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Home telehealth for chronic disease management: A systematic review and an analysis of economic evaluations

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Objectives: The research objectives were two-fold: first, to systematically review the literature on the cost-effectiveness of home telehealth for chronic diseases, and second to develop a framework for the conduct of economic evaluation of home telehealth projects for patients with chronic diseases.
Methods: A comprehensive literature search identified twenty-two studies ($n = 4{,}871$ patients) on home telehealth for chronic diseases published between 1998 and 2008. Studies were reviewed in terms of their methodological quality and their conclusions.
Results: Home telehealth was found to be cost saving from the healthcare system and insurance provider perspectives in all but two studies, but the quality of the studies was generally low. An evaluative framework was developed which provides a basis to improve the quality of future studies to facilitate improved healthcare decision making, and an application of the framework is illustrated using data from an existing program evaluation of a home telehealth program.
Conclusions: Current evidence suggests that home telehealth has the potential to reduce costs, but its impact from a societal perspective remains uncertain until higher quality studies become available.

Keywords: Telehealth, Chronic disease, Economic evaluation, Cost-effectiveness, Systematic review, Framework

Chronic diseases are prolonged conditions that normally do not improve with time and are rarely cured completely (5). They may cause premature deaths, decrease quality of life (QoL) of individuals, and have a negative economic impact on the individuals' families and society (36). According to the World Health Organization, noncommunicable diseases, such as cardiovascular diseases, diabetes, obesity, cancer, and respiratory diseases, currently account for 59 percent of the 57 million annual deaths and 46 percent of the global burden of disease (48). A 2007 study stated that the total costs of chronic disease in 2003 in the United States alone was US$1,324 trillion dollars (treatment expenditures =

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US$277 billion and lost productivity = US$1,047 trillion dollars) (15).

Advancements in treatment for chronic diseases have resulted in reduced length of hospital stay, and in some cases, the avoidance of hospital visits, so the demand for home care services has increased (41). Healthcare providers can deliver home care services by visiting a patient's home or by using information and communication technology, also known as home telehealth. Home telehealth is a subset of telehealth that brings healthcare delivery to the home environment by connecting the patient with medical professionals. It is not intended to replace health professional care or visits, but rather to enhance the level of care (7).

The research objectives were to systematically review the current literature on the cost-effectiveness home telehealth and to provide a framework for economic evaluations of home telehealth to assist future studies. The economic review is limited to three chronic conditions that are the most studied with respect to home telehealth: diabetes, congestive heart failure (CHF), and chronic obstructive pulmonary disease (COPD). In developed countries, CHF is diagnosed in 1–2 percent of the general population (6), and an estimated more than 180 million people worldwide have diabetes (46), and approximately 210 million people globally have COPD (47). Usual care involves follow-up by a primary care physician or specialist after patient discharge from hospital.

METHODS

A protocol for the review of economic evaluations was written a priori and was followed in detail. A framework for economic evaluations of home telehealth programs is also described, followed by an example of the framework.

Literature Search Strategy

The following bibliographic databases were searched through the Ovid interface: Medline, Medline Daily Update, Medline In-Process & Other Non-Indexed Citations, BIOSIS Previews, and EMBASE. Parallel searches were run in PubMed, Cochrane Library, CRD Health Technology Assessment (HTA) database, CRD NHS Economic Evaluation Database (NHS EED), and Health Economic Evaluations Database (HEED). The search strategy included usual controlled vocabulary, such as the National Library of Medicine's MeSH (Medical Subject Headings), and keywords. The main search concept was home telehealth (including variations such as telehome care, home telecare, e-health, home telemedicine); methodological filters were applied to limit retrieval to cost analyses and other economic studies. OVID AutoAlerts and PubMed MyNCBI were set up to send monthly updates for new literature; monthly searches were also performed in Cochrane Library, HEED, and CRD. Results were limited to articles published from 1998 to 2008, and language restrictions were not imposed.

Selection Criteria

To be eligible, studies had to concern patients with at least one chronic disease and had to have home telehealth as the intervention compared with usual care. Economic evaluations, such as cost minimization analyses (CMA), cost-effectiveness analyses (CEA), cost utility analyses (CUA), or cost benefit analyses (CBA) were included. In addition, cost analyses were included if the assumption was made that home telehealth was at least as effective as usual care.

Selection Method

Two reviewers (D.C., K.C.) independently scanned the titles and abstracts that were identified through the electronic literature search. The full-text articles of citations deemed to be potentially relevant were reviewed using the selection criteria. The reviewers compared their selections of included studies and any disagreements were discussed and resolved by consensus.

Data Extraction Strategy

Data from each included study were extracted independently by two reviewers (D.C., K.C.), using a structured data extraction form. Country of origin, disease area, study design, patient population, comparators, resources measured, form of analysis, study perspective, time horizon, and study outcomes were noted. Any disagreements were discussed and resolved by consensus.

Quality Assessment

Study quality was assessed by one reviewer (D.C.) using a ten-point scale, which was developed based on criteria identified in three previous articles relating to the conduct of economic evaluation in telemedicine (29;31;45). The ten-point checklist is similar to that suggested by Drummond and colleagues (16) for assessing study quality for economic evaluations in general, but in this context is more specific to the requirements for studies in home telehealth. Questions were phrased for a yes/no answer, and the number of questions with a positive response was recorded for each study. This number should not be interpreted as a quality score, as the importance of each question is not equal. For example, the requirement to discount is limited and less important than the need that the data source be a study with high quality design. The questions and their description are found in Table 1.

RESULTS

Quantity of Research Available

The literature search identified 1,567 studies. The total number of studies reviewed includes both duplicates (i.e., the same paper identified through different databases) and duplicate publications (i.e., the same studies reported in more than one publication). After a review of 150 articles, 22 studies

Table 1. Quality Assessment Questionnaire

Question	Description
1. Was an appropriate question posed in an appropriate manner?	The study must contain a specific objective which relates to what was actually done, and it must relate to determining the economic impact of the program.
2. Is the study perspective appropriate?	An economic evaluation can be conducted from a number of perspectives, such as societal, healthcare system, and third-party payer. The study should be conducted from a societal perspective (incorporating costs to patients, their families, and caregivers) or must provide an argument for why such costs are not evaluated.
3. Is the methodology of high quality?	The estimates of incremental costs and effects must come from a valid and reliable source. Estimates of the incremental costs and effects for home telehealth programs must come from a suitable research design which minimizes potential bias, such as RCTs.
4. Is the methodology appropriate?	Studies of home telehealth require an estimate of the incremental costs of a program as well as the incremental effects on outcomes such as clinical end points or quality of life. Cost-effectiveness or cost utility analyses are ideal. Otherwise, studies would only be partial economic evaluations.
5. Is the comparator appropriate?	To assess the cost-effectiveness of home telehealth,a study must assess the incremental costs and effects of the program compared with usual care.
6. Is the quality of the medical evidence appropriate?	To allow assessment of whether the incremental costs of home telehealth are worthwhile, the study must compare outcomes with and without home telehealth.
7. Are appropriate costs considered?	All resources associated with the implementation of the home telehealth program must be identified and measured, and a unit cost for each item must be obtained.
8. Is discounting conducted?	Most telehealth studies are done over a short time horizon which would normally preclude the need for discounting. However, studies must incorporate the costs of equipment which should be allocated over their useful life.
9. Is marginal analysis conducted?	The study must address the volume of patients treated by assessing the costs of the program based on different numbers of patients to determine what level of enrolment is required for the program to be worthwhile.
10. Is sensitivity analysis performed?	It is necessary to assess the robustness of the study results to variations in assumptions through formal sensitivity analyses.

were found to be relevant for inclusion in the economic review. Figure 1 presents the QUOROM flow diagram detailing the process of study selection.

Study Characteristics

Country of origin. Most studies ($n = 17$) in our review were from the United States (1;4;10–12;20;23;25–27;32–34;38;39;43;44). Among the rest, one study was from Germany (3), one was from Spain (19), one was from Italy (28), one was from the United Kingdom (30), and one was from Canada (35).

Disease Area. Most selected studies ($n = 12$) focused on home telehealth for patients with CHF (1;4;20;23;25;27;32;33;38;39;43;44). Five studies focused on patients with diabetes (3;10–12;30), and three focused on patients with COPD (19;28;35). The two other studies included patients with a variety of diseases (all included CHF, diabetes or COPD) (26;34).

Patient Population. Studies that focused primarily on CHF imposed numerous inclusion criteria. One study (43) allowed patients with coronary heart disease as well as those with heart failure. Three studies required patients to have moderate or severe CHF (32;33;44). Six studies required either recent discharge from hospital or frequent emergency department visits (2;27;32;38;39;44). One study (25) required patients to be at least 40 years old, while another (38) studied Hispanics only.

All five studies on diabetes included patients with different baseline criteria: adolescents (10), patients on intensive insulin therapy (3), indigent or economically disadvantaged patients with diabetes (11), elderly patients with diabetes who were recently discharged from a hospital (12), and patients with type 2 diabetes (30).

Two of the three COPD studies (19;28) involved patients who required long-term oxygen therapy, whereas the other COPD study (35) focused on patients with severe disease after discharge from their first hospitalization.

For studies that examined multiple chronic diseases, one (34) required patients with at least three chronic or complex conditions and who received home care for at least 6 months. In the other study (26), patients were eligible if they had any one of the following conditions: CHF, diabetes, COPD, stroke, cancer, or require wound care.

Comparators. Usual care varied in terms of whether it involved a specified organized home care or another support program (1;4;10;12;26;32–35) or care as directed by the physician, which may or may not have included home care (3;11;19;20;23;25;27;28;30;38;39;43;44). The home telehealth interventions tended to be complex, often with more than one facet of patient management changed in the intervention arm of the study. All but one home telehealth strategy (30) involved augmented interactions between the patient and

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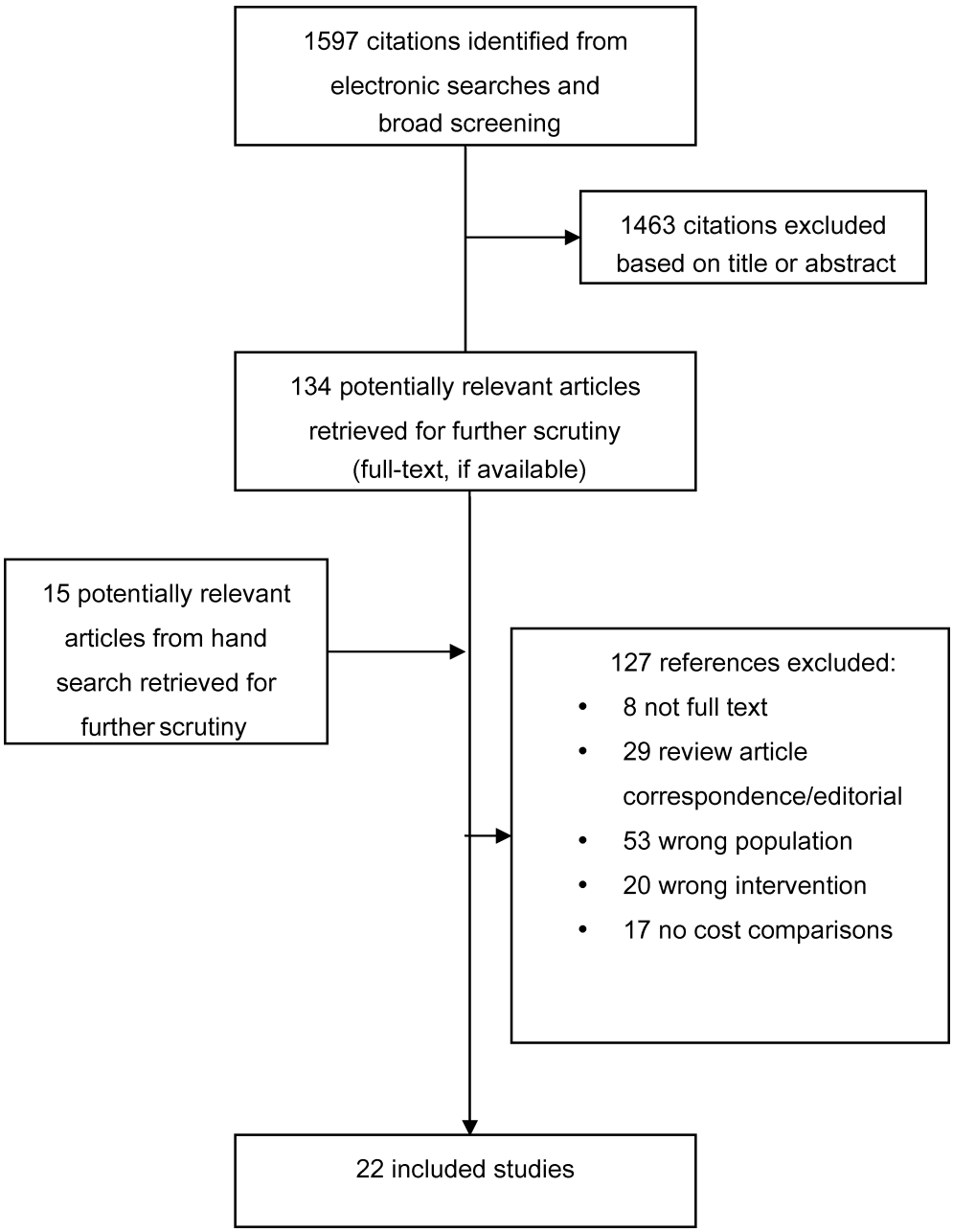

Figure 1. Selection of included studies.

a nurse. The majority of studies on home telehealth for patients with CHF involved regular telephone monitoring of patients by nurses (1;4;20;25;27;38;39), with one also incorporating video interactions (25). Other studies involved a system whereby patient information was sent either by telephone (23) or through a computer (32;33;42;43) to the nursing staff to monitor the patient's condition. Three of the five diabetes studies (3;10;11) evaluated different systems where patient data were relayed to a nurse, physician, or diabetes center followed by advice provided to the patient by telephone. One study (12) evaluated a program of video visits between patients and home care nurses, and another study evaluated a call station managed by non-healthcare professionals (30). Table 2 provides details of comparators in the included studies.

Form of Analysis. All selected studies were a cost-analysis, except for one which was a CUA (30). In the CUA, the long-term costs and utilities were derived from a previous U.S. study and then transformed to the UK setting, with no

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Table 2. Comparators of Included Studies

First author, publication year, country, disease area	Comparators	
	Intervention	Control
Benatar, 2003, US, CHF(1)	Home healthcare delivered primarily by nurse telemanagement ($n = 108$)	Home healthcare delivered primarily by home nurse visits ($n = 108$)
Bondmass, 1999, US, CHF(4)	Home healthcare delivered primarily by nurse telemanagement ($n = 60$)	Home healthcare delivered primarily by home nurse visits ($n = 60$)
Galbreath, 2004, US, CHF(20)	Initially weekly transitioning to monthly telephone calls from nurse disease manager focused on symptom monitoring and management, education, and treatment recommendations forwarded to family physicians ($n = 710$)	Managed as usual by their primary care physician ($n = 359$)
Heidenreich, 1999, US, CHF(23)	Patients were provided an automated blood pressure cuff with a digital scale. Each day, patients phoned in their blood pressure, pulse, weight, and symptoms. A nurse was paged if data were a concern and the patients could contact their physician if required ($n = 68$)	Care prior to enrolment to program ($n = 68$)
Jerant, 2001,US, CHF(25)	Two interventions: Telephone care: scheduled phone calls from a nurse with access to nurse 8–5, Monday to Friday ($n = 12$) Video-based telecare: scheduled telecare visits from a nurse with access to nurse 8–5, Monday to Friday ($n = 12$)	Usual outpatient care as directed by their primary care physician ($n = 13$)
Laramee, 2003, US, CHF(27)	Early discharge planning, patient and family CHF education, 12 weeks of telephone follow-up and promotion of optimal CHF medications ($n = 141$)	Usual care as determined by local family physician ($n = 146$)
Myers, 2006, US, CHF(32)	Home monitoring involving patients transmitting data on vital signs and weight to a nurse daily and the nurse phoning the patient to advise on medication modification or the need for referral to other health care ($n = 83$)	Traditional home health care ($n = 83$)
Nobel, 2003, US, CHF(33)	Daily home-based biometric monitoring looking at weight and symptoms. Results were forwarded to a nurse and if results suggested clinical deterioration, the patient's physician contacted them to advise that they seek further care ($n =$ unreported)	Support program to reinforce careful attention to medications and diet ($n =$ unreported)
Riegel, 2006, US, CHF(38)	Telephone case management with nurses directed to examine factors linked to CHF hospitalization. Emphasis on education and monitoring, not on changing medications or follow up care ($n = 69$)	Usual care with patients educated about CHF management ($n = 65$)
Riegel, 2002, US, CHF(39)	Telephone case management with nurses directed to examine factors linked to CHF hospitalization. Patients contacted 5 days after discharge and followed based on symptoms, knowledge and needs ($n = 130$)	Patients educated about CHF management prior to discharge ($n = 228$)
Southard, 2003, US, CHF(43)	Internet program which was accessed for at least 30 minutes per week and included interaction with a nurse case manager and dietician, educational programs, a discussion group and small rewards for participation ($n = 53$)	Usual care ($n = 51$)
Vaccaro, 2001, US, CHF(44)	Patients provided a Health Buddy which is a device which directs patients to monitor symptoms and provides education. Results are sent to a case manager and relevant patients are assessed for further care ($n = 52$)	Previous health care ($n = 638$)
Biermann, 2002, Germany, diabetes(3)	Transmission of blood glucose every 2 weeks to a nurse or physician who phoned the patient with treatment advice in addition to 6-month clinic visits ($n = 30$)	Usual care which consisted of clinic visits every 3 months ($n = 33$)
Chase, 2003, US, diabetes(10)	Above except information on blood glucose levels was sent to diabetes centers through mode with advice on dose adjustment being provided through telephone communication ($n = 17$)	Structured diabetes education program involving self care of blood glucose with monitoring of insulin dose ($n = 16$)
Cherry, 2002, US, diabetes(11)	Patients are given a Health Hero iCare Desktop and a Health Buddy, which helps the patient manage their disease through monitoring, education, reinforcement, prompts to action, and interaction with a nurse case manager ($n =$ not reported)	Usual care for a sample of patients 1 year prior to start of study ($n = 169$)

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Table 2. Continued

First author, publication year, country, disease area	Comparators	
	Intervention	Control
Dansky, 2001, US, diabetes(12)	Skilled nursing home visits post discharge plus video visits through a patient station incorporating a camera, and medical sensors with telephone contact ($n = 86$)	Skilled nursing home visits post discharge ($n = 85$)
Mason, 2006, UK, diabetes(30)	Call station managed by trained telecarers (not nurses) who called patients relating to education, medication adherence and blood glucose usual care ($n = 394$)	Usual care (not defined) ($n = 300$)
Farrero, 2001, Spain, COPD(19)	Monthly telephone call and 3-month home visit performed by a nurse focused on symptom assessment, spirometry and evaluation of oxygen therapy. Patients also have on demand access ($n = 62$)	Usual care as directed by patient's chest and family physician ($n = 62$)
Maiolo, 2003, Italy, COPD(28)	Twice weekly home oximetry monitoring with telephone follow up by respiratory physicians in addition to 3-month hospital visits ($n = 30$)	Usual face to face care with hospital visits every 3 months ($n = 30$)
Paré, 2006, Canada, COPD(35)	Usual care plus a Webphone for monitoring measures of health to both assist patients in monitoring their own health and to allow staff to send advice ($n = 19$)	Home care with personalized patient-based management of medications ($n = 10$)
Johnston, 2000, US, multiple diseases(26)	Video visits in addition to telephone and in person visits. Video access available 24 hours a day ($n = 102$)	Video visits in addition to telephone and in person visits. Video access available 24 hours a day ($n = 102$)
Noel, 2000, US, multiple diseases(34)	Nurse case management plus 24-hour telemonitoring for 3 months – monitoring involved the transmission over regular phone lines of physiological data ($n = 10$)	Nurse case management as prior to the study ($n = 9$)

further information provided on the costs included. None of the studies included a formal assessment of either utilities or the program impact on long-term outcomes.

Resources Included. Most studies involved an assessment of the costs associated with specific healthcare resources, such as hospitalizations, primary care, and emergency department visits and included costs required to set up a home telehealth program. The majority did not involve consideration of all healthcare resources, and only two (3;10) incorporated patient-based costs. Four studies did not report the healthcare resources included (23;30;33;34). Seven studies failed to adequately incorporate the costs of home telehealth (11;20;23;25;33;38;44).

Study Perspective. Study perspective was deduced as it was unspecified in the majority of studies. Two studies adopted a societal perspective (3;10). Ten studies (1;4;23;25;32–34;38;39;44), adopted the perspective of a specific health insurance provider. The remaining studies in the review adopted a healthcare system perspective.

Study Design. Fourteen studies were based on data from randomized controlled trials (RCTs) (1;3;10;12;13;19;20;25;26;30;34;38;39;43). Four studies were based on data from a case-control study (32;33;35;44), and four were based on data from a pre–post study (4;11;23;28).

Time Horizon. The time horizon across all studies ranged from 2 (12;32) to 18 (20) months.

Quality Assessment. Based on the quality assessment questionnaire derived from published economic evaluations of home telehealth, most studies were considered to be of poor quality. Only seven studies had affirmative answers to more than half of the ten items on the checklist (Table 3). However, even the studies with a high proportion of affirmative responses had major methodological weaknesses. All studies had a positive response to question 5, which focused on whether the study compared a strategy of home telehealth with an alternative strategy. This item was an inclusion criterion for this review. Several studies also had a positive score for question 1 (appropriate study question; 17/22 studies) and question 3 (RCT or good quality observational study; 17/22 studies). The questions that had the least adherence to good quality were question 2 (appropriate study perspective; 3/22 studies), question 9 (marginal analysis; 4/22 studies), and question 10 (appropriate sensitivity analysis; 3/22 studies).

Data Synthesis and Analysis

A formal meta-analysis was not feasible due to variations in the patient populations, study designs and interventions and comparators. Instead, the results in each selected study were reviewed and summarized qualitatively. In one CUA (30), a diabetes call station managed by non-healthcare professionals was associated with higher costs leading an incremental cost per quality-adjusted life-years (QALYs) of £43,300. In another study, there was no difference in costs between telephone management by a nurse manager and usual care for

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Table 3. Study Outcomes and Quality Assessment

First author, publication year, country, disease area	Study outcomes	Quality items with positive response
Benatar, 2003, US, CHF(1)	Hospitalization charges were substantially lower for the telemanagement group – a saving of approximately $1,000 per patient. QoL was similar across treatments. The telemanagement program cost $2.87 per day.	1, 3, 4,5, 6
Bondmass, 1999, US, CHF(4)	Hospitalization charges were substantially lower during the period of the intervention compared to the prior period. It is not possible to derive the cost of the telemanagement program from the study.	1, 5
Galbreath, 2004, US, CHF(20)	The total costs for each 6-month period ranged from $3,001.26 to $3,711.65 in the usual care group and from $2,919.38 to $3,602.67 in the intervention group. There were no significant differences between the two groups with respect to costs.	1, 3, 4,5, 6
Heidenreich, 1999, US, CHF(23)	Medical claims were lower than in the year prior to enrolment in the program, whereas for the usual care group costs increased over the same period.	1, 5
Jerant, 2001, US, CHF(25)	Costs of CHF-related admission and frequency of emergency visits were lower in the video-based telecare group and the telephone care group compared to the usual care group.	1, 3, 5, 7
Laramee, 2003, US, CHF(27)	Although not statistically significant, the overall costs in the intervention were lower than those in the usual care group ($23,054 vs. $25,536).	1, 3, 5, 7, 8
Myers, 2006, US, CHF(32)	Telemonitoring reduced the frequency of home visits and led to savings of $189 per patient over a 2-month period.	1, 3, 5, 7, 9
Nobel, 2003, US, CHF(33)	Telemonitoring led to a 60% reduction in healthcare costs from the previous year compared to a 16% reduction in the usual care group.	5
Riegel, 2006, US, CHF(38)	At 6 months, telephone case management led to lower all cause inpatient costs per patient ($10,015 versus $13,967) and lower CHF-related inpatient costs ($5,567 versus $6,151). Neither difference was statistically significant. No difference in quality of life was found.	1, 3, 5, 6
Riegel, 2002, US, CHF(39)	Telephone case management led to lower CHF-related inpatient costs at 6 months for the intervention group ($1,192 versus $2,186). Patients on the program reported less physician office visits but more emergency department visits though differences were not statistically significant. The program costs $443 per patient for 6 months.	1, 3, 4, 5, 6, 9
Southard, 2003, US, CHF(43)	A net cost savings of $965 was calculated for the intervention group including the costs of the intervention. There were also fewer cardiovascular events within the intervention group (4.1%) as compared with the usual care group (15.7%) ($p = 0.053$).	1, 3, 4, 5, 6, 7
Vaccaro, 2001, US, CHF(44)	The telehealth program led to annual cost savings in terms of hospitalizations and emergency department visits per patient of $5,271. This would offset the program costs.	1, 5
Biermann, 2002, Germany, diabetes(3)	Telemanagement led to cost savings of approximately 648 Euro per patient from the societal perspective. From the healthcare perspective, telemanagement had an associated incremental cost of 218 Euro.	2, 3, 5, 6, 7, 8
Chase, 2003, US, diabetes(10)	The average cost per patient in the usual care group was $305 compared with $163 in the intervention group. Diabetes usual care and the incidence of acute diabetes-related complications were comparable between the two groups.	1, 2, 3, 4, 5, 6, 7, 8, 10
Cherry, 2002, US, diabetes(11)	There was an inflation adjusted reduction in average healthcare service costs per patient of $747 per year during the telehealth intervention.	1, 5
Dansky, 2001, US, diabetes(12)	Home telehealth involves additional costs, but may reduce home visits and hospitalizations.	1, 3, 5, 7, 8, 9, 10
Mason, 2006, UK, diabetes(30)	Telecare program cost £43,400 per QALY gained under trial conditions and £33,700 assuming routine use.	1, 3, 4, 5, 6, 7, 8, 9, 10
Farrero, 2001, Spain, COPD(19)	After 1 year, the total costs for the intervention group were 15.8 million pesetas including the 6.7 million pesetas cost of the intervention as compared with 24.0 million pesetas for the usual care group, a cost savings of 8.2 million pesetas. No difference in QoL was found.	1, 3, 4, 5, 6, 7, 8

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Table 3. Continued

First author, publication year, country, disease area	Study outcomes	Quality items with positive response
Maiolo, 2003, Italy, COPD(28)	Cost of hospitalizations during usual care phase was 233,000 Euros versus 133,000 Euros in the intervention phase. After incorporating the 60,000 Euro cost of the telemedicine service there was a net savings of 40,000 Euros in the intervention group.	1, 3, 4, 5, 6
Paré, 2006, Canada, COPD(35)	The costs of the telehomecare program were primarily offset by reductions in further hospitalizations leading to a cost saving per person of $355 per patient.	1, 2, 3, 5, 7, 8
Johnston, 2000, US, multiple diseases(26)	Costs per patient in the video care group were greater for home telehealth ($1,830 versus $1,167) and less for other healthcare resources ($1,948 versus $2,674).	1, 3, 5, 8
Noel, 2000, US, multiple diseases(34)	No significant differences in costs or quality of life between the two groups in the trial.	1, 3, 5, 6

patients with CHF (20). In the remaining twenty studies, the home telehealth strategies were found to lead to reductions in the costs of the healthcare resources included from a healthcare system or insurance provider perspective. Study outcomes for each selected study are described in Table 3.

Framework for Economic Evaluation

Focus. An analysis of the economic impact of home telehealth must focus on the incremental costs and health benefits associated with the application of the program to a population of patients, rather than to an individual patient. Such evaluations would allow an assessment of the impact of the program as a whole by including costs from both the patient and population levels. This would allow evaluation of costs based on different patient population sizes, as required for marginal analysis.

Study Perspective. Studies must specify and justify the perspective from which the home telehealth programs and health resource use are measured. Societal, healthcare system, third-party, and patient perspectives each have a unique focus that is reflected in the included costs.

Direct Costs to Be Included. *Telehealth program specific costs:* Cost of program administration, program delivery, and program capital costs (i.e., costs of technology required for the delivery of home telehealth) must be measured. The costs of technology used over a period of time must be amortized over the technology's useful life.

Home healthcare costs: These costs comprise the volume of nursing and other homecare visits and contacts.

Healthcare costs: All pertinent healthcare resources, such as family physician visits, specialist outpatient appointments, emergency department visits, hospitalizations, diagnostic tests and investigations, medications, and specialized equipment (including prostheses) must be calculated.

Patient borne costs: The potential financial impact on patients and their families and caregivers must be measured. Some items to consider are travel and other directly borne costs, medication costs, and family caregiver time.

Indirect Costs to be Included. Indirect costs are required for studies measuring costs from a societal perspective, but are more challenging to measure. Costs in this category may include the patient or caregiver's productivity losses as a result of disease management or travelling time to the patient's residence incurred by the healthcare provider.

Outcomes. An economic evaluation requires an assessment of incremental costs and incremental outcomes of each healthcare program evaluated. Thus, the majority of published studies are not economic evaluations of home telehealth and cannot assist in determining whether a treatment is justifiable based on the impact on costs and treatment outcomes. Many studies interpret a reduced use of healthcare resources as evidence of improved outcomes. Healthcare resources use may be limited due to fewer home healthcare contacts with home telehealth, meaning reduced frequency of access to other services and not necessarily a reduced need for these services. Studies should, therefore, have either clinical outcomes (which may be surrogate outcomes such as disease markers) or patient QoL. If home telehealth is more costly compared with usual care, then studies must take the form of either cost-effectiveness or cost utility analysis using these outcomes.

Quality of Life. A cost-utility analysis of home telehealth programs must include a formal assessment of patients' QoL to measure the QALY and an estimation of any short-term effects on utility due to the intervention.

Effectiveness. A cost-effectiveness analysis of home telehealth programs must consider collecting data on clinical outcomes associated with the particular disease studied, such as event rates and deaths. In many instances, an evaluation of home telehealth programs may have a short time horizon, which will not facilitate a demonstration of differences in long-term clinical outcomes. The studies should then consider inclusion of surrogate markers as indicators of no differences in clinical outcomes, such as glycemic control (HbA1c) for diabetes, forced expiratory volume in one

second (FEV_1) for COPD, and systolic blood pressure for CHF.

Study Population. A vast array of patients participate in a home telehealth program. Studies with diverse patient populations increase the external validity of their outcomes. If there is substantial heterogeneity due to the study populations, subgroup analyses based on patient characteristics may be carried out.

Comparator. The home telehealth program must be compared with an appropriate alternative strategy that represents the existing form of health service delivery for the study population. Some examples include regular home care visits by a healthcare provider or primary care visits or longer hospital stays.

Marginal analysis. In an economic evaluation, it is necessary to assess the marginal costs and benefits associated with health interventions that relate to the additional costs and outcomes associated with the interventions being considered. When evaluating home telehealth, it is generally required to evaluate the implementation of a program. Marginal analysis should focus on the additional costs and outcomes of program implementation and not necessarily on the additional cost and outcomes on a per patient basis. However, it would be necessary to conduct such analysis using alternative estimates of the number of participants in the program as the marginal costs per patient will be much lower than the forecasted average costs. Subsequently, average costs are likely to fall the more patients covered within the program.

Sensitivity Analysis. An economic evaluation must include at least one sensitivity analysis to determine the robustness of the study findings based on the assumptions made. Sensitivity analyses are done by varying the underlying assumptions over a possible range of possible values.

Application of the Economic Evaluation Framework

In the supplementary section, which can be viewed online at www.journals.cambridge.org/thc, an illustrative application of the framework is provided. The application relates to an evaluation of a telehomecare demonstrator project, "EMPcare@home"(40) conducted in New Brunswick, Canada. The evaluation of the telehealth demonstrator project was used to measure whether the combination of telehomecare, timely staff intervention and an enhanced patient education program produces a better QoL for patients, is accepted by patients and health professional and reduces the need for hospital care. The objective was to highlight how such analyses can be conducted and what additional data would be required.

DISCUSSION

The literature search identified twenty-two studies relevant for inclusion in the systematic review. No attempt was made to quantitatively synthesize the selected studies. Instead, data were summarized and appraised to identify common results and the related strengths and weaknesses.

Most studies in our economic review found home telehealth to be cost saving from healthcare system and insurance provider perspectives. Conclusions must be qualified as the quality of the studies in terms of economic evaluations was poor. The studies were also heterogeneous possibly due to diverse study populations, interventions, and the healthcare systems in which they are based, so it remains a challenge to make an informed decision on resource allocation. Several studies were published in 1999 (4;12;32) or in 2000 (26;34). It is possible given the likely decrease in technology costs that telemedicine costs were higher in those studies compared with costs in the more recent studies, so the cost-effectiveness of the home telehealth program may be confounded by the study's publication year. Numerous studies in this review did not measure simultaneous changes in outcomes and costs, so they did not measure the cost-effectiveness of a home telehealth program. Finally, no home telehealth study in the published literature involved a formal assessment of health-related utilities or the impact of the program on long-term outcomes.

The economic evaluation framework presented advocates that an assessment of a home telehealth program include costs at both the patient and population levels to facilitate assessment based on different size populations. The sample analysis demonstrates how the economic evaluation framework of home telehealth could be implemented. There are limitations to how the economic evaluation can be done, given the absence of data on all healthcare resources, patient costs, quality of life, and clinical outcomes.

The critical appraisal checklist for economic evaluations by Drummond et al. helps readers to identify strengths and weaknesses of published health economic studies (16). The Canadian Agency for Drugs and Technologies' Guidelines for the Economic Evaluation of Health Technologies: Canada is further guidance for individuals conducting an economic evaluation, especially in the Canadian healthcare system context (8). Our framework is consistent with the above-mentioned guidelines and can serve as a guide for future studies that evaluate the economic impact of home telehealth programs. Mair et al. produced ten recommendations for the design of economic evaluations of telemedicine based on a quality assessment checklist designed for pharmacoeconomics studies (29), and authors McIntosh and Cairns also developed a framework for economic evaluations of telemedicine (31). The checklist by Mair et al. does not outline in great detail the types of outcomes and costs to consider in an economic evaluation of telemedicine. Moreover, McIntosh and Cairns's framework was limited to direct costs

(e.g., equipment, medical personnel in telemedicine, and cost of treatment) and clinical and nonhealth outcomes (e.g., length of waiting, time to diagnosis and improved education and reassurance). Healthcare resource use, such as number of primary care visits to the general practitioner, was also mentioned (31). The current framework presented is specific to home telehealth programs and can serve as a guide for all types of economic evaluations from various perspectives because it explicitly describes both the direct and indirect costs for consideration. In addition to the clinical and healthcare resource use outcomes, our framework also discusses the quality-of-life outcomes necessary for a CUA.

There are some limitations to our study. Some studies in the economic review had small sample sizes and a lack of information on patient characteristics, clinical outcomes, and study perspectives and, overall, were of poor quality. There are no published economic reviews specific to home telehealth on which to make an informed policy decision. Past systematic reviews on the cost-effectiveness of telemedicine interventions found the existing evidence on which to draw a conclusion to be very limited (29;45). Hailey et al. also found high-quality studies assessing the clinical and economic evidence in telemedicine to be scarce (21).

Future research should measure the economic impact of home telehealth programs on more diverse patient populations with chronic diseases to increase the external validity of their results and help identify those patients who can benefit most from home telehealth interventions and compare real-time versus asynchronous technologies to provide additional insight on the most effective disease management strategy for chronic diseases. Several studies interpreted decreased healthcare resource use as improved clinical outcomes. Studies should always include clinical outcomes, such as a disease marker or patient QoL to determine whether reduced use of health services is a result of limited access to health services versus the need for these services. Finally, a standardized approach to the evaluation of home telehealth should be developed to increase the quality of studies and amount of evidence available.

Home care is an instrumental part of the chronic disease management model, and home telehealth is an extension of healthcare delivery in a patient's home environment. Our economic review reported that home telehealth was cost saving from both the healthcare system and insurance provider perspectives, but the overall quality of the original research was low. A framework for economic evaluations in home telehealth was also presented as a guide to measure its economic impact, and an illustration demonstrated the constraints with conducting an economic evaluation with a lack of data on healthcare resources, patient costs, quality of life and clinical outcomes. If future studies adopted our proposed economic evaluation framework for home telehealth programs, then their relevance to healthcare decision making would be greatly improved.

SUPPLEMENTARY MATERIALS

Supplementary section and Supplementary Tables 1–3 (www.journals.cambridge.org/thc)

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REFERENCES

1. Benatar D, Bondmass M, Ghitelman J, Avitall B. Outcomes of chronic heart failure. *Arch Intern Med.* 2003;163:347-352.
2. Berger RA. Mini-incision total hip replacement using an anterolateral approach: Technique and results. *Orthop Clin North Am.* 2004;35:143-151.
3. Biermann E, Dietrich W, Rihl J, Standl E. Are there time and cost savings by using telemanagement for patients on intensified insulin therapy? A randomised, controlled trial. *Comput Methods Programs Biomed.* 2002;69:137-146.
4. Bondmass M, Bolger N, Castro G, Avitall B. The effect of physiologic home monitoring and telemanagement on chronic heart failure outcomes. *Internet J Adv Nurs Pract.* 1999;3:17.
5. British Columbia Ministry of Health. *Chronic disease management*. Victoria: British Columbia Ministry of Health; 2007.
6. Bundkirchen A, Schwinger RHG. Epidemiology and economic burden of chronic heart failure. *Eur Heart J Suppl.* 2004;6:D57-D60.
7. Canada Health Infoway. *Home telehealth business case report*. Toronto: Canada Health Infoway; 2007.
8. Canadian Agency for Drugs and Technologies in Health (CADTH). *Guidelines for economic evaluation of health technologies*. Ottawa, Canada: CADTH; 2006.
9. CDW Corporation. CDW Product Overview: Oracle Database 11g Standard Edition One. CDW-G: IT Products and Services for Government, Education and Healthcare. Vernon Hills, IL: CDW; 2008.
10. Chase HP, Pearson JA, Wightman C, Roberts MD, Oderberg AD, Garg SK. Modem transmission of glucose values reduces the costs and need for clinic visits. *Diabetes Care.* 2003;26:1475-1479.
11. Cherry JC, Moffatt TP, Rodriguez C, Dryden K. Diabetes disease management program for an indigent population empowered by telemedicine technology. *Diabetes Technol Ther.* 2002;4:783-791.

12. Dansky KH, Palmer L, Shea D, Bowles KH. Cost analysis of telehomecare. *Telemed J E Health.* 2001;7:225-232.
13. DeBusk RF, Miller NH, Parker KM, et al. Care management for low-risk patients with heart failure: A randomized, controlled trial. *Ann Intern Med.* 2004;141:606-613.
14. Department of Health. *Extra-mural program*. St. John's, NB: Government of New Brunswick; 2008.
15. DeVol R, Bedroussian A. *An unhealthy America: The economic burden of chronic disease*. Santa Monica, CA: Milken Institute; 2007.
16. Drummond MF, O'Brien BJ, Stoddart GL, Torrance GW. *Methods for the economic evaluation of health care programmes*. 2nd ed. New York: Oxford University Press; 1997.
17. ECRI. Portable blood glucose monitors. *Health Devices.* 1994;23:62-99.
18. ECRI. Portable blood glucose monitors. *Health Devices.* 1997;26:338-394.
19. Farrero E, Escarrabill J, Prats E, Maderal M, Manresa F. Impact of a hospital-based home-care program on the management of COPD patients receiving long-term oxygen therapy. *Chest.* 2001;119:364-369.
20. Galbreath AD, Krasuski RA, Smith B, et al. Long-term healthcare and cost outcomes of disease management in a large, randomized, community-based population with heart failure. *Circulation.* 2004;110:3518-3526.
21. Hailey D, Ohinmaa A, Roine R. Study quality and evidence of benefit in recent assessments of telemedicine. *J Telemed Telecare.* 2004;10:318-324.
22. HealthFrontier. *Shopping cart: ecg@home*. Branchburg, NJ: HealthFrontier; 2008.
23. Heidenreich PA, Ruggerio CM, Massie BM. Effect of a home monitoring system on hospitalization and resource use for patients with heart failure. *Am Heart J.* 1999;138(Pt 1):633-640.
24. Hewlett-Packard. HP ProLiant DL360 G5 Server series. HP ProLiant DL Servers. Canada-English website. Mississauga, ON: Hewlett-Packard (Canada); 2008.
25. Jerant AF, Azari R, Nesbitt TS. Reducing the cost of frequent hospital admissions for congestive heart failure: A randomized trial of a home telecare intervention. *Med Care.* 2001;39:1234-1245.
26. Johnston B, Wheeler L, Deuser J, Sousa KH. Outcomes of the Kaiser Permanente Tele-Home Health Research Project. *Arch Fam Med.* 2000;9:40-45.
27. Laramee AS, Levinsky SK, Sargent J, Ross R, Callas P. Case management in a heterogeneous congestive heart failure population: A randomized controlled trial. *Arch Intern Med.* 2003;163:809-817.
28. Maiolo C, Mohamed EI, Fiorani CM, de Larenzo A. Home telemonitoring for patients with severe respiratory illness: The Italian experience. *J Telemed Telecare.* 2003;9:67-71.
29. Mair FS, Haycox A, Williams T. A review of telemedicine cost-effectiveness studies. *J Telemed Telecare.* 2000;6(Suppl 1):S38-S40.
30. Mason JM, Young RJ, New JP, et al. Economic analysis of a telemedicine intervention to improve glycemic control in patients with diabetes mellitus: Illustration of a novel analytic method. *Dis Manag Health Outcomes.* 2006;14:377-385.
31. McIntosh E, Cairns J. A framework for the economic evaluation of telemedicine. *J Telemed Telecare.* 1997;3:132-139.
32. Myers S, Grant RW, Lugn NE, Holbert B, Kvedar JC. Impact of home-based monitoring on the care of patients with congestive heart failure. *Home Health Care Manag Pract.* 2006;18:444-451.
33. Nobel JJ, Norman GK. Emerging information management technologies and the future of disease management. *Dis Manag.* 2003;6:219-231.
34. Noel HC, Vogel DC. Resource costs and quality of life outcomes for homebound elderly using telemedicine integrated with nurse case management (Structured abstract). *Care Manage.* 2000;6:22-24.
35. Pare G, Sicotte C, St-Jules D, Gauthier R. Cost-minimization analysis of a telehomecare program for patients with chronic obstructive pulmonary disease. *Telemed J E Health.* 2006;12:114-121.
36. Patra J, Popova S, Rehm J, Bondy S, Flint R, Giesbrecht N. *Economic cost of chronic disease in Canada*: 1995-2003. Toronto: Ontario Public Health Association; 2007.
37. Quick Medical. *Piko-1 electronic peak flow meter. Quick medical equipment and supplies*. Snoqualmie, WA: Quick Medical; 2008.
38. Riegel B, Carlson B, Glaser D, Romero T. Randomized controlled trial of telephone case management in Hispanics of Mexican origin with heart failure. *J Card Fail.* 2006;12:211-219.
39. Riegel B, Carlson B, Kopp Z, LePetri B, Glaser D, Unger A. Effect of a standardized nurse case-management telephone intervention on resource use in patients with chronic heart failure. *Arch Intern Med.* 2002;162:705-712.
40. River Valley Health. *An evaluation of the Telehomecare Demonstrator Project: EMPcare@home*. Final Report. Fredericton, NB: River Valley Health; 2008.
41. Romanow RJ. *Building on values: The future of health care in Canada*. Final report. Saskatoon: Commission on the Future of Health Care in Canada; 2002.
42. Sanchez W, Harewood GC, Petersen BT. Evaluation of polyp detection in relation to procedure time of screening or surveillance colonoscopy. *Am J Gastroenterol.* 2004;99:1941-1945.
43. Southard BH, Southard DR, Nuckolls J. Clinical trial of an Internet-based case management system for secondary prevention of heart disease. *J Cardiopulm Rehabil.* 2003;23:341-348.
44. Vaccaro J, Cherry J, Harper A, O'Connell M. Utilization reduction, cost savings, and return on investment for the PacifiCare Chronic Heart Failure Program, "Taking Charge of Your Heart Health". *Dis Manag.* 2001;4:131-138.
45. Whitten PS, Mair FS, Haycox A, May CR, Williams TL, Hellmich S. Systematic review of cost effectiveness studies of telemedicine interventions. *BMJ.* 2002;324:1434-1437.
46. World Health Organization. *Diabetes: What is diabetes?* Geneva: WHO; 2006.
47. World Health Organization. *Chronic obstructive pulmonary disease (COPD)*. Programmes and projects: Chronic respiratory diseases. Geneva: WHO; 2008.
48. World Health Organization. *Facts related to chronic diseases*. Geneva: WHO; 2008.