Tele-monitoring and self-management in the control of hypertension (TASMINH2)

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Telemonitoring And Self-Management In The Control Of Hypertension (TASMINH2): A cost-effectiveness analysis

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Abstract

Background: Little evidence exists regarding the cost-effectiveness of self-monitoring of blood pressure in general and self-management of hypertension in particular.

Objective: To evaluate whether self-management of hypertension was cost-effective when compared to usual care.

Design: A Markov model-based probabilistic cost-effectiveness analysis.

Data sources: Cost and utility data collected from the telemonitoring and self-management in hypertension trial (TASMINH2) and from the literature.

Target population: UK population with mean age 66 years.

Time Horizon: Lifetime

Perspective: UK Health Service perspective

Intervention: Self-management of hypertension including self-monitoring and self-titration of antihypertensives

Outcome measures: Lifetime costs, quality adjusted life years (QALYs) and incremental cost-effectiveness ratios

Results of Base-Case Analysis: In the long-term, when compared to usual care, self-management was more effective, by 0.1290 (95% CI 0.0854, 0.1762) QALYs gained per patient, but also more expensive per patient albeit not significantly, (£590 (US$896) (95% CI £-810 to £1,903)). The resultant incremental cost-effectiveness ratio for self-management was £4,576 (US$ 6,952) per QALY (95% CI: usual care dominated to £16,814), with a 99%

chance of the intervention being cost-effective at a willingness to pay threshold of £20,000 (US$ 30,000) per QALY gained.

Results of sensitivity analyses: These results were robust to the effect of different time horizons, reduced effectiveness over time from self-management and the distributional uncertainty in Markov model inputs.

Limitation: Adverse effects were not expressly modelled but are taken into account in quality of life measures and were infrequent in the underlying trial.

Conclusion: Self-monitoring with self-titration of antihypertensives and telemonitoring of blood pressure measurements not only reduces blood pressure, compared to usual care, but also represents a cost-effective use of health care resources.

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Clinical Trial Registration: http://www.controlled-trials.com/ISRCTN17585681/TASMINH2 (ISRCTN17585681)

Introduction

Raised blood pressure remains a key factor in determining lifetime risk of cardiovascular disease, the largest cause of morbidity and mortality worldwide, yet only about a half of people on treatment for hypertension have their blood pressure controlled to recommended levels.(1-3) This difficulty in achieving control is despite significant advances in the evidence base for both lifestyle and pharmaceutical interventions.(4;5) Therefore, there is a potentially important role for novel interventions to lower blood pressure, particularly in primary care, where most hypertension management takes place.

One such approach is patient self-management, which has gained widespread use in other chronic conditions such as diabetes (6) and anticoagulation control.(7) Self-management comprising self-monitoring and self-titration of antihypertensive medication, has recently been shown to reduce blood pressure but prior to implementation the implications of the additional requirements (training, monitoring equipment) on costs and cost-effectiveness need to be evaluated.(8)

Previous work has largely evaluated the cost-effectiveness of self-monitoring of hypertension. The results of these evaluations have been inconsistent and have not been extrapolated to the longer term. (9-15) One study reported trial costs of self-monitoring with a behavioural self-management intervention and then conducted an informal cost-effectiveness analysis with results expressed in terms of costs per life years (10). To our knowledge, no studies to date have examined the long-term cost-effectiveness of self-monitoring combined with self-titration in hypertension.

This study aimed to assess the long-term cost-effectiveness of self-monitoring with self-titration of antihypertensives and telemonitoring of blood pressure measurements, hereafter simply referred to as self-management of hypertension or intervention, in comparison with usual hypertension care. A model-based probabilistic cost-effectiveness analysis was undertaken extrapolating from cost and utility data collected from the first major randomised controlled trial (RCT) of such self-management (TASMINH2).(8)

Methods

Development of the cost-effectiveness model

The long-term cost-effectiveness of self-management of hypertension compared to usual care in patients with treated but poorly controlled hypertension was estimated using a Markov model. The model was built in TreeAge Pro 2009 (16) using previously documented methods (17;18) Briefly, this entailed dividing a patient's possible course of disease progression into a number of health states with transition probabilities assigned for the movement between these states over a discrete time period called the Markov cycle. Long-term costs and health outcomes were assessed by attaching estimates of resource use and health outcomes to the states in the model and then running the model over a large number of cycles.

In the model, the long-term progress of a hypothetical cohort of hypertensive patients moving along the two alternative pathways of care as received in the trial was compared. The methodological details of this prospective RCT are reported elsewhere.(19) Briefly, primary care physicians identified potential participants from among their own patients using electronic searches of practice clinical record systems from 24 general practices in the West Midlands, United Kingdom (UK) between March 2007 and May 2008. (20) To be eligible, patients had to be aged 35-85, have a blood pressure at baseline of over 140/90 mmHg, be receiving treatment for hypertension with two or fewer antihypertensive drugs and also be willing to self-monitor and self-titrate medication. Patients following the self-management pathway were trained in the use of an automated sphygmomanometer (Omron 705IT, Omron Healthcare Europe, Hoofddorp, Netherlands) and associated equipment to take and transmit blood pressure readings.(8) On the basis of their readings and following an initial consultation with their primary care physicians, patients could make medication changes without needing to re-consult. (8) For usual hypertension care, patients received an annual hypertension review as per UK national guidelines.(21;22) Thereafter health resources use for both groups was as observed in the trial, with subsequent clinical pathways designed to mirror the natural progression of the condition in the population (see below).

Model-based predictions of costs and outcomes were compared for the intervention and usual care groups in a cost-utility analysis (CUA) from the UK National Health Service (NHS) perspective. This choice of cost perspective reflected the effect that the NHS budget constraint has on decision making by the UK National Institute for Health and Clinical Excellence (NICE) and was also in recognition of the fact that the burden of financing of healthcare in the UK falls on the NHS.

Model structure and inputs

The structure of the Markov model is shown in Figure 1. Only health states for the 'Self-management of hypertension' arm are shown but these are identical to those in the 'usual care' arm. In broad terms, individual patient data were used from the TASMINH2 trial,(8) supplemented by the best available estimates from published sources, where necessary. The mean age of patients on entry into the model was 66 years.(8) The time horizon for the model was 35 years which was the patient lifetime assumed in the analysis.

The Markov process for each arm began with the initial health state, 'well,' representing individuals with stable but poorly controlled hypertension. Patients could remain in the well state or move to one of five possible acute health states namely stroke, myocardial infarction (MI), angina, heart failure (HF) and peripheral vascular disease (PVD).(23) Individuals that survived an acute phase in any of the five health states naturally progressed into a chronic phase where quality of life was lower than in the "well" state (see table 2 for utilities). Individuals in a chronic health state remained in that state for the rest of their lives unless they died before the end of the time horizon for the model. The risk of secondary events was not modelled and a cycle length of one year was used.

Transition probabilities governing movement between the six states were obtained from published sources (24-31) and are shown in table 1. In order to arrive at the annual risk rates of experiencing any of the five cardiovascular events used in the model, 10 year risk values were calculated using the Framingham equation.(31) These rates were then split between the

five health states by weighting the risks according to proportions obtained from D'Agostino et al. (23)

Age-related relative risks of having a cardiovascular event following use of antihypertensive drugs, together with associated reductions in BP, were obtained from Law et al.(4) This information was then used to extrapolate from the 12 month reductions in BP recorded in the TASMINH2 trial (17.6mmHg and 12.2mmHg for the intervention and control arms, respectively (8)) to the age-related relative risks subsequently used in the model. The base case assumed that the 12-month difference in BP between self-management and usual care was maintained over the lifetime of the model, as were the costs of the intervention and this assumption was then tested in sensitivity analyses (see below). The extrapolated relative risk for coronary heart disease (CHD) was also assumed for MI, angina and HF using data on the breakdown of CHD events from Wood et al (32) while that for stroke was assumed for PVD as well. Risk rates, depicting the probability of developing a condition as well as that of dying from it or from other causes, were incorporated in the model as shown in table 1.

Resource use and costs

All costs are reported in UK pounds at 2009/10 unit prices and, where appropriate, were discounted at 3.5% as recommended by NICE.(33) Resource use and subsequent costs per patient obtained from the TASMINH2 trial were applied to the initial health state in the model. Total costs per patient in the trial were calculated as the sum of the costs of inpatient and outpatient visits, primary care consultations, drugs, equipment and training. Equipment and training costs (£230) were annuitized at 3.5% and based on a lifetime of five years.(34) Replacement costs for the equipment and costs of additional training were included at 5-yearly intervals over the lifetime of the model. Equipment used by individuals who died within any 5-year interval was assumed to be discarded. Costs for the acute and chronic states were obtained from a number of other sources.(35;35-38) Costs considered over the lifetime of the model included costs of treatment, the intervention, consultation, and subsequent cardiovascular events. All cost data are shown in table 2.

Utility values

All utility scores, which reflect the health-related quality of life associated with each health state in the model, are shown in table 2. The starting quality of life (QoL) for individuals in the model was assumed to be 0.82. This was calculated as the average of the baseline EQ-5D scores for patients in the TASMINH2 trial.(8) Where an acute event occurred, it was assumed to happen approximately six months into a one year cycle; individuals stayed in that acute state for six months before transitioning into a chronic state. Utilities for the acute state were therefore applied mid-way through the one-year cycle and those for the chronic state at the start of the next cycle following an acute event. Utility values for all acute and chronic health states were obtained from Cooper et al.(38)

Analysis

The analyses were undertaken from a UK NHS perspective and the primary result reported in terms of the incremental cost per quality adjusted life year (QALY) gained. A QALY is a measure of health obtained by adjusting a year of life for its quality or value.(34) Probabilistic analyses were used in the base case based on 50,000 Monte Carlo simulations. A gamma distribution was fitted to the costs obtained from the TASMINH2 trial.(8) Lognormal distributions were used for the increased risks of death from any of the conditions, for the one year risk of experiencing an event and for the age-dependent relative risks associated with each of the events. Beta distributions were used to model the probability of dying from any of the cardiovascular events as well as the uncertainty around the utility values. The parameters used for these distributions are shown in Tables 1 and 2. Deterministic analyses were also undertaken.

A cost-effectiveness plane (CEP) and a cost-effectiveness acceptability curve (CEAC) were constructed.(39;40) The CEP shows the relationship between the incremental cost and incremental effect of one intervention relative to another while the CEAC depicts the probability of one intervention being more cost-effective compared to an alternative at different willingness-to-pay thresholds. (39)

Uncertainty in the model results was assessed using sensitivity analyses. These involved varying the time horizon for the model from a lifetime time horizon to between 5 and 30 years. These time periods were chosen to represent plausible points at which the cost-effectiveness of the intervention could be assessed. In further sensitivity analyses, the assumption regarding the long term effectiveness of the intervention was tested by assessing the impact of reductions in effectiveness after the initial year of the study: a 25% reduction in blood pressure lowering in the intervention arm (from 17.6mmHg to 13.2mmHg) meant that the blood pressure difference between the two groups dropped from 5.4mmHg to 1mmHg, while a 30.7% reduction (from 17.6mmHg to 12.2mmHg) modelled the impact of a complete loss of incremental effectiveness of the intervention. These reduced effects were applied at three time points: 1, 4 and 14 years after commencement of the intervention. Extra time points relating to the effect of the 30.7% reduction (at 2 and 3 years post-intervention commencement) were also included to show points at which the intervention became cost effective when assessed against the threshold of £20,000-£30,000 (US$ 30,000–45,000)/QALY gained, which is the conventional criterion adopted by decision makers in the UK NHS, such as NICE.(33)

Role of the Funding Source

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Results

The mean lifetime costs and QALYs, based on the probabilistic approach, are presented in Table 3. Compared to usual care, self-management of hypertension was associated with a trend towards higher mean costs of £590 ($896) (95% CI £-810 to £1,903) [self-management

£6,831 (95% CI: £5,753 to £8,310) vs usual care £6,241 (95% CI: £4,748 to £8,158)] and higher QALY gains of 0.1290 (95% CI 0.0854 to 0.1762) [10.5111 (95% CI: 9.9396 to 10.9270) vs 10.3865 (95% CI: 9.7633 to 10.8415) respectively] giving an ICER of £4,576 (US$ 6,952)/QALY gained. The 95% CI for this ICER ranged from self-management of hypertension dominating usual care to an upper limit of £16,814 (US$ 25,544)/QALY gained i.e. 95% CI: SM to £16,814. These results from the probabilistic analysis did not differ in any substantive way from those based on the deterministic analysis, also presented in table 3.

Figures 2a and 2b present the cost-effectiveness plane (CEP) and cost-effectiveness acceptability curve (CEAC), respectively, comparing self-management of hypertension to usual care when distributional uncertainty was incorporated. The CEP in figure 2a shows the joint distribution of the mean incremental costs and mean QALYs gained with most results in the north-east and south-east quadrants. The CEAC in figure 2b shows that the probability of self-management of hypertension being cost-effective compared to usual care was at least 99% if decision makers were willing to pay at least £20,000 (US$ 30,000) per QALY-gained. (39) At lower thresholds, however, the probability of the intervention being cost-effective compared to the control was lower, dropping to 50% at around £5,000 (US$ 7,596) per QALY-gained.

Table 3 shows that the ICERs for all time horizons considered were below £20,000 (US$ 30,000) per QALY gained. The other sensitivity analyses conducted involved modelling a declining impact of the intervention on BP reduction (Table 4). When a 25% decline in effectiveness of the intervention was applied 1, 4 and 14 years after commencement of the intervention,, this resulted in ICERs of £16,027 (95% CI: SM to £67,291), £10,587 (95% CI: SM to £48,723) and £6,074 (95% CI: SM to £23,504) per QALY gained, respectively. When no difference between the two groups in terms of effectiveness was assumed (i.e. when a 30.7% decline in effectiveness of the intervention was applied), the following ICERs were obtained at 1, 2, 3, 4 and 14 years after commencement of the intervention, respectively: £36,278 (95% CI: SM to £515,176), £23,964 (95% CI: SM to £174,573), £18,477 (95% CI: SM to £99,440), £15,376 (95% CI: SM to £110,610) and £6,705 (95% CI: SM to £26,982).

Discussion

Statement of principal findings

The primary analysis shows that self-monitoring and self-titration of antihypertensive medication is more cost-effective than usual hypertension care, provided decision makers are willing to pay at least £4,500 (US$ 6,800) per QALY which is well within the cost-effectiveness criteria applied in the UK NHS.(33) Despite the intervention being more costly than the control, it was associated with better quality of life due to reduced cardiovascular events. No evidence was found that self-management of hypertension was associated with deleterious direct effects on quality of life. (8) The main driver of benefit was a decline in the number of cardiovascular events associated with self-management.

Varying the time horizons of the model from the life time (35 years) period used in the base case analysis and assuming a threshold of £20,000-30,000 (US$ 30,000–45,000)/QALY(33;41) showed that self-management of hypertension was still more cost-effective than usual care at all time periods. Similarly, provided the effects of blood pressure reduction observed (5.4 mmHg systolic) lasted at least 2 years, the intervention was cost effective. Furthermore, the intervention remained cost-effective after incorporating distributional uncertainty around the inputs used in the Markov model.

Strengths and limitations

A strength of this the study was the incorporation of cost and outcome data from the first major randomised controlled trial of self-management which had high levels of follow up and data capture.(8) The use of a Markov model overcame limitations associated with within-trial analyses due to the short time scale which makes it difficult to observe or model effects on long term events. It was thus possible to use generalisable data to assess the long term cost-effectiveness beyond the trial period and model cardiovascular events and mortality.

Adverse effects, such as anxiety or drug side effects, were not modelled as robust data on the consequences of these on quality of life were not available, although no difference in anxiety between groups was seen in the trial.(8) Additional costs of monitoring potential side effects were captured by the primary care resource data collection. A potential weakness was that effectiveness of the intervention after the year of the study was unknown: the blood pressure curves were still diverging at that point. (8) Other studies have found persisting differences in outcome despite cessation of interventions.(42) The base case therefore assumed that the effects of the intervention persisted after the year of study. Sensitivity analyses modelled the effect of various potential reductions in efficacy of the intervention. The results remained robust to such reduction in efficacy, provided that some element of effectiveness was maintained for at least an additional 12 months after the initial year of intervention.

While the Framingham risk score (31) is not based on contemporary data, it is still the recommended and most widely used system. (43) Further, any inaccuracies in the equation should not have affected the results as cardiovascular risk was estimated in the same way for both intervention and control but may have reduced the size of the ICERs observed. Data on quality of life for the different health states came from published sources which may have led to some variability in terms of the way QALYs were calculated. Again, because these were applied to both groups, biases would have been reduced. Finally, the model has the structural limitation of not considering secondary events. This is a conservative assumption as reduction of blood pressure would be expected to reduce these in addition to the primary events considered hence self-management may be more cost effective than found.

Comparisons with other studies

This is the first economic analysis of self-monitoring and self-titration of hypertensive medication. A US randomised trial comparing usual care with twice weekly self-monitoring found a reduction in costs but not blood pressure in the intervention group. However the increased cost of medical care in the US and the age of the study mean that these results are not immediately transferable outside of that setting.(9) Reed et al found that a tailored behavioural self-management intervention combined with home blood pressure monitoring led

to statistically and clinically significant reductions in blood pressure but raised costs to the health-care system.(10) An informal estimate with a shorter time horizon of 12 years estimated an ICER of approximately $23,000 per life-year saved (10) A trial of self-monitoring in practice waiting rooms found that this intervention was not significantly more expensive than usual care.(11) Fukunaga established that self-monitoring of hypertension was cost-effective, although this was in terms of the detection of 'white coat' hypertension.(12) A Danish study found that the cost savings of home telemonitoring of blood pressure due to lower consultation and medication costs were negated by the cost of the telemonitoring equipment with uncertainty around the cost effectiveness results.(13) A final study comparing cost-effectiveness of different adherence-improving interventions for antihypertensive and lipid-lowering treatment found that self-monitoring, in combination with reminders and educational materials, was more cost-effective than usual care but less cost-effective than pharmacist/nurse management. (14)

In other clinical areas, economic analyses have reached varying conclusions: self-management of anticoagulation was not cost-effective under conventional criteria due to increased costs with equivalent efficacy, (38;44) whereas self-management of asthma was associated with both increased effectiveness and lower costs.(45) Richardson and colleagues showed that a generic, lay administered self-management course for chronic disease was cost-effective.(15) Uncertainties in the data underline the importance of accompanying implementation of self-management with ongoing cost-effectiveness evaluation to ensure that the results are replicated outside of trial conditions.

Clinical Implications

The introduction of new technologies into health systems requires robust evidence of both effectiveness and cost-effectiveness. Previous work has shown the former (8) and this paper provides data on the latter which should encourage commissioners of health to consider the utilisation of self-management of hypertension in daily practice. Whilst self-management may only be appropriate for a minority of individuals with hypertension, the numbers of people

affected both in the UK (2) and worldwide (46) mean that many millions of people could benefit from the implementation of this technology.

Conclusions

The results of this model-based economic evaluation suggest that self-monitoring with self-titration of antihypertensives is a cost-effective strategy in the long term, resulting in QALY gains as well as lower blood pressure (8). Self-management of hypertension represents an important new addition to the management of hypertension in primary care.

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Approval

This study was approved by an Institutional Review Board

Contributorship

RJM had the original idea for the study and gained funding in collaboration with JM, SB, RH, PL, BW and FDRH. Data for the trial were collected by the research team supervised by EB and RJM. BK undertook the analyses and wrote the first draft supervised by SB and SJ. Subsequent drafts were contributed to by all authors who have approved the final version. RJM will act as guarantor.

Disclosures

None

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Table 1. Estimates of risk rates, probabilities & distributions used in the reference case and sensitivity analyses

Description	Point estimate*	Distribution†	Source
Risks & probabilities			
Increased risk of death from Angina	2.19 (2.05, 2.33)	Lognormal	NCGC (2010) (24)
Increased risk of death from Heart Failure (HF)	2.17 (1.96, 2.41)	Lognormal	de Guili et al (2005) (25)
Increased risk of death from Myocardial Infarction (MI)	2.68 (2.48, 2.91)	Lognormal	Bronnum-Hansen et al (2001) (26)
Increased risk of death from Peripheral vascular disease (PVD)	2.44 (1.59, 3.74)	Lognormal	Leng (1996) (27)
Increased risk of death from stroke	2.72 (2.59, 2.85)	Lognormal	Bronnum-Hansen et al (2001) (26)
1 year risk of Angina‡	0.008 (0.004, 0.012)	Lognormal	Anderson et al (1991) (31)
1 year risk of HF‡	0.002 (0.001, 0.004)	Lognormal	Anderson et al (1991) (31)
1 year risk of MI‡	0.005 (0.003, 0.009)	Lognormal	Anderson et al (1991) (31)
1 year risk of PVD‡	0.004 (0.002, 0.006)	Lognormal	Anderson et al (1991) (31)
1 year risk of stroke‡	0.004 (0.002, 0.006)	Lognormal	Anderson et al (1991) (31)

Relative risks of angina, HF & MI events by age (Self-monitoring arm)[§,]			
66-69 years	0.58 (0.52, 0.63)	Lognormal	Law et al (4) & TASMINH2(8)
70-79 years	0.64 (0.59, 0.69)	Lognormal	Law et al (4) & TASMINH2(8)
>79 years	0.70 (0.66, 0.74)	Lognormal	Law et al (4) & TASMINH2(8)
Relative risks of PVD & stroke events by age (Self-monitoring arm)[‖]			
66-69 years	0.47 (0.41, 0.54)	Lognormal	Law et al (4) & TASMINH2(8)
70-79 years	0.54 (0.47, 0.60)	Lognormal	Law et al (4) & TASMINH2(8)
>79 years	0.70 (0.66, 0.74)	Lognormal	Law et al (4) & TASMINH2(8)
Relative risks of angina, HF & MI events by age (Usual care arm)[§,]			
66-69 years	0.69 (0.63, 0.74)	Lognormal	Law et al (4) & TASMINH2(8)
70-79 years	0.74 (0.69, 0.79)	Lognormal	Law et al (4) & TASMINH2(8)
>79 years	0.79 (0.74, 0.83)	Lognormal	Law et al (4) & TASMINH2(8)
Relative risks of PVD & stroke events by age (Usual care arm)[‖]			
66-69 years	0.60 (0.54, 0.67)	Lognormal	Law et al (4) & TASMINH2(8)
70-79 years	0.66 (0.60, 0.72)	Lognormal	Law et al (4) & TASMINH2(8)
>79 years	0.79 (0.74, 0.83)	Lognormal	Law et al (4) & TASMINH2(8)

Probability of death from HF	0.17 [r=68, n=396][¶]	Beta	Mehta et al (2009) (28)
Probability of death from MI	0.52 [r=351, n=675][¶]	Beta	Volmink et al (1998) (29)
Probability of death from stroke	0.23 [r=125, n=545][¶]	Beta	Bamford et al (1990) (30)

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* Figures in round parentheses are 95 % Confidence interval limits

[†] Distributions used in probabilistic sensitivity analysis

[‡] These baseline risk values were calculated from 10 year risk values in Anderson et al (1991) (31) and split among 5 disease using probabilities from D'Agostino et al (2008) (23)

[§,] The relative risk for having a coronary heart disease (CHD) event was also applied to angina, HF and MI events.

[‖] The relative risk for having a stroke event was also applied to PVD events.

[§, ‖] Age-related relative risks were extrapolated from Law et al (2009) (4) based on 12 month BP reductions of 17.6mmHg in the intervention arm and 12.2mmHg in the control arm (from TASMINH2 trial(8)). BP reduction in both arms was assumed to be maintained over the lifetime of the model.

[¶] Figures in squared parentheses are occurrences (r) and population size (n).

Table 2. Estimates of costs, utilities & distributions used in the reference case and sensitivity analyses

Description	Point estimate	Distribution*	Source
Costs for the initial (well) health state (UK £)[†]			
Self–monitoring arm	£475 (413, 597)[‡,] SE=27	Gamma	TASMINH2 trial (8)
Usual care arm	£370 (239, 393)[‡] SE=47	Gamma	TASMINH2 trial (8)
Costs for acute disease health states (UK £)			
Angina	£2,521	Gamma[§]	Palmer et al (2004) (35)
Heart Failure (HF)	£1,860	Gamma[§]	Department of Health (2010) (36)
Myocardial Infarction (MI)	£1,763	Gamma[§]	Palmer et al (2004) (35)
Peripheral vascular disease (PVD)	£1,546	Gamma[§]	Department of Health (2010) (36))
Stroke	£8,316	Gamma[§]	Youman et al (2003) (37)

Costs for long-term (chronic) disease health states (UK £)			
Angina	£556	Gamma[§]	Cooper et al (2008) (38)
HF	£556	Gamma[§]	Cooper et al (2008) (38)
MI	£556	Gamma[§]	Cooper et al (2008) (38)
PVD	£285	Gamma[§]	Cooper et al (2008) (38)
Stroke	£2,555	Gamma[§]	Youman et al (2003) (37)
Utilities for initial (well) health state			
Self–monitoring arm	0.82[‖] (0.212)[¶]	Beta	TASMINH2 (8)
Usual care arm	0.82[‖] (0.212)[¶]	Beta	TASMINH2 (8)
Utilities for acute disease health states			
Angina	0.77 (0.038)[¶]	Beta	Cooper et al (2008) (38)
HF	0.68 (0.020)[¶]	Beta	Cooper et al (2008) (38)
MI	0.76 (0.018)[¶]	Beta	Cooper et al (2008) (38)
PVD	0.90 (0.020)[¶]	Beta	Cooper et al (2008) (38)
Stroke	0.63 (0.040)[¶]	Beta	Cooper et al (2008) (38)

Utilities for long-term (chronic) disease health states

Angina	0.88 (0.018)[¶]	Beta	Cooper et al (2008) (38)
HF	0.68 (0.020)[¶]	Beta	Cooper et al (2008) (38)
MI	0.88 (0.018)[¶]	Beta	Cooper et al (2008) (38)
PVD	0.90 (0.020)[¶]	Beta	Cooper et al (2008) (38)
Stroke	0.63 (0.040)[¶]	Beta	Cooper et al (2008) (38)

* Distributions used in probabilistic sensitivity analysis

† Total costs included costs of drugs, outpatient visits, inpatient visits, GP visits and the intervention (equipment and training). The cost difference between self-monitoring and usual care was driven by cost of the intervention.

‡ 95% confidence interval

§ As only point estimates were obtained for these costs, the standard error was assumed to be equal to the mean as has been done elsewhere (38;47).

ǁ Average of the EQ-5D scores for the intervention and control arms in the TASMINH2 trial ¶ Standard error

Table 3. Cost-effectiveness results (Base case based on probabilistic analysis, sensitivity analysis involving changing time horizons and deterministic analysis)

Time Horizon	Costs/QALYs	Intervention group	Control (Usual Care) group	Difference	ICER* (95% CI[†])
Base case results – Probabilistic Analysis					
Life time	Mean total health care costs	£6,831	£6,241	£590	£4,576 (SM[‡] to £16,814)
	(95% CI[†])	(£5,753 to £8,310)	(£4,748 to £8,158)	(£-810 to £1,903)	
	Mean QALYs gained	10.5155	10.3865	0.1290	
	(95% CI[b])	(9.9396 to 10.9270)	(9.7633 to 10.8415)	(0.0854 to 0.1762)	
Changing the time horizon – Probabilistic Analysis					
30 years	Mean total health care costs	£6,750	£6,182	£568	£4,677 (SM[‡] to £17,785)
	(95% CI[†])	(£5,683 to £8,223)	(£4,710 to £8,089)	(£-834 to £1,886)	
	Mean QALYs gained	10.3984	10.2770	0.1214	
	(95% CI[†])	(9.8572 to 10.7850)	(9.6900 to 10.7058)	(0.0793 to 0.1676)	

	Mean total health care costs	£6,514	£5,983	£531	
25	(95% CI[†])	(£5,479 to £7,938)	(£4,535 to £7,814)	(£-807 to £1,810)	£5,116
years	Mean QALYs gained	10.0720	9.9682	0.1038	(SM[‡] to £19,970)
	(95% CI[†])	(9.6059 to 10.3910)	(9.4592 to 10.3238)	(0.0672 to 0.1465)	
	Mean total health care costs	£5,999	£5,540	£459	
20	(95% CI[†])	(£5,051 to £7,065)	(£4,209 to £7,231)	(£-803 to £1,635)	£5,897
years	Mean QALYs gained	9.3647	9.2869	0.0779	(SM[‡] to £24,177)
	(95% CI[†])	(9.0263 to 9.5966)	(8.9146 to 9.5473)	(0.0494 to 0.1119)	
	Mean total health care costs	£5,091	£4,747	£344	
15	(95% CI[†])	(£4,300 to £6,185)	(£3,616 to £6,166)	(£-745 to £1,367)	£7,040
years	Mean QALYs gained	8.1324	8.0835	0.0489	(SM[‡] to £32,226)
	(95% CI[†])	(7.9251 to 8.2696)	(7.8535 to 8.2389)	(0.0308 to 0.0716)	
	Mean total health care costs	£3,744	£3,545	£200	
10	(95% CI[†])	(£3,177 to £4,494)	(£2,719 to £4,560)	(£-641 to £996)	£8,372
years	Mean QALYs gained	6.2712	6.2473	0.0239	(SM[‡] to £47,466)
	(95% CI[†])	(6.1771 to 6.3334)	(6.1422 to 6.3184)	(0.0151 to 0.0349)	

5 years	Mean total health care costs	£1,962	£1,949	£14	
	(95% CI[†])	(£1,666 to £2,349)	(£1,502 to £2,498)	(£-474 to £465)	£2,131
	Mean QALYs gained	3.6441	3.6377	0.0064	(SM[‡] to £18,845)
	(95% CI[†])	(3.6206 to 3.6592)	(3.6114 to 3.6551)	(0.0041 to 0.0092)	
Deterministic Analysis					
Life time	Mean total health care costs	£6,824	£6,235	£589	£4,597
	Mean QALYs gained	10.5458	10.4176	0.1282	

* ICER – Incremental cost-effectiveness ratio

[†] CI – confidence interval

[‡] Where the acronym for the self-management of hypertension arm (SM) is given instead of an ICER, it means that SM dominates usual care i.e. less costly and more effective

. **Table 4. Cost-effectiveness results of declining impact of self-monitoring on BP reduction**

Time Horizon	**Costs/QALYs**	**Intervention group**	**Control (Usual Care) group**	**Difference**	**ICER*** (95% CI†)
25% decline‡ in impact of intervention on BP reduction applied 1 year after commencement of intervention					
Life time	Mean total health care costs (95% CI†)	£6,883 (£5,750 to £8,451)	£6,245 (£4,749 to £8,111)	£638 (£-767 to £1,953)	£16,027 (SM‖ to £67,291)
	Mean QALYs gained (95% CI†)	10.4284 (9.8365 to 10.8633)	10.3886 (9.7681 to 10.8444)	0.0398 (0.0191 to 0.0683)	
25% decline‡ in impact of intervention on BP reduction applied 4 years after commencement of intervention					
Life time	Mean total health care costs (95% CI†)	£6,872 (£5,757 to £8,440)	£6,242 (£4,738 to £8,150)	£629 (£-768 to £1,942)	£10,587 (SM‖ to £48,723)
	Mean QALYs gained (95% CI†)	10.4480 (9.8443 to 10.8696)	10.3885 (9.7611 to 10.8417)	0.0594 (0.0278 to 0.0827)	

25% decline[‡] in impact of intervention on BP reduction applied 14 years after commencement of intervention

	Mean total health care costs	£6,857	£6,249	£608	
Life	(95% CI[†])	(£5,757 to £8,325)	(£4,748 to £8,131)	(£-789 to £1,918)	£6,074
time	Mean QALYs gained	10.4862	10.3861	0.1001	(SM[ll] to £23,504)
	(95% CI[†])	(9.9000 to 10.9028)	(9.7617 to 10.8420)	(0.0609 to 0.1383)	

30.7% decline[§] in impact of intervention on BP reduction applied 1 year after commencement of intervention

	Mean total health care costs	£6.893	£6,242	£652	
Life	(95% CI[†])	(£5,755 to £8,508)	(£4,754 to £8,137)	(£-729 to £1,965)	£36,278
time	Mean QALYs gained	10.4058	10.3878	0.0180	(SM[ll] to £515,176)
	(95% CI[†])	(9.8132 to 10.8376)	(9.7657 to 10.8381)	(-0.0005 to 0.0474)	

30.7% decline[§] in impact of intervention on BP reduction applied 2 years after commencement of intervention

	Mean total health care costs	£6,888	£6,246	£642	
Life	(95% CI[†])	(£5,749 to £8,455)	(£4,746 to £8,107)	(£-749 to £1,959)	£23,964
time	Mean QALYs gained	10.4137	10.3869	0.0268	(SM[‖] to £174,573)
	(95% CI[†])	(9.8184 to 10.8501)	(9.7596 to 10.8445)	(0.0056 to 0.0589)	

30.7% decline[§] in impact of intervention on BP reduction applied 3 years after commencement of intervention

	Mean total health care costs	£6,883	£6,237	£646	
Life	(95% CI[†])	(£5,759 to £8,436)	(£4,744 to £8,139)	(£-779 to £1,960)	£18,477
time	Mean QALYs gained	10.4246	10.3896	0.0350	(SM[‖] to £99,440)
	(95% CI[†])	(9.8273 to 10.8530)	(9.7575 to 10.8412)	(0.0117 to 0.0697)	

30.7% decline[§] in impact of intervention on BP reduction applied 4 years after commencement of intervention

	Mean total health care costs	£6,886	£6,245	£641	
Life	(95% CI[†])	(£5,740 to £8,461)	(£4,739 to £8,151)	(£-765 to £1,953)	£15,376
time	Mean QALYs gained	10.4289	10.3872	0.0417	(SM[‖] to £110,610)
	(95% CI[†])	(9.8360 to 10.8530)	(9.7695 to 10.8430)	(0.0100 to 0.0666)	

30.7% decline[§] in impact of intervention on BP reduction applied 14 years after commencement of intervention

	Mean total health care costs	£6,855	£6,245	£611	
Life	(95% CI[†])	(£5,753 to £8,367)	(£4,737 to £8,122)	(£-796 to £1,933)	£6,705
time	Mean QALYs gained	10.4780	10.3890	0.0911	(SM[‖] to £26,982)
	(95% CI[†])	(9.8947 to 10.8981)	(9.7630 to 10.8465)	(0.0516 to 0.1317)	

* ICER – Incremental cost-effectiveness ratio

[†] CI – confidence interval

[‡] A 25% decline in the impact of the intervention (from 17.6mmHg to 13.2mmHg) meant that the difference in the effects between the two groups dropped from 5.4mmHg to 1mmHg i.e. 12 month BP reduction in the usual care arm was 12.2mmHg.

[§] A 30.7% decline in the impact of the intervention (from 17.6mmHg to 12.2mmHg) implied that there was no difference at all between the two groups in terms of effectiveness as the 12 month BP reduction in the usual care arm was 12.2mmHg.

[||] Where the acronym for the self-management of hypertension arm (SM) is given instead of an ICER, it means that SM dominates usual care i.e. less costly and more effective.

Figure legends

Figure 1: Markov model structure

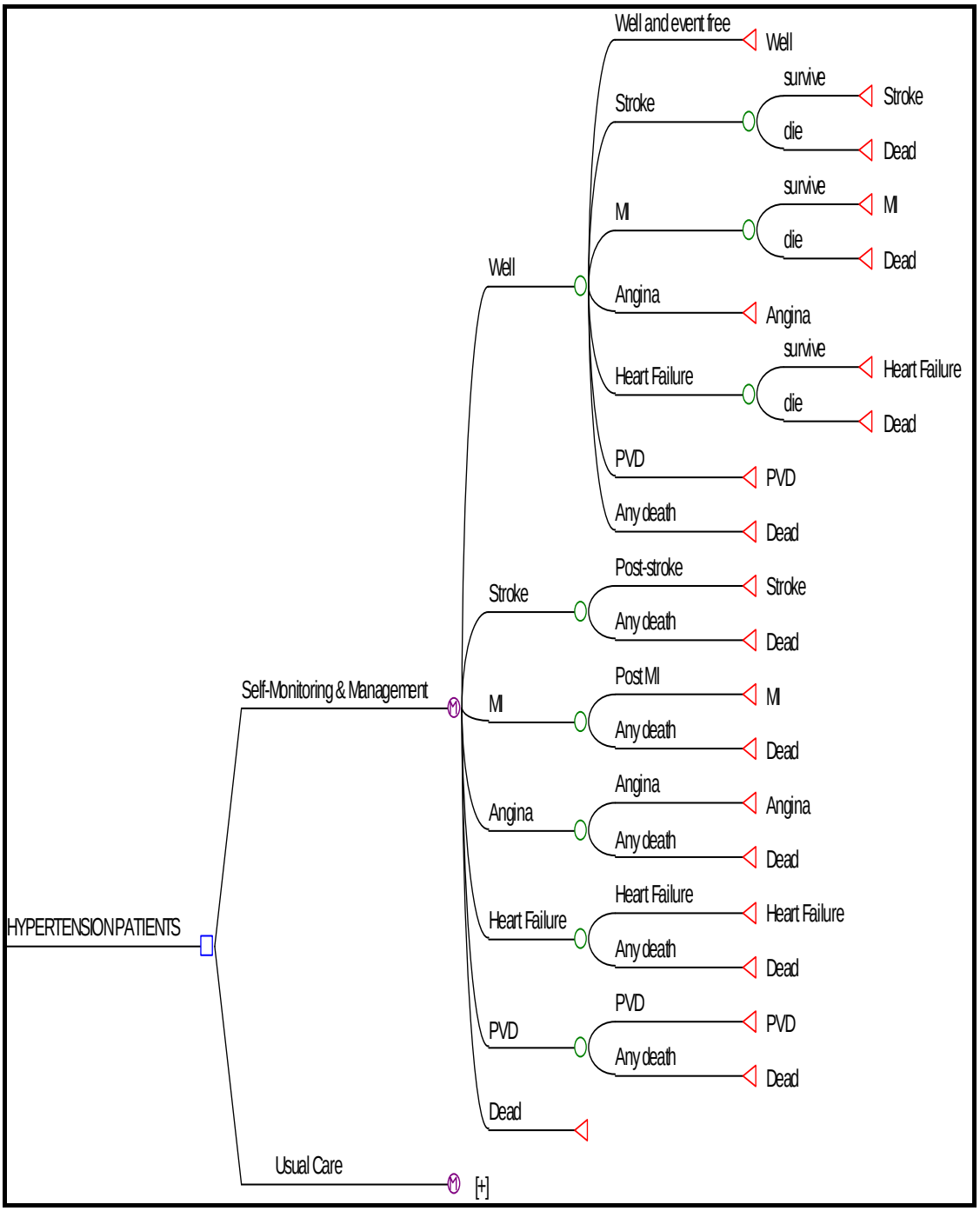
Figure 1 shows the structure of the Markov model used to conduct the cost-effectiveness analysis. Only health states for the 'Self-management of hypertension' arm are shown but these are identical to those in the 'usual care' arm. [+] means 'same structure but with appropriate changes in parameter estimates'. The Markov process for each arm began with the initial health state, 'well,' representing individuals with stable but poorly controlled hypertension. Patients could remain in the well state or move to one of five possible acute health states namely stroke, myocardial infarction (MI), angina, heart failure (HF) and peripheral vascular disease (PVD). Individuals that survived an acute phase in any of the five health states naturally progressed into a chronic phase. Individuals in a chronic health state remained in that state for the rest of their lives unless they died before the end of the time horizon for the model.

Figure 2: Cost-effectiveness plane of self-management of hypertension versus usual care and the Cost-effectiveness acceptability curve of self-management of hypertension versus usual care

Figure 2a is a cost-effectiveness plane showing the relationship between the incremental cost and incremental QALYs of self-management of hypertension to usual care. It shows that most results are in the north-east and south-east quadrants.

Figure 2b depicts the cost-effectiveness acceptability curve of self-management of hypertension versus usual care. It shows that the probability of self-management of hypertension being cost-effective compared to usual care was at least 99% if decision makers were willing to pay at least £20,000 (US$ 30,000) per QALY-gained. This probability dropped to 50% at around £5,000 (US$ 7,596) per QALY-gained.

Figure 1


HYPERTENSION PATIENTS
Self-Monitoring & Management
Usual Care
[+]
Well
Stroke
MI
Angina
Heart Failure
PVD
Dead
Well and event free
Well
Stroke
survive
Stroke
die
Dead
MI
survive
MI
die
Dead
Angina
Angina
Heart Failure
survive
Heart Failure
die
Dead
PVD
PVD
Any death
Dead
Stroke
Post-stroke
Stroke
Any death
Dead
MI
Post MI
MI
Any death
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Angina
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Figure 2

Figure 2a

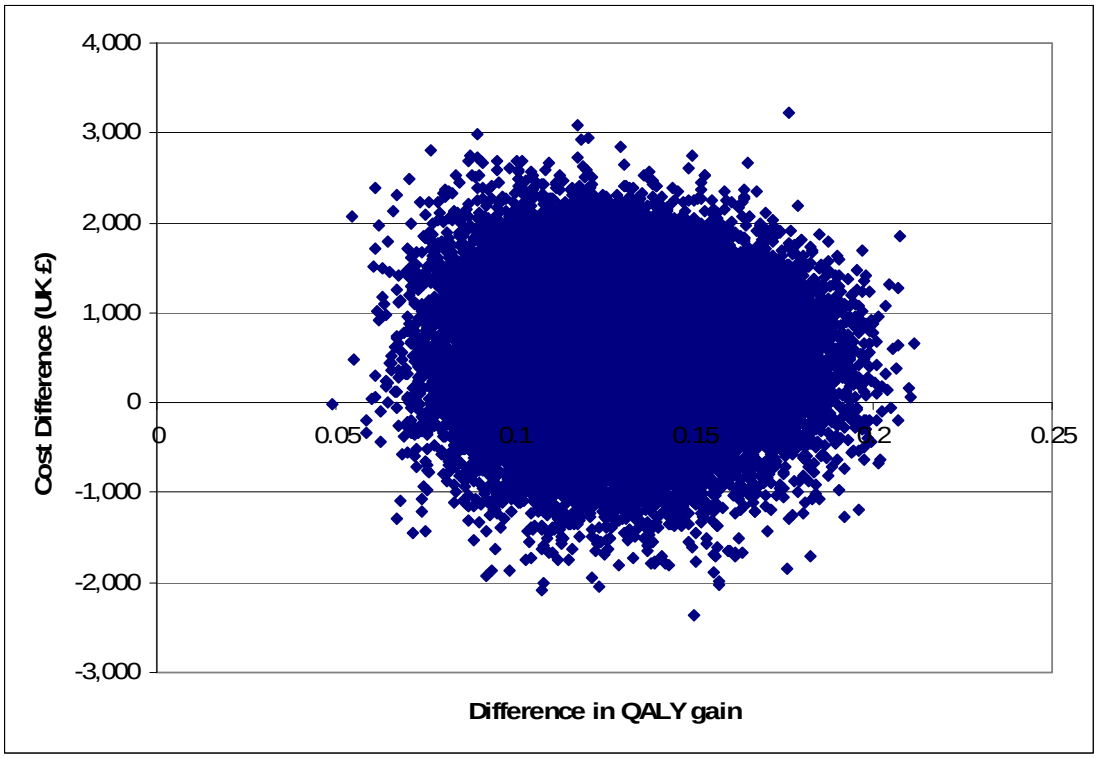

Figure 2b