controlled trials. The quality of most cost and economic analyses was relatively poor.
- Nineteen of the studies concluded that telemedicine had advantages over the alternative approach, 16 also drew attention to some negative aspects or were unclear whether telemedicine had advantages and three found that the alternative approach had advantages over telemedicine.
- For several applications, savings and sometimes clinical benefit were obtained through avoidance of travel and associated delays. The home care studies showed convincing evidence of benefit, while those on teledermatology indicated that there were cost disadvantages to health care providers, though not to patients.
- Twenty three of the studies appeared to have potential to influence future decisions on the telemedicine application under consideration. However, a number of these had methodological limitations.
- The overall findings are similar to those of a previous review. Useful data are emerging on some telemedicine applications, but good quality studies are still scarce and generalisability of most assessment findings may be limited.

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INTRODUCTION

In August 1999, a report on the assessment of telemedicine applications was prepared jointly by the Finnish Office for Health Care Technology Assessment (FinOHTA) and the Alberta Heritage Foundation for Medical Research (AHFMR) on behalf of the International Network of Agencies for Health Technology Assessment (INAHTA) ⁽²⁹⁾. The report included a systematic review of assessments that reported the outcomes of telemedicine, covering the literature between 1966 and November 1998. The earlier report considered studies that had included comparison with a non-telemedicine alternative and which reported administrative changes, patient outcomes or results of economic assessment.

A total of 29 studies were deemed to fulfill the inclusion criteria of the review, of which 11 were primarily economic evaluations. The most convincing evidence regarding the effectiveness of telemedicine dealt with teleradiology, teleneurosurgery, telepsychiatry and transmission of echocardiographic images. Promising results had also been obtained for the transmission of electrocardiograms. However, even in these applications, most of the available literature referred only to pilot projects and short term outcomes. Economic assessments were mostly cost studies and were generally of limited quality. It was concluded that further scientific assessment studies of telemedicine were needed.

The present report is an update of the systematic review, covering the literature that has emerged since publication of the INAHTA report. It is intended to provide a further overview of the available evidence on the efficacy, effectiveness and economic impact of telemedicine applications, as a guide to decision makers in health care. Once again, studies meeting selection criteria are listed and discussed in terms of the clinical area of the application, the strength of evidence presented and the conclusions reached. In addition, a further listing has been compiled which gives some consideration to the limitations of the selected studies and to their potential effects on administrative decisions.

METHODS

Literature search

Computerized literature searches were performed in February 2000 using the MEDLINE, EMBASE, CINAHL, HealthStar and CRD databases and the Cochrane Library (all from November 1998). Updates of the search were undertaken in May, August and December 2000. The search strategy followed the approach taken in the earlier review (Table 1).

Table 1: Search strategy

001	exp telemedicine/
002	telemedicine.tw. not 1
003	telepsychiatry.tw. not 1
004	teleradiology.tw. not 1
005	teleconsultation\$.tw. not 1
006	or/1-5
007	assess\$.tw. and 6
008	evaluat\$.tw. and 6
009	validat\$.tw. and 6
010	feasib\$.tw. and 6
011	pilot.tw. and 6
012	or/7-11
013	or/6-12

Selection of publications

Initial screening of the identified articles was based on their abstracts. All abstracts were read independently by each author. Selection of relevant articles was based on the information obtained from the abstracts and was agreed upon in discussion between the authors. When an abstract did not give sufficiently precise information about the study or such information was not available at all, the article was obtained for further review.

As in the previous report ⁽²⁹⁾, articles were selected which compared, in a scientifically valid manner, outcomes of a telemedicine application in terms of administrative changes, patient outcomes or economic assessment with those of a conventional alternative. Articles which were limited to describing the feasibility or the technical evaluation of a certain system were excluded.

Full-text articles obtained for closer inspection were evaluated independently by all the authors, who then reached a consensus on whether or not an article should be included in the final review, using the criteria given above.

Studies without a comparison between a telemedicine application and a conventional alternative were rejected. Articles which were duplicates of the same authors' other published studies were excluded - the most representative of the studies was included for further consideration.

In considering the strength of evidence given in each selected article, reference was made again to the study design used, according to the nine level classification of Jovell and Navarro-Rubio shown in Table 2 ⁽¹⁹⁾. Judgments on the quality of the studies took account of factors such as numbers and selection of subjects, adequacy of description of interventions and methods of analysis, presentation and analysis of data, and relevance of the conclusions to the analysis.

Table 2: Levels of scientific evidence

Level Highest (I) to Lowest (IX)	Strength of evidence	Type of study design	Conditions of scientific rigour*
I	Good	Meta-analysis of randomized controlled trials	Analysis of patient individual data Meta-regression Different techniques of analysis Absence of heterogeneity Quality of the studies
II		Large sample randomized controlled trials	Assessment of statistical power Multicentre Quality of the study
III	Good to	Small sample randomized controlled trials	Assessment of statistical power Quality of the study
IV	Fair	Non-randomized controlled prospective trials	Concurrent controls Multicentre Quality of the study
V		Non-randomized controlled retrospective trials	Historical controls Quality of the study
VI	Fair	Cohort studies	Concurrent controls Multicentre Quality of the study
VII		Case-control studies	Multicentre studies Quality of the study
VIII	Poor	Non-controlled clinical series Descriptive studies: surveillance of disease, surveys, registers, data bases, prevalence studies Expert committees, consensus conferences	Multicentre
IX		Anecdotes or case reports	

* Quality of the study assessed by specific protocols and conditions of scientific rigour.

Source: Reference 19

Several studies that compared outcomes of telemedicine and non-telemedicine alternatives were excluded because there were substantial reservations regarding their scientific validity. Limitations included inadequate specification of the study population and absence of data to substantiate the conclusions reached.

Retrieved articles

A total of 540 publications were identified in the literature searches of which 77 were retrieved for closer inspection. From these, 36 studies were judged to meet the selection criteria and were included in the review. Two other publications were identified through projects undertaken by AHFMR and both were included to give a total of 38 studies for consideration. One of the papers was an earlier report that had not been located in the previous review ⁽³⁹⁾.

RESULTS

Study classification

The 38 selected publications were classified in two ways. The first followed the approach taken in the INAHTA review and considered the studies in terms of area of application, objectives, approach taken, the setting and results and conclusions, including any economic analysis. Details are shown in Appendix A.

The intention of the second classification was to provide further context for the studies through considering their potential effects on decision making in respect of telemedicine services, any methodological limitations and suggestions made for future work. Details are provided in Appendix B.

In both classifications, the studies were grouped in the 12 areas of application shown in Table 3. Thirty-one of the articles assessed at least some clinical or administrative outcomes and 15 of these had cost or economic analyses. The remaining seven papers were economic studies. As with the earlier INAHTA review, the economic analyses in the articles were mostly variants of cost analysis. Judgements made on reviewing the contents of the papers suggested that 23 studies appeared to have a potential to influence future decision making on telemedicine services.

Nine of the studies were based on randomized controlled trials, corresponding to Categories II or III from the Jovell and Navarro-Rubio list given in Table 2. Of the remaining studies that considered clinical or administrative outcomes, four were level IV or V, seven level VI, four level VII and seven level VIII.

Conditions of scientific rigour varied considerably. Nine of the 38 studies were considered to be of good quality. Only some of these corresponded to the papers that described work based on randomized controlled trials. As in the studies considered for the earlier INAHTA review, the quality of most cost and economic analyses was relatively poor. In many papers, procedures for selection of patients, and for reading and interpretation of clinical findings were not adequately described. Outcome measures used were sometimes vaguely defined or clinically not very relevant.

The settings for the studies are indicated in Table 4. Most involved links between a hospital and a smaller centre and most were preliminary in nature, referring to pilot projects. Nineteen of the studies were from the USA, eight from the UK, four from Finland and one each from Australia, Canada, France, Italy, New Zealand, Norway and a group of four European countries.

Table 3: Telemedicine studies by area of application

Area of application	Number of studies	Cost or economic analysis	Studies based on RCTs	Potential influence on policy decisions
Burns	1	1		
Cardiology	4	1		2
Dermatology	7	6	3*	6
Emergency room	1		1	1
Home care	5	2	3	5
Medical consultation	6	4	1	3
Mental health	3	2	1	2
Neurology	2			
Ophthalmology	2	2		1
Pathology	2	2		1
Radiology	4	2		2
Rheumatology	1			
Totals	38	22	9	23

* two studies were based on the same RCT

Table 4: Settings for telemedicine studies

Type of setting	Number
Hospital and outreach clinic or health centre	18
Major hospital and smaller hospital	11
Home care and hospital or clinic	7
Major hospital – major hospital	1
Clinic – consultant	1

Conclusions reached in studies

Overall conclusions reached in the reviewed papers are summarised in Table 5. Most indicated that telemedicine had advantages over the alternative approach, though a number also drew attention to disadvantages or uncertainties.

Table 5: Conclusions regarding telemedicine

General conclusions	Number of studies
Telemedicine had advantages over the alternative approach	19
Telemedicine had advantages over the alternative approach but there were also some negative aspects	8
Unclear whether telemedicine had advantages, further work probably needed	8
Alternative approach had advantages over telemedicine	3

Outcomes of telemedicine by application gave some indication of efficacy or cost implications though, as in the papers considered for the earlier review, these were influenced strongly by local conditions, making generalisation difficult. Overall conclusions indicated by the studies are shown in Table 6. For several applications, savings and sometimes clinical benefit were obtained through avoidance of travel and associated delays. The home care studies showed convincing evidence of benefit, while those on dermatology suggested cost disadvantages to the health care providers, though not to patients. Possible concerns regarding quality of telemedicine services emerged in some studies.

Many of the studies would have provided useful information on use of telemedicine in the health systems concerned, and are helpful in considering a number of applications in a broader context. However, there were various limitations in 22 of the papers, so that even this highly selected portion of the telemedicine literature is giving only an imperfect description of the status of this technology. In addition to methodological limitations (some noted by the authors of the reviewed papers), several papers omitted important details of the clinical setting and of how data were obtained and analysed. A few appeared to tend towards advocacy rather than assessment. About half of the studies that might have influenced decisions had substantial limitations.

The need for further work on the telemedicine application under consideration was noted in 25 of the studies. In ten cases, the authors reported active follow up of their work through further research.

Table 6: Indications of outcomes by type of application

Area of application	Number of studies	Indications of costs and benefits
Burns	1	Savings to patients through avoidance of travel. Possible increased costs to burns centre, some clinical limitations.
Cardiology	4	Limited evidence of clinical or cost benefits in the settings for these studies.
Dermatology	7	Five of the studies suggested this application would result in additional costs to health care providers, while providing savings to patients. Savings were suggested for a nursing home setting, with some limitation on accuracy, and availability in a health care system appropriately increased access to services.
Emergency room	1	Equivalent patient outcomes to alternative approach and faster throughput.
Home care	5	Economic savings, equivalent outcomes for high risk pregnancies, various chronic diseases (HMO), improved outcomes for diabetes, chronic heart failure, equivalent performance for HIV testing.
Medical consultation	6	Increased efficiency and cost savings associated with electronic referral for a general hospital. Increased availability of required information for consultations on surgical cases. Indications of cost savings for prison health services, time savings for inner city general practices.
Mental health	3	Savings to health system and patients through avoidance of travel – related costs. Improved outcomes with telephone – based nurse telehealth care.
Neurology	2	Preliminary indications of feasibility.
Ophthalmology	2	Savings through avoiding patient travel and benefits to health professional training.
Pathology	2	Indications of feasibility, inconclusive on cost issues.
Radiology	4	Savings through avoidance of unnecessary patient transfer or patient travel.
Rheumatology	1	Preliminary indications of feasibility. Some limitations on accuracy of telemedicine approach.

DISCUSSION

As in the earlier INAHTA review, the focus here is on studies reporting outcomes in comparison with non-telemedicine alternatives. Such studies can be expected to provide stronger evidence on the performance of telemedicine than those without a comparative content.

This does not mean that studies not meeting selection criteria for the review are of no value. Such studies may, for example, include helpful preliminary work on newer telemedicine developments or illustrate the place of the technology in situations where the alternative option is clearly inferior or impractical to measure. For example, Mavrogeni et al. describe use of telemedicine in the management of patients on six remote Aegean islands who had had acute myocardial infarction ⁽²³⁾. Diagnosis using electrocardiograms and consultations on thrombolytic treatment and management of complications were achieved using links with a major cardiac care centre. The alternative was essentially ineffective care for such patients in the absence of appropriate expertise. It may be that other evaluation criteria will be needed in some societies and health care systems.

However, in the common situation where there is some form of credible existing health service, comparative data on costs and outcomes are required to establish whether use of telemedicine is an appropriate option. This review has indicated that there are still few reasonable quality comparative studies of telemedicine, and also that it may be difficult to generalise findings on a particular application because of the significance of local circumstances. While good quality studies are still scarce, the situation may be improving in that, compared with the earlier INAHTA review, a higher proportion of located studies were selected for inclusion. Even so, many of those selected have substantial limitations.

In selecting papers for inclusion in this review it was sometimes hard to decide whether a study was truly measuring outcomes or was essentially addressing only the accuracy or technical feasibility of a telemedicine application. Judgements were made to exclude some studies which gave useful indications of the place of telemedicine in a particular application. For example, the study by Pelletier-Fleury et al. of telemonitored polysomnography made helpful suggestions for future policy on such services, but was seen as an exploratory trial that assessed the reliability of two forms of monitoring ⁽³¹⁾.

The focus of this review was on telemedicine applications and studies of teleeducation, such as distance learning, were not covered. Educational telehealth applications will also require comparative outcomes studies to assess their appropriateness. Good comparative studies noted during preparation of this review included the evaluation by Brown et al. of the impact of telephone support to caregiver groups in a rehabilitation program ⁽⁶⁾ and the assessment by

Pullum and colleagues of performance and acceptability of training programs for rural pre-hospital providers in Montana ⁽³⁴⁾.

It is possible that significant material on telemedicine assessment has not been located. No attempt has been made to thoroughly survey all the relevant grey literature, for example. However, it is likely that there will not be many studies meeting the review criteria from that source. It is also possible that more information has been obtained in some of the studies but was excluded from the papers describing them.

The overall findings seem similar to those of the earlier review. Useful data are emerging on some telemedicine applications, but good quality studies are still scarce and generalisability of most assessment findings may be limited.

APPENDIX A: CLASSIFICATION OF STUDIES THAT EVALUATED TELEMEDICINE APPLICATIONS

Abbreviations

ECG:	Electrocardiography
ER:	Emergency room
HIV:	Human immunodeficiency virus
HRQOL:	Health related quality of life
NICU:	Neonatal intensive care unit
NSD:	No significant difference
RCT:	Randomized controlled trial
SS:	Statistically significant/statistical significance

Table 7: Studies evaluating telemedicine applications

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Burns treatment					
Massman et al., 1999 ⁽²²⁾ Level VIII Comparison of patients' costs, case series.	To assess efficiency and effectiveness of burn consultations via telemedicine.	Travel distances and costs between patients' homes, telemedicine sites and burn center estimated.	Burn Center and 15 telemedicine sites in 6 US states. 87 follow up consultations with 40 patients.	Travel costs between homes and telemedicine centres were \$37 per consultation and \$81 per patient, compared with \$223 and \$486 for travel between homes and the burn centre.	Telemedicine burn consultations said to be cost-effective for the patient, but more time consuming for the physician and therapist. Telemedicine consultations said to be twice as long as face to face physician-patient encounters, but no data are given.
Cardiology					
Scholz & Kienzle, 1999 ⁽³⁷⁾ Level VIII Case series comparison, physician v cardiologist decision.	Comparison of test ordering patterns from physicians (most by telemedicine) and specialists visiting outreach centers.	Recorded details of echocardiography tests ordered by two groups. Community physicians sent echocardiograms to a hospital laboratory for interpretation. Pediatric cardiologists attending outreach clinics ordered and interpreted echocardiograms.	Pediatric cases referred to community physicians or outreach clinics in Iowa.	Cost calculations and issues mentioned, no details provided.	For children < 1 year, much higher proportion (73%) of studies ordered by physicians than by cardiologists (8%). NSD in proportion of normal echocardiograms on children <1y for both groups, SS higher normals in tests ordered by physicians in older children, linked to 12% increase in charges. Conclude that selection of patients influences diagnostic yield of pediatric echocardiography services.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Cardiology (cont'd)					
McConnell et al., 1999 ⁽²⁴⁾ Level VIII Case series, prospective. Blinded comparison of telemedicine and face to face exams.	Study accuracy, patient satisfaction, cost of pediatric telecardiology.	Exams by two cardiologists blinded to each other's findings; personnel performing additional tests also blinded; outcome measures included frequency of additional tests.	21 children referred to rural pediatric cardiology outreach clinic, North Carolina, USA.	Cost issues briefly discussed, no data other than cited cost of \$250 for echocardiography.	Fewer Echo and ECG studies ordered following telemedicine consultation, but did not reach SS. Telecardiology may lessen need for echo exams, with potential cost savings. Note that there were differences in ability of telemedicine physician to discern subtle aspects of physical exam.
Rendina et al., 1998 ⁽³⁵⁾ Level VI Comparison of pre-telemedicine and telemedicine groups.	To assess whether utilization of telemedicine reduces the intensive care length of stay of low birthweight infants.	Transmission of neonatal echocardiograms for rapid interpretation.	48 infants in the telemedicine group and 39 infants in the historical control group. NICU at New Hanover, North Carolina, USA.	The capital start-up costs and fixed line charges increased the cost per echocardiogram by \$33 compared to the overnight courier service.	A statistically non-significant reduction of 5.4 days in the intensive care length of stay in the telemedicine group.
Rendina et al., 1998 ⁽³⁶⁾ Level VI Comparison of pre-telemedicine and telemedicine groups.	To determine whether a more rapid turn-around of echocardiographic interpretations and availability of interactive video reduces morbidity of very low birthweight infants.	Use of a telecardiology system for transmission of echocardiograms for expert interpretation.	21 subjects in the pre-telemedicine group and 28 subjects in the telemedicine group. NICU at Fayetteville, North Carolina, USA.	None	A composite index of respiratory therapy intensity and duration was similar in both groups. The results show little evidence of reduction in respiratory therapy utilization due to telemedicine.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Dermatology					
Zelickson & Homan, 1997 ⁽⁴³⁾ Level VII Case-control study (repeat in-person studies as controls).	To examine a still-image store-and-forward teledermatology system for use in the care of nursing home residents.	Diagnosis and treatment plans made from a teledermatology system were compared with those made from an on-site dermatology consultation.	29 nursing home patients with 30 skin conditions. Diagnoses and treatment plans made both based on still images and a faxed history as well as face-to-face encounters with consulting dermatologists from the University of Minnesota, Minneapolis, USA with the patients.	The teledermatology consultation cost \$US 71.45, the in-office consultation \$105, and the nursing home consultation \$295, respectively.	Correct diagnoses were made for 67%, 85% and 88% of the patients given the history alone, image alone, and both, respectively. Correct treatment plan was seen in 70%, 87% and 90% of the patients given history alone, image alone, and both, respectively.
Bergmo et al., 2000 ⁽³⁾ Cost study with breakeven analysis.	To analyse whether investing in technology to forward still images via telemedicine is cost-effective and to assess how many centres have a sufficient workload to reach this requirement.	Additional costs of using still images compared to patient travel costs to the University Hospital of Tromsø from primary health centres.	Data from primary health centre of Kirkenes and regional hospital of Tromsø were compared to the workloads of the other municipalities in the counties of Tromsø and Finnmark, Norway.	Cost-effectiveness of still image telemedicine depends on distance and workload. 18 of 44 municipalities have sufficient patients with a dermatological problem to make telemedicine cost-effective.	Less than half of the municipalities in the two northernmost counties have an efficiency potential in using still images. However, telemedicine may be justified because it saves time for patients and increases equal access to care.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Dermatology (cont'd)					
Loane et al., 2000 ⁽²⁰⁾ Level II RCT with cost study.	Comparison of efficacy of real time and store and forward teledermatology compared with conventional care.	Compared clinical outcome for two modes of teledermatology.	Two hospital dermatology departments and four health centres in Northern Ireland, UK. 102 patients randomized to real time dermatology, store and forward results also available for 96 of these. 102 controls.	Indicative costs in relation to distance between centres shown graphically for three approaches.	In this series, 69% of store and forward results led to requests for hospital appointment compared with 46% for real time and 45% for conventional consultations. 39% of conventional consultations were finished consultant episodes compared with 21% and 22% for the two teleconsultation approaches. GP review was requested in 15% conventional consultations, 10% store and forward and 32% real time. Authors suggest both real time and store and forward teledermatology will have roles in provision of primary care.
Oakley et al., 2000 ⁽²⁸⁾ Level II RCT with cost study.	Comparison of real time dermatology with hospital consultations, assessment of patient costs and benefits.	Compared patient referral patterns, time, travel distance and costs for both approaches.	Two local health centres and dermatology department at hospital in North Island, New Zealand. 119 patients in initial teledermatology consultation and 94 in initial conventional consultation.	Distance traveled, time spent and travel costs for patients having teleconsultations were 51 min, 12 km and \$7, compared to 4.3h, 271 km and \$160 for those travelling for consultation. 24% of teleconsultation patients and 26% of hospital patients were followed up by a dermatologist, for similar reasons.	Teledermatology consultations were less time consuming and less costly for patients than hospital consultations. Comparison with results from Northern Ireland study which reached similar conclusions.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Dermatology (cont'd)					
Wootton et al., 2000 ⁽⁴²⁾ Level II RCT with minimum follow up of 3 months.	Comparison of real time teledermatology with outpatient dermatology in terms of clinical outcomes, cost-benefits, and patient reattendance.	Compared reported clinical outcome of initial consultation, and also primary care and outpatient reattendance data.	Four health centres (two urban, two rural) and two regional hospitals in Northern Ireland, UK. 204 general practice patients requiring referral to dermatology services; (102 teledermatology and 102 to outpatient consultation).	Net societal cost of initial consultation £132.10/ patient for teledermatology, £48.73/ patient for conventional. If each centre had 12 patients/ week (rather than 0.5) to teledermatology and average round trip to hospital had been 78 km and not 26 km, costs of the two methods would have been equal.	54% teledermatology patients managed within primary care, 46% required at least one hospital appointment. 45% conventional consultation patients had hospital appointment, 15% general practice review and 39% no follow up visits. Real time teledermatology was clinically feasible but not cost effective compared with conventional outpatient care. If equipment were purchased at current prices and the travelling distances were greater, teledermatology would be a cost effective alternative to conventional care.
Perednia et al., 1998 ⁽³²⁾ Level VI Before/ after comparison.	Measure impact on referral patterns and management of rural patients.	Data collected prior to installation of telemedicine; 4-6 months and 10-12 months post installation.	3 primary health care clinics, 1 specialty consultation site in Oregon, USA. About 200 consultations, patients with skin disorders.	None	Telemedicine referral led to modest, appropriate increase in specialist consultations. Availability of telemedicine appeared to increase primary physician confidence and quality of treatment decisions.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Dermatology (cont'd)					
Stensland et al., 1999 ⁽⁴⁰⁾ Cost study with breakeven analysis	To compare costs of outpatient care to orthopedic and dermatology patients via live, interactive telemedicine to those of direct face-to-face care.	Costs, cost savings of telemedicine evaluated from perspectives of patients, providers, insurers, employers, and society as a whole.	Minnesota, USA. University of Minnesota telemedicine system, link to a hospital in Wadena.	Variable cost of a telemedicine referral \$144, v estimated face-to-face referral cost of \$183. Break-even point was 1,449 consultations/ y. Sensitivity analysis: breakeven point varied from 152 telemedicine consultations for a 'best case' scenario to no possible breakeven point for a 'worst case' scenario.	At current level of 300 consultations per year, the telemedicine system was estimated to add \$45,000 to society's costs of providing medical care for these patients. The additional cost is primarily due to personnel expenses and an increase in the volume of specialty care. Patients see specialists more often due to improved access to care and lower transportation costs. Providers bear the cost while patients and employers enjoy substantial savings.
Emergency department					
Brennan et al., 1999 ⁽⁵⁾ Level II RCT	To evaluate emergency physicians' ability to use real-time interactive telemedicine to evaluate and treat patients in an emergency department.	Patients at major centre randomized to treatment via telemedicine by physicians at remote site or to face to face assessment. Change in treatment after discharge main outcome measure.	100 patients (50 in each arm) presenting to suburban hospital ER in New Jersey, USA. Experienced emergency physicians and nurses at this site and at remote site (rural) 64 km away.	No (though noted faster throughput for telemedicine group)	NSD in return visits, need for additional care or overall patient satisfaction. Telemedicine is a satisfactory technique for such patients in the emergency department.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Home care					
Dawson et al., 1999 ⁽⁹⁾ Level III Randomized trial and cost study	Evaluate approaches to ante natal care of women with high risk pregnancies.	Compared conventional care – frequent checks at hospital clinics including fetal monitoring (heart rate, movements, uterine contractions) – with domiciliary care including more frequent visits by midwives and fetal telemonitoring, with overview of data by a consultant team.	81 women in South Wales, UK with high risk pregnancies, 38 randomized to conventional care, 43 to domiciliary care.	Domiciliary care increased costs per woman by £21.02 for midwife time & travel, £18.38 for telemonitoring. Offset by savings of £44.61 in clinic costs, £184.24 for hospital inpatient days and £34.38 in lost productivity to women and their partners.	Neonatal outcomes were similar for the two groups. Women in both groups had similar levels of anxiety and depression. Authors conclude that the study provides evidence to justify greater use of domiciliary support for women with pregnancies of moderately high risk. There were useful practical advantages for both patients and the health service.
Frank et al., 2000 ⁽¹²⁾ Level IV Prospective, blinded, subject-as-control evaluation	Evaluate safety and efficacy of a home care HIV-1 test system compared with traditional HIV-1 testing.	Subjects provided with home collection kit to collect their own finger-stick blood spot samples for analysis. Subjects received pretest counseling by telephone (automated or telephone counselor) and their comprehension was subsequently assessed. Compared with professionally drawn blood samples for adequacy and accuracy.	1,255 subjects at 9 outpatient clinics in the USA.	None	Subject-collected blood spot sample results were in complete agreement with venous blood sample results. Following pretest counseling, subjects answered 96% of HIV risk questions correctly. There were no serious adverse reactions. Anonymous HIV-1 home collection kits with pretest and post test telephone counselling can provide a safe and effective alternative to conventional venous HIV-1 antibody testing.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Home care (cont'd)					
Mehra et al., 2000 ⁽²⁶⁾ Level V Cohort study.	To assess efficacy of electronic home monitoring (HomMed system) in chronic heart failure.	Hospitalization and ER rates for patients who used HomMed system over 3 months, compared with that for matched control group.	Study at 3 US academic health centres. 53 patients with congestive heart failure, 60 controls.	None	Treatment group had 7% per month hospitalization rate compared to 11.7% for controls. 13 of 21 hospitalizations for the unmonitored group were preceded by an ER visit, compared to 2 of 11 for those using HomMed. Compliance rate of 95% for treatment group.
Johnston & Wheeler, 2000 ⁽¹⁸⁾ Level II RCT	Evaluate use and costs of remote video technology in the home health care setting.	Patients randomized to video visits as well as in person and telephone visits. Controls had in person and telephone visits only. Used quality indicators and measured use of services and direct and indirect costs.	Home health department in Sacramento, CA, USA. Newly referred patients with congestive heart failure, chronic obstructive pulmonary disease, stroke, cancer, diabetes, anxiety or need for wound care. 102 randomized to intervention, 110 controls.	Average direct cost for the intervention group was \$US1,830 compared to \$1,167 for controls. However, average total mean costs, excluding home health care, were \$1,948 and \$2,674 respectively.	There were no differences in the quality indicators for the two groups. Remote technology has the potential to effect cost savings and can improve access to home health care staff.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Home care (cont'd)					
Piette et al., 2000 ⁽³³⁾ Level II RCT	Evaluate impact of automated telephone disease management (ATDM) calls with telephone nurse follow-up as strategy for improving outcomes among low-income patients with diabetes mellitus.	Intervention patients received biweekly ATDM calls with telephone follow-up by a diabetes nurse educator, plus usual care. Patients used the ATDM calls to report information about their health and self-care and to access self-care education. The nurse used patients' ATDM reports to allocate her time according to their needs. Patient-centered outcomes measured at 12 months via telephone interview.	280 adults (intervention, control) with diabetes enrolled at the time of visits to a county health care system in California, USA. 12 month outcome data collected on 248.	None	Follow-up HbA1c levels 0.3% lower in intervention group (P=0.1). About twice as many intervention patients had HbA1c levels within normal range (P=0.04). Serum glucose levels were 41 mg/dL lower among intervention patients (P=0.002) and they also reported better glycemic control (P=0.005) and fewer diabetic symptoms (P=0.0001). Intervention patients reported fewer symptoms of depression, greater self-efficacy to conduct self-care activities (P = 0.006), fewer days in bed because of illness (P = 0.026). Intervention and control patients had roughly equivalent scores for established measures of anxiety, diabetes-specific HRQOL, and general HRQOL. Intervention had positive effects on patient-centered outcomes of care but no measurable effects on anxiety or HRQOL.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Medical consultation					
Demartines et al., 1999 ⁽¹¹⁾ Level VIII Survey	Analyze the value of teleconferencing for patient care and surgical education by assessing the activity of an international academic network.	Questionnaire to participants following weekly surgical teleconferences over 2 years. [Also accuracy of telediagnosis assessed from 60 randomly selected cases.]	Six university hospitals in four European countries.	Includes illustrative costs of European expert visiting Strasbourg (\$640), US expert visiting (\$5,300) and 1h teleconference (\$425)	70 teleconferences were held. 95/114 participants (83.3%) completed final questionnaire. Proportion giving ratings as good or excellent were: surgical activity, 86%; scientific level 75.7%, daily clinical activity 55.8%; manual surgical technique 28.4%. Before discussion, initial clinical presentation sufficient in 55% of cases, additional information needed in 22%, advantageous, not essential in 23%. After interactive discussion, 95% of cases judged as well defined. 86% of the surgeons expressed satisfaction with telematics for medical education and patient care. Teleeducation and teleconsultation in surgery appear to be beneficial.
Harrison et al., 1999 ⁽¹⁵⁾ Level II RCT	Comparison of teleconsultations versus routine outpatient consultation.	A pilot study was carried out in preparation for a full-scale RCT. Of the 132 of 439 referrals eligible to enter the trial, 62 were randomized to the intervention group and 70 to the control group.	Four inner-city practices and hospital in London, UK.	None directly, but median time taken to visit surgery for teleconsultation was 0.5h compared with 2.5h for conventional outpatient appointment.	Results suggested patient satisfaction with teleconsultation may exceed that with conventional outpatient consultation, with a strong indication of overall time savings for patients; SF-12 generic measure of well being score at 3 months, NSD though higher for telemedicine group.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Medical consultation (cont'd)					
McCue et al., 1998 ⁽²⁵⁾ Cost study	Follow up to a cost-benefit analysis of telemedicine services.	Cost minimisation study, government payer perspective, consultations within a prison service.	Prison with tele-link to a university hospital, Virginia, USA.	Over a 12 month period, cost per visit for treating inmates was \$401 at the university hospital clinics and \$387 via telemedicine (290 telemedicine consultations).	Implementation of telemedicine achieved cost savings. Authors suggest that greater security and increased access to care should also be considered as net benefits.
Zollo et al., 1999 ⁽⁴⁴⁾ Cost study	To evaluate costs and benefits of a prison telemedicine program for the institutions involved and to assess early provider satisfaction.	Cost estimates were made for 4,396 prisoners transported to hospitals and clinics for health care, and for telemedicine the equipment and personnel. Breakeven analysis undertaken.	247 completed telemedicine encounters at four prisons and an academic tertiary care facility in Iowa, USA.	Average cost to the prisons for an on-site inmate visit \$115. Breakeven point would be around 2,000 teleconsultations/year. Cost studies excluded medical care, assumed comparable for both approaches.	Overall, referring physicians expressed a higher rate of satisfaction with telemedicine than specialists. Telemedicine ultimately becomes cost-effective as the volume of teleconsultations increases.
Harno, 1999 ⁽¹³⁾ Level VI Comparison of two hospitals using different referral systems	To determine costs of a district general hospital with an electronic referral system to another using a paper referral system.	Information on referrals was collected from hospital information systems.	Collection of data from departments of internal medicine and surgery for one year (1997) in two hospitals in Southern Finland.	Direct outpatient costs including all costs resulting from the patient's visit to the hospital.	Direct outpatient costs of internal medicine were at least 20% lower in the hospital using electronic referrals. Almost every paper referral led to an outpatient visit, whereas only one-third of the teleconsultations resulted in an actual outpatient visit.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Medical consultation (cont'd)					
Harno et al., 1999 ⁽¹⁴⁾ Level IV Comparison of two models for provision of outpatient services.	To compare computer and video-conferencing supported outpatient services to traditional outpatient treatment.	An electronic referral system enabling e-mail consultations and video-conferencing between primary and secondary health care was used in one hospital. The control hospital used paper based referrals.	Peijas Hospital in Southern Finland received 432 electronic referrals. Hyvinkää hospital acting as the control received 419 paper based referrals.	The cost of electronic consultation was only 10% of that of the traditional face-to-face consultation. In surgical outpatient visits video-conferencing, however, was more expensive than the face-to-face visit.	Electronic consultation enabled the secondary care hospital to handle 60% of referrals without an actual face-to-face patient visit. Peijas hospital was able to take care, without added costs, of twice the amount of referrals (in relation to population) than the control hospital.
Mental health					
Hunkeler et al., 2000 ⁽¹⁷⁾ Level II RCT	To assess the efficacy of augmentations to antidepressant treatment in primary care.	Randomized trial comparing usual physician care, nurse telehealth care and nurse telehealth care plus peer support. Outcomes included reduction in depressive symptoms, improvement in functioning, satisfaction with care, medication adherence.	Patients with major depressive disorders enrolled within Kaiser Permanente, Northern California, USA. 302 enrolled, 41% randomized to usual physician care, 39% to nurse telehealth, 21% to nurse telehealth plus peer support. 90% interviewed at 6 weeks, 85% at 6 months.	None	Compared with usual physician care, telehealth care improved depressive symptoms, mental functioning and treatment satisfaction. Medication adherence did not improve with nurse telehealth care. Adding peer support to telehealth did not improve the primary outcomes. Nurse telehealth improves clinical outcomes of antidepressant drug treatment.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Mental health (cont'd)					
Simpson et al., 1999 ⁽³⁸⁾ (Level VIII) Cost study as part of an observational study	To obtain data on costs associated with operation of a routine telepsychiatry service.	Breakeven analysis of telepsychiatry versus services provided by a psychiatrist travelling to smaller centres. Estimates of cost to patients who would have to travel to a major centre for consultation.	Service in central Alberta, Canada, psychiatric hospital linked to 5 smaller centres. Study covered 546 tele-consultations over a period of 2 years.	Breakeven point was 350 consultations/y (\$630/ consultation). With use of video - conferencing for administration, breakeven point was 224 consultations/y. Costs to patients who would have to travel to a major centre were \$300 per consultation.	Higher cost per consultation for telepsychiatry was offset by use of video network for administrative purposes and savings to those patients who would have had to travel to a major centre.
Mielonen et al., 2000 ⁽²⁷⁾ Level VIII And cost study	To assess costs of psychiatric in patient planning in comparison to face to face consultations. Measurement of satisfaction with the service.	Estimated costs based on exam and travel time, local costs. Questionnaires used for satisfaction survey.	University hospital and two primary health care centres, Finland. 14 patients had telepsychiatry; costs compared with 20 consultations at the hospital.	At a caseload of 20 patients a year, cost of telepsychiatry would be FM 2,510 per patient compared to FM 4,750 per patient for conventional consultation. If only one person travelled for a conventional meeting, costs were similar.	Generally high satisfaction with the teleconsultation approach (patients, health care personnel, relatives). Results show that videoconferencing produces almost as a good an outcome as conventional meetings.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Neurology					
Craig et al., 2000 ⁽⁷⁾ Level VII	Comparing the outcome of neurology patients admitted to two small hospitals, one using telemedicine the other normal management.	In one hospital all patients with neurological symptoms were seen by a neurologist at a distance using an interactive video-link; in the other patients with neurological problems were managed with usual practices. Case-mix, process of management, outcome were compared.	Northern Ireland, UK. All patients who had been coded using ICD-10 as having a final diagnosis of a neurological condition admitted over a four-month period to either hospital. The patients were followed up three months after admission.	None	No appreciable differences were noted between the two hospitals for measures of case-mix or outcome. It should therefore be possible to estimate the effect of telemedicine on the management of patients with neurological problems.
Craig et al., 2000 ⁽⁸⁾ Level IV Comparison of diagnoses and recommended action in single cohort.	To examine feasibility and safety of teleassessment of neurological outpatients,	Unselected new outpatient referrals assessed independently by two neurologists, blinded to each other" findings. One examination was face to face, the other by a telemedicine link.	25 neurological patients at small rural hospital in Northern Ireland, UK, telemedicine link to major hospital in Belfast.	None	Diagnoses were identical in 24/25 cases. 64 actions taken were the same and 11 were different. Disposal method for patients the same in 21/25 cases. Neurologists can deliver outpatient care via telemedicine.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Ophthalmology					
Blackwell et al., 1997 ⁽⁴⁾ Level VI Comparison of the situation before and after implementation of telemedicine.	To assess the use of remote telemedicine ophthalmology in patients presenting to an emergency department with acute eye problems.	A prospective review of referral patterns and telemedicine consultations over 3 months, with comparison of referral patterns from the same period one year before.	Emergency department of remote hospital in Queensland, Australia connected to a specialist center in Townsville. 24 patients requiring specialist consultation during the study period, 17 patients having been transferred urgently during the control period.	The hospital was estimated to have saved \$AUS 6,500 over the three months of the study.	Patients transferred for urgent assessment fell from 17 for the corresponding period in the previous year to 4 during the study period. Respective numbers of patients requiring non-urgent transfer during the same periods were 41 and 30.
Tuulonen et al., 1999 ⁽⁴¹⁾ Level VII Series compared to retrospective review of records	To test: feasibility of teleophthalmology in examining patients with glaucoma, use for training in a residency program and as a consultation link between primary healthcare unit and university eye clinic, and to introduce a preliminary model for economic assessment of teleophthalmology.	Comparison of rural centre exams, using interactive video consultation with glaucoma clinic versus records of patients previously examined at clinic.	29 patients with glaucoma examined in the rural healthcare center in Finland; control group of 41 glaucoma patients examined at clinic one year earlier.	Costs of the telemedicine and conventional visits were equal, but decreased traveling through teleophthalmology saved \$55 per visit.	Both patient groups equally satisfied with the ophthalmic service; 96% of telemedicine group wanted to have next visit in their own healthcare center instead of the university clinic (reduction in traveling, costs and time). Quality of images obtained in the remote center poorer than those obtained at the clinic. Further research with larger number of patients warranted to evaluate teleophthalmology.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Pathology					
Agha et al., 1999 ⁽¹⁾ Cost minimisation study	Comparing telepathology with on-site services and courier transport of specimens to a major center.	Modeling on local costs of services etc.	Veterans' Affairs facilities in USA. Cost model, no clinical details	Base case analysis: courier method \$US126,889/y Telepathology \$146,759/y; on-site pathology \$179,094/y Courier method remained cheapest after 1-way sensitivity analysis of all factors. Wide ranges of costs in 3-way analysis.	Conclude that telepathology can be an economic, timely and reliable approach.
Della Mea et al., 2000 ⁽¹⁰⁾ Cost analysis	Evaluate the economics of telepathology used to provide a frozen-section service to a mountain hospital, in comparison with three alternatives.	Cost of real time telepathology compared with those of visiting pathologist, ambulance transfer of specimens, on site pathology service. Measured fixed and variable costs.	Italy. Small hospital and university department of pathology.	Cost per service at breakeven point for ambulance/ telepathology options about 600 Euro.	No one model was always less expensive than the others. Ambulance least expensive for up to 73 frozen sections/y, at higher case-loads telepathology was cheaper. If ambulance transfer neglected, telepathology appears to be the most convenient approach. Suggest that in practice visiting specialist likely to be more acceptable because of lower initial investment.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Radiology					
Bailes et al., 1997 ⁽²⁾ Level VIII Clinical series, plus cost estimates.	To determine potential cost savings of a wide-area teleradiology network for delivery of specialty care in neurologic surgery.	Prospective review of cases before and after implementation of telemedicine with regard to disposition of the patient, mode of transportation and potential cost savings	100 consecutive telemedicine neurosurgical consultations from 20 community hospitals participating in the NeuroLink network in western Pennsylvania, USA.	Estimated savings based on avoided tertiary hospital care (based on average length of stay) and on avoided air transportation. Cost analysis showed savings of \$502,638 for the 100-patient series.	Of 100 patients, 33 did not require transportation as a direct result of remote diagnosis.
Spencer et al., 1991 ⁽³⁹⁾ Level VI	To assess the benefits of a system linking a regional neuroradiology department to six referring district general hospitals.	Diagnoses and management plans made by referring clinicians and radiologists before image transfer were compared with the scan diagnoses of the consulting neuroradiologists and the revised management plans after obtaining neurosurgical/neuro-radiological advice.	The regional neuroradiology department in Oxford, UK received 150 consecutive CT-scans of which 68 were of neurosurgical cases.	No	A significant change in management occurred after image transfer in 81% of the cases.
Heautot et al., 1999 ⁽¹⁶⁾ Level VI Comparison of pre-telemedicine and telemedicine groups	To assess the influence of teleradiology in the context of neurosurgical emergencies.	Phases without teleradiology, with transfer of digitized images over N-ISDN, and with transfer over ATM network. Evaluation based on records of advice request calls and patient transfers.	Link between a general hospital and a university hospital in France. 11 pre-telemedicine, 51 ISDN and 46 ATM submissions, respectively.	No	16- 50% of unnecessary patient transfers were avoided using ISDN and ATM submissions, respectively.

Table 7: Studies evaluating telemedicine applications (cont'd)

Study, study design	Objectives	Approach	Setting and subjects	Economic analysis	Results/Conclusion
Radiology (cont'd)					
Malone et al., 1998 ⁽²¹⁾ Economic analysis.	To describe cost implications of converting an established videotape review network to one based on telemedicine technology.	Retrospective review of costs associated with interpreting obstetric ultrasound examinations.	Three offices transmitting 600 obstetric ultrasound exams/ month to a tertiary level facility in Boston, MA, USA.	Fixed and non-fixed costs included.	Net monthly savings in non-fixed costs for a telemedicine network are \$7405-8585, which may pay for the initial fixed costs in 12-14 months.
Rheumatology					
Pal et al., 1999 ⁽³⁰⁾ Level VII Prospective study, patients as their own controls.	To study the feasibility and effect on work up and management plans of a rheumatology proforma placed on a website.	Two junior doctors completed proforma for new patients. Based on this information consultants provided provisional diagnoses, management plans. These compared with those drawn up following face-to-face assessments.	207 new patients of a UK rheumatology clinic.	No	Diagnostic concurrence between pre- and post-examination diagnoses in 86% of the patients. No changes in x-rays and other diagnoses requested in 62% of the patients. Suggested treatment remained the same in 74% of the patients. Suggest that it is feasible to offer an email or Internet based outpatient service.

APPENDIX B: POTENTIAL IMPACT AND LIMITATIONS OF TELEMEDICINE ASSESSMENT STUDIES

Abbreviations

ATDM Automatic telephone dialing management

HIV Human immunodeficiency virus

HRQOL Health related quality of life

LOS Length of stay

NICU Neonatal intensive care unit

NSD No significant difference

NSS Not statistically significant

RCT Randomized controlled trial

Table 8: Status and influence of assessments

Study	Area of health care	Status of study	Effect on decision-making	Limitations	Future work
Massman et al., 1999 ⁽²²⁾	Burns	Summary of initial experience with teleconsultations over 17 months.	Clear demonstration of savings for patients. Indications of inefficiencies for clinical staff at burn centre. Overall, major benefits to the large regional network being serviced.	Analysis extends only to patient travel costs. Other costs are not specified, though lower patient throughput with telemedicine identified as an issue. Accuracy/ acceptability of teleconsultations not discussed, though inability to palpate the healed burn and evaluate thickness and firmness of the scar noted as a disadvantage.	Not specific. Process details needing attention mentioned, also potential for telemedicine in emergency consultations.
Scholz & Kienzle, 1999 ⁽³⁷⁾	Cardiology	Case series, reflecting routine use of telemedicine and outreach visits, considering ordering patterns, test outcomes.	Unclear. Telemedicine associated with more tests, and expenditure. Other factors might need consideration.	Use of proportion of normal tests for those ordered by physicians and cardiologists is confusing, tends to soften the message that many echos ordered using telemedicine appeared unnecessary. Incomplete data on numbers of cases in groups. No details of cost calculations.	Unclear; process details mentioned that would influence provision of future services.
McConnell et al., 1998 ⁽²⁴⁾	Cardiology	Case series, looked at accuracy, satisfaction, test ordering.	Preliminary study. Point to possible limits of telecardiology, also need to consider these in context, e.g. of disease in population.	Small sample size. Objective of study included study of costs, but these are not given.	Larger prospective study needed to test clinical relevance of findings.

Table 8: Status and influence of assessments (cont.)

Study	Area of health care	Status of study	Effect on decision-making	Limitations	Future work
Rendina et al., 1998 ⁽³⁵⁾	Cardiology	Transmission of neonatal echocardiograms compared with pre-telemedicine management.	Indications of increased cost of telemedicine compared with courier service, but lower (though NSS) NICU stay for telemedicine group. Likely to influence decisions on continuing future use.	Data for both study and control groups obtained retrospectively. Relatively small numbers of subjects. LOS in the NICU has limitations as an outcome measure. Cost estimates do not include personnel-related items.	Not specified, though later study followed from this work.
Rendina et al., 1998 ⁽³⁶⁾	Cardiology	Comparison of pre-telemedicine and telemedicine groups, neonatal echocardiography.	Little evidence of reduction in respiratory therapy utilization due to telemedicine.	Data for both study and control groups were obtained retrospectively. Small numbers of subjects. Objective was to measure whether there was a reduction in morbidity associated with telemedicine, though some of the discussion refers to resource allocation.	Call for additional studies and makes reference to other work in progress at the University of North Carolina.
Zelickson & Homan, 1997 ⁽⁴³⁾	Dermatology	Case-control study of still-image store-and-forward teledermatology system in the care of nursing home residents.	Teledermatology cost saving compared with in person consultation, accuracy acceptable.	Small number of patients. Low response rate in satisfaction survey. Authors note results may be valid for nursing homes but efficiency and cost-effectiveness for other settings (e.g. prisons, rural health clinics) need to be established.	Minimum resolution requirements and changes in utilization need to be studied.
Bergmo et al., 2000 ⁽³⁾	Dermatology	Cost study on transfer of images to major hospital from smaller centres.	Study shows the health centers where the use of still images in dermatological consultations would be cost saving.	The cost estimates used are derived from one health center and district hospital.	Not specified.

Table 8: Status and influence of assessments (cont'd)

Study	Area of health care	Status of study	Effect on decision-making	Limitations	Future work
Loane et al., 2000 ⁽²⁰⁾	Dermatology	RCT comparing real time, store and forward and conventional consultation options. Preliminary report (full study under Wootton et al.)	Indication that real time teledermatology more expensive than conventional care, store and forward less clinically efficient.	No comment on apparent clinical inefficiency of real time compared to conventional consultations in terms of requested GP review. Discussion on cost issues, but data are not provided, other than for graphical presentation of sensitivity analysis.	Suggesting need for studies to address costs and benefits of teledermatology to urban and rural health centres.
Oakley et al., 2000 ⁽²⁸⁾	Dermatology	RCT with cost study, considering patient travel and time.	Rural patient time, travel, costs substantially less using teledermatology than hospital consultation. Similar follow up referral patterns for both groups.	While economic benefits are said to favour patients rather than the health care system, no data are given on costs of the telemedicine service. The comparison is on basis of distances traveled (questionnaires) and standard travel allowance. Few details of incidental expenses obtained. Few questionnaires completed after follow up exams and these not analysed. Details of follow up exams are not discussed.	Not specified.
Wootton et al., 2000 ⁽⁴²⁾	Dermatology	RCT, considering clinical follow up, reattendance, cost effectiveness.	Clinically feasible, not cost effective; estimated changes to make cost effective. Concluded teledermatology not likely to be useful in large cities, except possibly for tertiary consultation.	Low utilisation of telemedicine service. Travel distance for breakeven useful illustration but possibly not relevant to practice realities.	Not specified.

Table 8: Status and influence of assessments (cont'd)

Study	Area of health care	Status of study	Effect on decision-making	Limitations	Future work
Perednia et al., 1998 ⁽³²⁾	Dermatology	Before/after study considering effect of telemedicine on referral and management.	Appropriate increase in consultations. Seen by authors as a preliminary study, giving indicator for practice in rural areas.	Only limited detail on management plans, no follow up of treatment outcomes.	Adding two additional sites to study and will report on referral rates and outcomes for all five sites.
Stensland et al., 1999 ⁽⁴⁰⁾	Dermatology (plus orthopedic consultations)	Cost study on existing telemedicine network.	Suggestions for telemedicine centre, insurers and employers on increasing facility fees, providing reimbursement for telemedicine services, streamlining operation of telemedicine centre.	Authors note marginal benefits and costs are sensitive to a number of factors. Study is from the perspective of the provider. Limited consideration of patients' costs.	Not specified, though suggestion of linking telemedicine to specialists' face-to-face systems indicates useful area for future study.
Brennan et al., 1999 ⁽⁵⁾	Emergency department	RCT, patients with 15 types of complaints; change in treatment after discharge main outcome measured.	NSD for occurrence of 72h return visits etc. Telemedicine group had faster throughput (106 v 117 min) telemedicine a satisfactory technique for this group of patients in emergency dept. No specific decision related to future programs mentioned		Not specified.
Dawson et al., 1999 ⁽⁹⁾	Home care/ antenatal	RCT, with implications for effectiveness; cost study. Telemedicine only one component of the domiciliary approach.	Strong indication of usefulness of domiciliary approach for both patients and providers.	Authors note that availability of home telemonitoring influenced management of the conventional care group. They also note that they were unable to obtain marginal costs for clinic visits.	Not specified.

Table 8: Status and influence of assessments (cont'd)

Study	Area of health care	Status of study	Effect on decision-making	Limitations	Future work
Frank et al., 2000 ⁽¹²⁾	Home testing	Blinded, subject as control study.	Demonstrates feasibility of a telemedicine – assisted approach to HIV testing. Suggests useful further option for HIV testing services.	151/1255 subjects did not complete study, though authors note that this is lower attrition rate than observed in clinical practice. Differences in comprehension between automated system and telephone counsellor not specified.	Not specific on program; notes need to consider effects on tracking of HIV statistics and partner tracking.
Mehra et al., 2000 ⁽²⁶⁾	Home care/ cardiac	Preliminary, controlled, study on efficacy of system.	Strong indication that worth proceeding with further use/ investigation of this approach.	Authors note data are preliminary. Relatively short study period. No data for matching of controls.	Authors suggest several areas for further study, including appropriate patient characteristics, cost and cost effectiveness studies, length of monitoring, potential drug titration at home to avoid clinic visits.
Johnston & Wheeler, 2000 ⁽¹⁸⁾	Home care	RCT with cost study	Video approach achieved cost savings and improved access to home health care support. Paper indicates that study was influential for decision makers, leading to adoption of the system.	As noted by the authors, depreciation of the video equipment was not considered for the purpose of the study. There are some differences in the composition of the two groups in terms of primary diagnosis, though comparability of groups is considered by the authors who found that the difference between SF-12 scores for the intervention and control groups was not statistically significant.	Suggestion that potential of the technology warrants further study.

Table 8: Status and influence of assessments (cont'd)

Study	Area of health care	Status of study	Effect on decision-making	Limitations	Future work
Piette et al., 2000 (2 studies) ⁽³³⁾	Home care/diabetes	Long term RCT in existing patient population and health care network.	Conclusion that ATDM calls with nurse telephone follow up improves some patient-centered outcomes of diabetes management. Suggests clear message to decision-makers, but no specific mention regarding decision on program.	Authors note HRQOL instrument used, which was developed for Type 1 diabetics, might have had validity and reliability problems in study population (mostly Type 2).	Not specified, though notes particular population in study and use of a single site; indicates need for future, broader studies.
Demartines et al., 2000 ⁽¹¹⁾	Surgical consultation	Survey of evolving consultation network. Before/ after considering effect of interactivity on information available on treatment.	Substantial increase in number of cases where information judged to be acceptable; confirms usefulness of this approach.	Only general points on cost - benefit are included, rather than a study.	Suggesting wider role for teleconferencing including mentoring and accreditation.
Harrison et al., 1999 ⁽¹⁵⁾	Medical consultation	Pilot study as preparation for larger RCT.	Showed shorter time for teleconsultation than surgery visits, NSD in health status.	Some limitations in response rates to certain items in questionnaires. High drop out rate.	Proceeding to large multicentre study covering rural and urban areas.
McCue et al., 1998 ⁽²⁵⁾	Medical consultation	Cost minimisation study covering first year's experience with telemedicine at a prison.	Analysis indicate cost savings through use of telemedicine.	Several assumptions in the analysis. Not clear if all the services detailed for the hospital clinics would actually have been used for the cases handled through telemedicine.	General indication of the need for follow up research.

Table 8: Status and influence of assessments (cont'd)

Study	Area of health care	Status of study	Effect on decision-making	Limitations	Future work
Zollo et al., 1999 ⁽⁴⁴⁾	Medical consultation	Survey of primary care and consulting providers from four prisons and an academic tertiary care facility in Iowa during the first year of telemedicine service.	Determined breakeven figure for teleconsultation in comparison to conventional consultations. Suggesting that a telemedicine program can be "cost-acceptable" initially and become cost effective as volume of teleconsultations increases.	Limited on cost-effectiveness of a whole program. Individual prisons might want more specific data before joining a program. Large gap between the number of actual telemedicine consultations and the number needed to reach breakeven.	Prison-by-prison evaluation to determine the number of telemedicine consultations for each prison to reach breakeven.
Harno 1999 ⁽¹³⁾	Medical consultation	Cost comparison of electronic and paper referral systems at two hospitals for a one year period.	Direct outpatient costs of internal medicine 20 % lower in the hospital using electronic referrals. Only one-third of the teleconsultations resulted in an actual outpatient visit, electronic consultations were given in 65% of cases. There was little difference in outpatient costs for surgery.	Only brief details on the basis for cost estimates are provided in this preliminary paper. Authors note that they were unaware of all direct costs imposed by the system. Reference is made to the increase in number of referrals at the hospital using electronic referrals (20% for internal medicine, 44% for surgery), though there are no comparative data given for earlier years.	Further study to examine direct costs of the whole patient process.
Harno et al., 1999 ⁽¹⁴⁾	Medical consultation	Computer supported outpatient clinical model in one hospital was compared, regarding costs and referral patterns, to another hospital with traditional outpatient treatment.	Cost of electronic consultation in internal medicine only 10% of that of face-to-face consultation, but in surgical outpatient visits videoconferencing was more expensive than face-to-face visit. Hospital using electronic referrals was able to take care, without added costs, of twice the amount of referrals than the control hospital.	Effect of electronic referral system on patient outcomes is not reported.	Not specified, though effect on patient outcomes has been followed up for one year in an extension of the study.

Table 8: Status and influence of assessments (cont'd)

Study	Area of health care	Status of study	Effect on decision-making	Limitations	Future work
Hunkeler et al., 2000 ⁽¹⁷⁾	Mental health	RCT comparing nurse telehealth with usual physician care in augmenting antidepressant treatment.	Strong indication of efficacy of nurse telehealth, using approach that could be implemented within busy primary health care settings. Findings 'received with great interest by clinical leaders in Kaiser Permanente Health Plan and in other health maintenance organizations'.	Limited contact between patients and peers in third arm of study.	Authors suggest it would be worthwhile to further explore value of peer support when it is more clearly structured. They also conclude that their findings need to be replicated in other circumstances to judge how confidently broad adoption of nurse telehealth in this application can be recommended.
Simpson et al., 1999 ⁽³⁸⁾	Mental health	Cost analysis as part of an observational study of a routine telepsychiatry service.	Indication that costs of the telepsychiatry service are acceptable, and below breakeven point when use of administrative videoconferencing is considered. Also indications of savings to patients.	Limited details on costs to patients, estimate of impact is only indicative.	Authors note need for studies on impact on health status, quality of life and impact of delay in receiving specialist consultation.
Mielonen et al., 2000 ⁽²⁷⁾	Mental health	Preliminary study, in patient planning	Cost advantages of teleconsultations at moderate workloads. Satisfaction with content and interaction in teleconsultation. Implication that approach should be adopted.	Small sample size. Cost savings magnitude highly dependent on practice adopted for number of staff in conventional visits.	Not specified
Craig et al., 2000 ⁽⁷⁾	Neurology	Retrospective, preliminary	Unclear – videoconferencing can be used for consultation in neurology. Cohort studies can be used in the future to investigate the effects of telemedicine.	Relatively small number of patients studied. Final coded diagnoses from the hospital databases which possibly include some bias.	Cohort studies can be used to investigate the effect of expert neurological care, delivered using telemedicine, on the management of neurological patients.

Table 8: Status and influence of assessments (cont'd)

Study	Area of health care	Status of study	Effect on decision-making	Limitations	Future work
Craig et al., 2000 ⁽⁸⁾	Neurology	Feasibility study, blinded comparison of conclusions following face to face consultations and teleconsultations on diagnosis and recommended action.	Suggests need for further work to validate the approach.	Relatively limited detail on disposal method.	Proceed to larger, randomized trial, test cost effectiveness.
Blackwell et al., 1997 ⁽⁴⁾	Ophthalmology	Comparison of referral patterns with retrospective control sample from previous year.	Strong indication of cost savings associated with telemedicine, benefits to patients and practitioners.	Small numbers. Retrospective comparison in which case-mix might have been variable. Cost estimates are indicative, but appear realistic.	Authors indicate future use of the network and call for users of telemedicine to evaluate their services.
Tuulonen et al., 1999 ⁽⁴¹⁾	Ophthalmology	Feasibility study and preliminary economic assessment model	Further work needed before widespread implementation of teleophthalmology	Retrospective control group.	Further research with larger number of patients on methods, effectiveness, economics, technology.
Agha et al., 1999 ⁽¹⁾	Pathology	Cost minimisation study comparing telepathology with on-site and courier services	Endorsing telepathology in context of specific public-sector program.	Authors note difficulty in generalising these results. Need for real time advice is not established, and conclusions on reliability are not supported by inclusion of data. Options for lower courier costs are not explored.	Call for further studies on effectiveness and economics of telepathology.
Della Mea et al., 2000 ⁽¹⁰⁾	Pathology	Comparison of costs for frozen section service with three alternatives.	Unclear – indication of cost of telepathology might influence decisions.	Only limited data in paper. Unclear how the derived cost per case curves reflect actual practice.	Not specified.

Table 8: Status and influence of assessments (cont'd)

Study	Area of health care	Status of study	Effect on decision-making	Limitations	Future work
Bailes et al., 1997 ⁽²⁾	Radiology	To determine potential cost savings of a wide-area teleradiology network. Prospective review of cases before and after implementation of telemedicine. Estimated savings based on avoided hospital care and air transportation.	Indicated cost savings and changes to more appropriate referral decisions as a result of telemedicine use. Probable strong influence on decisions regarding management of neurosurgical cases.	Authors note that savings to patients and families were not studied, but are potentially significant.	Not specified.
Spencer et al, 1991 ⁽³⁹⁾	Radiology	Before/after comparison, effect of image transfer on clinical decisions.	Significant change in management in majority of cases, principally through avoidance of unnecessary patient transfer. Authors note that use of the telemedicine system continued to increase after the end of the study.	No actual comparison with non-telemedicine situation, though a strong implication that in the absence of telemedicine a number of unnecessary or ineffective patient transfers would have occurred.	Not specified.
Heautot et al., 1999 ⁽¹⁶⁾	Radiology	Introduction and initial use of teleradiology network for neurosurgical cases. Before/after comparisons.	Demonstrated efficacy of teleradiology in this application; feasibility study for some aspects.	Focus on transfers made and avoided does not extend to subsequent patient history.	Extending research to transfer of other types of image/cases and including additional hospitals.

Table 8: Status and influence of assessments (cont'd)

Study	Area of health care	Status of study	Effect on decision-making	Limitations	Future work
Malone et al., 1998 ⁽²¹⁾	Radiology (obstetrics)	Retrospective review of costs associated with interpreting obstetric ultrasound exams, using medical records.	Identified savings from telemedicine, suggested would pay for fixed costs in 12 – 14 months.	Authors draw attention to limitations of their cost study, which relates to experimental conditions.	Outline of areas for future research and need for evaluation by each potential telemedicine network.
Pal et al., 1999 ⁽³⁰⁾	Rheumatology	Information from Web-based proforma completed by junior staff compared to face to face consultation	The study establishes feasibility of the concept, though reliability of results suggests need for further work. Immediate effect on decision making unclear.	While authors' conclusions are positive, data indicate that a large minority of decisions on main diagnosis, X-ray requests, other investigations and other treatments were changed after patients were examined at the outpatient clinic.	State that they will explore use of simultaneous transmission of photographic images when e mailing.

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