Cost-effectiveness analysis of telemonitoring versus usual care in patients with heart failure: the TEHAF-study

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Summary

We examined the incremental cost-effectiveness of telemonitoring (TM) versus usual care (UC) in patients with congestive heart failure (CHF). In one university and two general hospitals, 382 patients were randomised to usual care or telemonitoring and followed for 1 year. Hospital-related and home costs were estimated, based on resource use multiplied by the appropriate unit prices. Effectiveness was expressed as QALYs gained. Information was gathered, using 3 monthly costs diaries and questionnaires. The mean age of the patients was 71 years (range 32–93), 59% were male and 64% lived with a partner. Health related quality of life improved by 0.07 points for the usual care and 0.1 points for the telemonitoring group, but the difference between groups was not significant. There were no significant differences in annual costs per patient between groups. At a threshold of €50,000 the probability of telemonitoring being cost-effective was 48%. The cost effectiveness analysis showed a high level of decision uncertainty, probably caused by the divergence between the participating institutions. It is therefore premature to draw an unambiguous conclusion regarding cost-effectiveness for the whole group.

Introduction

The prevalence of congestive heart failure (CHF) will rise in ageing populations and so will the related health care costs for these patients.[1,2] The prevalence of CHF is 1–2% in industrialised countries and increases with age.[3] Expenditure on CHF consumes 1–2% of the total healthcare budget in industrialised countries.[4,5] The danger is that the demand for care will exceed available resources.

Telemonitoring (TM) is a promising method for managing CHF,[6] but it has not yet been widely adopted. Studies regarding cost reductions are not convincing, mainly due to inconsistent methodology.[7,8] One study and two reviews suggested a tendency to lower costs, yet none reached definitive conclusions about costs.[9–11] We conducted the Telemonitoring in Heart Failure (TEHAF) study, to assess the effects on hospital admissions, quality of life, adherence, self-care, self-efficacy, disease specific knowledge and depression. Although the overall result, using time to first CHF hospitalisation as the endpoint, did not show a benefit, post-hoc analysis showed a significant decrease in CHF hospitalisations in the subgroup of patients with CHF duration less than 18 months (without a significant difference in mortality rate) and in face-to-face contacts with the heart failure nurse HFN.[11]

The aim of the present study was to investigate the incremental cost-effectiveness of TM versus usual care (UC) in patients with CHF and also in the subgroups of patients with CHF duration shorter or longer than 18 months.

Methods

A detailed description of the TEHAF study has been published elsewhere.[11,12] In short, 382 patients were included in the CHF outpatient clinics of three hospitals,

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if diagnosed for CHF, capable of providing informed consent, treated by a cardiologist and heart-failure nurse and being older than 18 years. Patients were excluded if operating the telemonitoring system was impracticable, the expected life span was <1 year, in case of chronic pulmonary disease Gold classification 3–4, or when receiving haemodialysis.

One academic and two general hospitals participated in the study, with 172, 144 and 66 patients respectively. All hospitals delivered care according the relevant guidelines, although the place where care was delivered differed between hospitals. In the academic centre, patient contacts took place in the outpatient clinic and at home; in one general hospital (144 patients) patient contacts occurred in the outpatient clinic and in the other centre (66 patients) patients were visited at home.

Patients were randomly allocated to UC or TM, and followed for 1 year. Patients in the UC group received oral and written information about CHF, had easy access to the HFN and four pre-planned outpatient clinic visits during follow-up. Patients in the TM group received identical information, but had only two pre-planned outpatient clinics. Instead they received a telemonitoring device (Health Buddy®, Sananet, Sittard, The Netherlands) at home.

The telemonitoring device had a display and four keys, and was connected to a telephone line. Patients received daily preset dialogues and questions about symptoms, knowledge and behaviour, which had to be answered by touching one of the keys. Subsequently the answers were transmitted to a server and made available via a server to the nurses' desktop. Responses were categorised into risk profiles, (low, medium, high)[13] allowing the nurse to quickly identify high-risk patients. Positive answers for symptoms were categorised as high-risk, and triggered immediate action by the heart-failure nurse.

We created four sets of dialogues with different emphasis on symptoms or knowledge and behaviour.[13] At the start of the study all patients received the same initial set of dialogues, which was evenly balanced for symptoms and education. After three months the first evaluation of symptoms and education level occurred, whereupon patients were allocated to an educational or an intensive symptom-monitoring program. This was based on the number of high-risk alerts during the last 30 days before the end of a program. Following an admission for heart failure, patients were always allocated to an intensive symptom monitoring set of dialogues. Monitoring of vital signs was not part of the system.

The study was approved by the appropriate ethics committees.

Outcome measurements

Effectiveness was expressed as quality adjusted life years (QALYs) gained. A QALY is calculated by multiplying the utility score of being in a certain health state by the time that the patient experienced that state. Utility scores were derived by conversion of the EQ-5D.[14] This is an instrument assessing five health-related quality of life (HRQoL) dimensions: mobility, self-care, daily activities, pain/discomfort and depression/anxiety. Patients at baseline and after 3, 6 and 12 months completed a postal questionnaire to measure EQ-5D. Based on preferences elicited from a general UK population,[15] EQ-5D status can be converted into utility scores, ranging from −0.59 (worst health state) to 1 (best health state).

Costs

The cost analysis was performed from the healthcare perspective, i.e. all costs inside the healthcare sector were included. Cost data were gathered by means of a 3-monthly prospective cost diary and provided by post with every questionnaire. Information was obtained at baseline, after 3, 6, 9 and 12 months. For calculation of the cost-effectiveness, baseline costs were not included, because the data reflected information from the 3 months prior to the study baseline. The cost diary collected data regarding contacts with the general practitioner (GP), telephone and face-to-face contacts with the HFN and specialists, emergency room visits, ambulance transport, sessions with the physiotherapist and psychologist, and homecare including household, personal and nursing care. Data about in-hospital procedures and hospital admissions were gathered from the hospital registry systems of the three participating centres. The patients' pharmacist provided costs about delivered medication. If this information was not available, costs were based on the prescriptions. Medication costs were calculated for all HF medications. Prices for medication were derived from the Dutch Pharmacotherapeutic Compass.[16] Prices of in-hospital procedures were provided by the participating hospital financial departments. Because of the follow-up time of 1 year, no discounting was used.

For the costs of hospitalisations and emergency room visits, GP, HFN, specialists, physiotherapist, psychological support and home care, prices were derived from a national cost manual.[17]

When necessary, prices were converted to the price level of 2008 using the price index number provided by the Dutch Central Bureau for Statistics.[18] For the intervention group, supplier-derived telemonitoring costs were added, such as device rental, maintenance and telecommunication costs. In case of a contact from a caregiver with a patient, the participating centres were responsible for the telephone bills. Costs were rounded to the nearest Euro.

Cost-effectiveness

Cost-effectiveness was expressed as an Incremental Cost-Effectiveness Ratio (ICER), which was calculated as incremental costs divided by incremental effects. The ICER can be interpreted as the extra monetary resources needed for the intervention strategy to gain one extra QALY compared to UC.

Table 1 Baseline characteristics

	Number	Total	Intervention (n = 197)	Control (n = 185)	*P*-value
Mean age, years (SD)	382	71.0 (11)	71.0 (11.9)	71.9 (10.5)	0.62
Number aged ≥75 years		173 (45)	88 (45)	85 (46)	0.20
Gender – male		226 (59)	115 (58)	111 (60)	
Married / partner	379	245 (64)	122 (62)	123 (66)	0.27
History of HF (months)	382	31 (±38)	32 (±38)	29 (±38)	0.41
HF history <18 months (SD)		196 (51)	98 (26)	98 (26)	
Ejection fraction, % (SD)	374	38 (14)	38 (14)	38 (14)	0.75
Ischaemia	382	190 (50)	99 (50.3)	91 (49.2)	0.84
NYHA classification / no (%)	382				0.40
NYHA II		219 (57)	110 (56)	109 (59)	
NYHA III		153 (40)	79 (40)	74 (40)	
NYHA IV		10 (3)	8 (4)	2 (1)	
Medication					
Diuretics	380	333 (87)	170 (86)	163 (88)	0.78
ACE inhibitors	378	217 (57)	113 (58)	104 (57)	0.83
ATII-antagonists	373	123 (33)	67 (35)	56 (31)	0.46
Beta-blockers	379	310 (82)	161 (82)	149 (81)	0.69
Digoxin	372	91 (24)	46 (24)	45 (25)	0.77
Charlson index (SD)	382	2.5 (1.5)	2.6 (1.5)	2.4 (1.4)	0.36

Data analyses

Demographic interval and ratio variables were investigated for normality of distribution with the Shapiro-Wilk test. Missing QALY and costs data were imputed using SPSS multiple imputation.[19] Data from patients without a valid utility score were removed from the analysis. Cost data were generally skewed and not normally distributed. Therefore, a non-parametric bootstrap with 1000 replications to estimate confidence intervals was performed.[20,21] The 2.5th and 97.5th percentiles represent the confidence interval.

The results of the bootstrap iterations were presented in cost-effectiveness planes and cost-effectiveness acceptability curves (CEACs).[22] The CEAC represents the probability that the intervention is cost-effective, for a range of thresholds for the willingness to pay (WTP) for one QALY. A CEAC is constructed by taking a certain WTP threshold and calculating the percentage of the 1000 bootstrapped ICERs that fall below that threshold, and therefore considered cost-effective at that threshold. By repeating this procedure for various thresholds, a curve is generated, with the WTP threshold on the x-axis and probability of the intervention being cost-effective on the y-axis. Severity of a disease co-determines the WTP threshold. While HF is considered a severe disease, for this analysis the threshold is conservatively assumed to be €50,000.[23]

Subgroup analysis was performed for the duration of CHF, in accordance with previously published results. In addition, subgroup analysis was performed per participating centre.[12] Analyses were performed using a standard package (SPSS version 18).

Results

The mean age of the patients was 71 years, 59% were male, 64% lived with a partner and 57% were in NYHA class II (Table 1). More detailed information regarding patient characteristics has been published elsewhere.[12]

Health-related quality of life

Data of 192 patients in the TM and 182 patients in the UC group were analysed. No significant differences were found at baseline. Utility scores improved by 0.07 points for the UC and 0.1 points for the TM group, but the difference between groups was not significant. This effect correlated with the QALY-score, which also showed no difference. The difference between the groups was −0.0031 QALY, with a 95% confidence interval (CI) of −0.0552 to 0.0578, indicating no difference in health-related quality of life. In addition the EQ-5D was assessed for the subgroup duration of CHF less or more than 18 months, and again there was no significant difference. For both the group as a whole and the subgroups, the EQ-5D rose consistently in the intervention group, in contrast to the UC group (Figure 1).

Costs

The total costs were €16,687 (CI 14,041–19,114) in the TM group and €16,561 (CI 13,635–20,218) in the UC group, see Table 2. The difference between groups was €126, indicating no significant difference (CI −4374–3763). None of the costs showed a significant difference between groups except for physiotherapy costs in the telemonitoring group, which were €46 (CI 9–101) higher. In the TM group the frequency of contacts with the HFN was higher, yet costs were lower as a result of fewer face-to-face contacts (€−31, CI −88–145).

Cost-effectiveness

The ICER for TM versus UC amounted to €40,321 per QALY gained. The incremental cost-effectiveness plane for cost per QALY is shown in Figure 2. The fact that the incremental

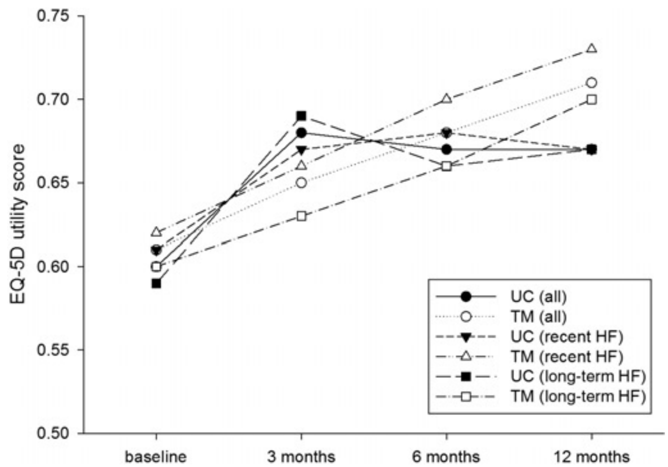

Figure 1 Mean EQ-5D utility scores for all assessments (Recent = heart failure duration ≤18 months; Long-term = heart failure duration >18 months)

cost-effectiveness pairs are located around zero and equally spread over the four quadrants indicates substantial uncertainty, for both costs and QALYs. The probability of telemonitoring being cost effective may depend on the amount that society is willing to pay (WTP) to gain a QALY. However, within the WTP range chosen, the WTP does not influence this probability (Figure 3). At a threshold of € 50,000 the probability of TM being cost-effective is 48%.

Subgroup analyses

Incremental cost effectiveness pairs in the subgroup of HF duration less than 18 months were located for 72% and 27% respectively in the upper- and lower right quadrant indicating that telemonitoring generated more QALYs and mostly at higher costs compared to UC (CI −4038–8063) (Figure 4). For incremental costs per QALY, the probability of telemonitoring being cost-effective compared to UC therefore was 75% (Figure 3). In the subgroup of patients with HF duration more than 18 months, 90% of the pairs were located in the left quadrants of the ICER plane, indicating lower QALYs, mostly combined with lower costs, and a probability of being cost effective of 42% (Figure 4).

Incremental cost effectiveness pairs from two centres (the university centre and general hospital 1) were located at the right quadrants indicating better health-related quality of life for the telemonitoring group. For the university centre, cost-effectiveness pairs were located in both right quadrants, indicating more QALYs with uncertainty of costs, whereas for general hospital 1, pairs were mostly located in the upper right quadrant, indicating more QALYs at higher costs for telemonitoring compared to the university centre (Figure 5). The respective ICERs for costs per QALY gained were €22,216 and €23,051. Cost effectiveness pairs for the remaining centre were mainly located in the lower left quadrant indicating lower QALYs at lower costs, with an ICER per QALY of €55,256.

Discussion

The incremental cost effectiveness analysis of the present study showed a high level of decision uncertainty for costs and QALYs. Therefore, for the group as a whole, it is not possible to draw an unambiguous conclusion. However, the subgroup analyses showed different effects between the three centres, of which two were in the same direction (Figure 5). All patients had contacts with the HFN, yet institutions had the opportunity to organise care according to their local procedures. Thus apparently the way that UC is organized may be a success or failure factor for telemonitoring to show cost-effectiveness. In centre 1, as depicted in Figure 5, patient contacts took place both in the outpatient clinic and at the patients' home in case of poor

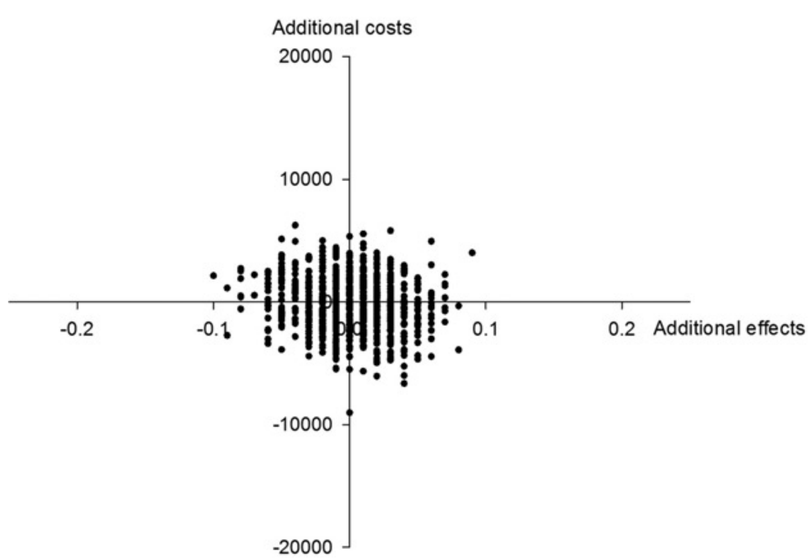

Figure 2 Incremental cost-effectiveness plane for cost per QALY (telemonitoring versus usual care)

Table 2 Mean volumes (SD) and costs (SD). Mean differences in costs with bootstrapped 2.5th and 97.5th percentiles. Significant differences are shown in bold. Both unit price and costs have been rounded to the nearest Euro

Cost category	Unit price, €	Usual care Volume (SD)	Cost, € (SD)	Telemonitoring Volume (SD)	Cost, € (SD)	Difference [TM-UC], € (Bootstrapped 2.5^{th}– 97.5^{th} percentile)
Total costs			16,561 (1510)		16,687 (1325)	126 (−4374–3763)
Device related costs	562	–		197	506 (135)	99,776
Hospital days						
University	567	4.5 (12.3)	2570 (6805)	5.7 (15.6)	3260 (8928)	690 (−1489–3086)
General	429	4.8 (11.7)	2061 (4671)	5.7 (12.2)	2447 (5299)	386 (−474–2557)
Hospital procedures#						
University	NA (various prices)		19,499 (20701)		18,8209 (19,390)	−679 (−5196–5956)
General	NA (various prices)		3110 (9276)		2406 (20,684)	−703 (−2930–859)
Emergency	151	0.6 (1.3)	94 (199)	0.57 (1.2)	87 (186)	−13 (−48–27)
GP-contacts*	37*	6.2 (7.1)	270 (345)	7.8 (12.2)	340 (1115)	127 (−88–145)
Heart failure nurse	52**	6.4 (6.3)	404 (639)	7.3 (6.0)	374 (615)	−30 (−134–101)
Specialists	91?	6.4 (5.1)	697 (512)	6.5 (5.9)	730 (613)	33 (−122–105)
Physiotherapist	36	1.4 (4.1)	54 (156)	2.9 (9.2)	100 (321)	**46 (9–101)**
Homecare						
Household care	24	5.1 (7.6)	124 (183)	4.9 (7.5)	117 (177)	−7 (−37–34)
Personal care	44	2.3 (6.1)	97 (259)	2.2 (5.3)	100 (239)	3 (−47–57)
Nursing care	65	0.4 (2.1)	29 (153)	0.4 (2.2)	31 (146)	2 (−18–36)
Medication#	NA		335 (290)		379 (352)	45 (−20–109)

Homecare and heart-failure nurse costs per hour; Costs for GP, specialists and physiotherapist per contact.
* Sum of all contacts with GP at practice. at home or telephonic and night care contacts
** Mean costs for contacts with heart-failure nurse in academic and general hospital; costs of telephone per telephonic contact
?Mean price for specialists in academic and general hospital
#No volumes because of high variety

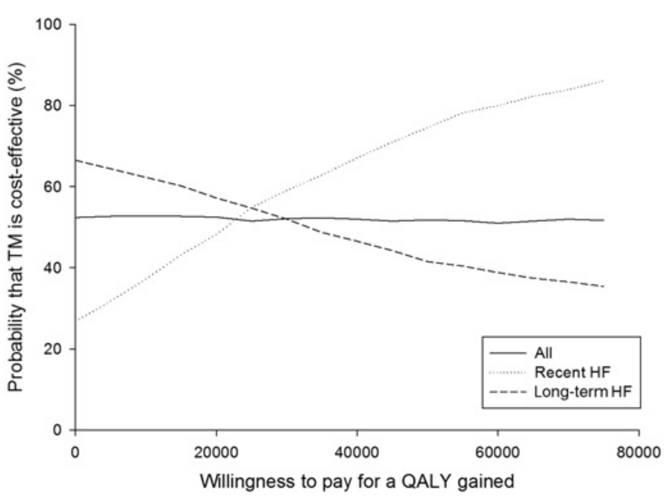

Figure 3 Cost-effectiveness acceptability curve for cost per QALY

mobility. In centre 2, contacts between nurse and patient occurred only in the outpatient clinic, and in centre 3 patients referred to the nurse were mostly in NYHA class III or IV and were only visited at home. Centre 3 included the lowest number of patients (66). Subgroup analyses showed that for patients with less than 18 months of HF, telemonitoring is probably a cost-effective treatment option, as the probability of the intervention being cost-effective was 75% at the prevailing WTP of €50,000/QALY.

Integration of rehabilitation is recommended in CHF guidelines.[24] In UC referral to a rehabilitation programme is often not part of structured care. In contrast, telemonitored patients with a low activity level were identified by the system and referred to the physiotherapist or a rehabilitation programme. This may have led to higher physiotherapist related costs.

Although the number of contacts with the HFN was higher caused by the higher number of telephone contacts, the related costs were lower due to fewer face-to-face contacts.[12] Frequent telephone contacts related to risk alerts were part of the protocol to ensure the safety of patients.

Medication information was not available via pharmacists in 25% of the cases, mostly due to confidentiality concerns. Data about in-hospital procedures and admissions were obtained via the hospital registration of the three participating centres, yet we had no insight into the manner that registration was performed.

In the cost-effectiveness analysis the healthcare perspective was chosen because most patients were, due to their age, not working. Hence, the potential productivity losses could be excluded from the analysis.

Reports in the literature show economic impact results that are mainly based on the hospital costs related to admission for CHF, and do not include home care.[25,26] A systematic review[27] showed cost reductions ranging from 1.6% to 68.3%. Cost savings were mainly attributed to reduced hospital expenditures related to CHF. One study also discussed the effect of telemonitoring on direct patient costs and found a 3.5% reduction in travel costs for the TM group.[28] Our study examined hospital costs, and also

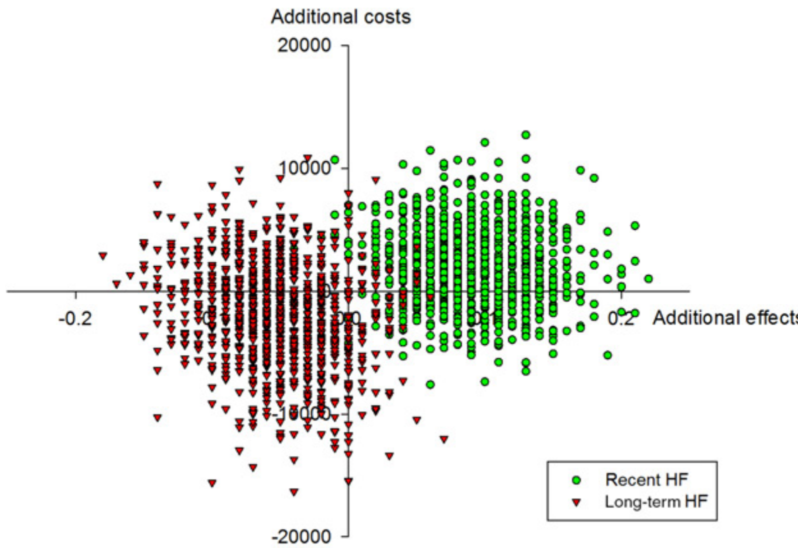

Figure 4 Incremental cost-effectiveness plane for cost per QALY

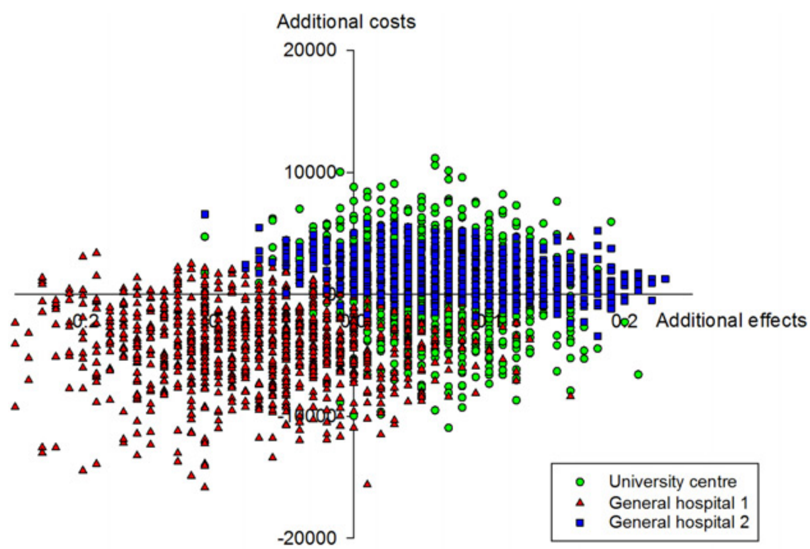

Figure 5 Incremental cost-effectiveness plane for cost per QALY for each participating centre

costs for general practice, non-CHF hospital admissions and medication. Given the lower admission rate for CHF,[11] the findings of the present study are consistent with the general results of Seto's review.[7] Another review[8] addressed the lack of long-term economic follow-up studies and the high heterogeneity regarding interventions, study populations and duration of follow-up. Klersy *et al.*[8] included 21 RCTs in their meta-analysis. However, in contrast with our study, costs were considered related to hospital admissions only and hospital length of stay. They found a significant difference in costs for all hospitalisations favouring telemonitoring, yet no difference for costs regarding hospital length of stay. The inclusion of only hospitalised patients in their analysis hampers the comparison with our study. The WHOLE study[9] performed in 3230 patients with different chronic diseases, included patients in primary care and found a significantly reduced number of hospitalizations and mortality, yet without a difference in costs. Our results were similar to the WHOLE study[9] regarding the number of hospitalisations for CHF and difference in costs. A review by Augustin *et al.*[10] reported divergent results for morbidity and mortality and a tendency for lower costs.

Mistry[11] criticised the reporting of the methodologies and findings of economic evaluations in a systematic review with 80 studies. It was reported that only one-third ($n = 28$) of the studies were RCTs and two-thirds had follow-up lasting less than 2 years, therefore not allowing an assessment of the long-term effects. Furthermore, most of the studies did not give adequate details about their design or information on how costs were collected, calculated or reported. In addition, nearly half of the articles ($n = 36$) did not explicitly report the study perspective. Consequently, it was concluded that no conclusive evidence exists to show that telemedicine interventions are cost-effective compared to conventional health care and that is in accordance with our findings.

Looking strictly at the CEACs (Figure 3), it seems that telemonitoring is the preferred strategy for patients with CHF >18 months, because the curve for this subgroup starts at a relatively high point. This was caused by the fact that most of the bootstrapped ICER estimates for these groups were located in the lower left quadrant, i.e. although costs were saved, QALYs were lost. From a broad health economic view, this can be considered cost-effective, since the money saved here can be used differently to generate QALYs at a better cost/QALY rate. But for the present population, it still means that QALYs are lost. Looking in more detail at the cost-effectiveness plane (Figure 4) it is suggested that in the subgroup with shorter duration of CHF, health-related quality of life is gained from the telemonitoring intervention. Our data suggest that telemonitoring for this group can be considered cost-effective at a rate of €50,000 or more for a QALY.

Limitations

Imputation of data for the three centres was performed in 11% of the cases. The centre with 66 participants was more heavily affected by imputation because of group size and outliers in costs. The patients provided very valuable data by means of a prospective diary. Although, some uncertainty remains, a cost diary is the most reliable way to collect non-institutional data.[29] Not all data about delivered medication were available via pharmacists. In 25% of the cases medication use was gathered by the prescriptions, yet it is uncertain if this medication was delivered.

Conclusion

The overall incremental cost effectiveness analysis showed a high level of decision uncertainty. Unambiguous conclusions about the whole group cannot therefore be drawn. However, there was a relatively high probability for telemonitoring to be cost effective in the subgroup with shorter duration of CHF. The telemonitoring system seemed to adequately identify patients at low activity level, resulting in more frequent referrals to the physiotherapist, hence generating higher effectiveness and physiotherapy costs. Our data suggest that patients with shorter CHF duration should be considered for telemonitoring.

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