Cost-effectiveness of self-management of blood pressure in hypertensive patients over 70 years with sub-optimal control and established cardiovascular disease or additional CV risk diseases (TASMIN-SR)

Maria Cristina Penaloza-Ramos MA[1], Sue Jowett PhD[1], Jonathan Mant MD[2], Claire Schwartz PhD[3], Emma P. Bray PhD[4], M. Sayeed Haque PhD[5], F.D. Richard Hobbs FMedSci[3], Paul Little MD[6], Stirling Bryan PhD[7,8], Bryan Williams MD[9], Richard J McManus FRCGP[3]

[1]Health Economics Unit, Institute for Applied Health Research, University of Birmingham, Birmingham, UK

[2]Primary Care Unit, Institute of Public Health, University of Cambridge, Cambridge, UK

[3]Nuffield Department of Primary Care Health Sciences, University of Oxford, Oxford, UK

[4]School of Psychology, University of Central Lancashire, Preston, Lancashire, UK

[5]Primary Care Clinical Sciences, Institute for Applied Health Research, University of Birmingham, Birmingham, UK

[6]School of Medicine, University of Southampton, Southampton, UK

[7]Centre for Clinical Epidemiology and Evaluation, Vancouver Coastal Health Research Institute, Vancouver, British Columbia, Canada

[8]School of Population and Public Health, University of British Columbia, Vancouver, British Columbia, Canada

[9]Institute of Cardiovascular Sciences, NIHR University College London Hospitals Biomedical Research Centre, University College London, London, UK

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Abstract

Background: A previous economic analysis of self-management, that is, self-monitoring with self-titration of antihypertensive mediation evaluated cost-effectiveness among patients with uncomplicated hypertension. This study considered cost-effectiveness of self-management in those with raised blood pressure plus diabetes, chronic kidney disease (CKD) and/or previous cardiovascular disease.

Design and methods: A Markov model-based economic evaluation was undertaken to estimate the long-term cost-effectiveness of self-management of blood pressure in a cohort of 70-year old 'high risk' patients, compared with usual care. The model used the results of the TASMIN-SR trial. A cost-utility analysis was undertaken from a UK health and social care perspective, taking into account lifetime costs of treatment, cardiovascular events and quality adjusted life years (QALYs). A sub-group analysis ran the model separately for men and women. Deterministic sensitivity analyses examined the effect of different time horizons and reduced effectiveness of self-management.

Results: Base-case results indicated that self-management was cost-effective compared with usual care, resulting in more QALYs (0.21) and cost savings (-£830) per patient.

There was a 99% chance of the intervention being cost-effective at a willingness to pay threshold of £20,000 per QALY gained. Similar results were found for separate cohorts of men and women. The results were robust to sensitivity analyses, provided that the blood pressure lowering effect of self-management was maintained for more than a year.

Conclusion: Self-management of blood pressure in ‘high risk’ people with poorly controlled hypertension not only reduces blood pressure, compared with usual care, but also represents a cost-effective use of health care resources.

Word count: 250

Keywords

Hypertension, self-management, cost-effectiveness, decision model, decision analysis

Background

Hypertension is a leading risk factor for cardiovascular mortality and morbidity worldwide.[1, 2] Despite evidence of cost saving from antihypertensive treatment,[3] and improvements in blood pressure monitoring, management and treatment,[3, 4] significant numbers of people remain inadequately controlled hence new models of care are required.[5] Self-management of hypertension, where an individual self-monitors their own blood pressure (BP) and adjusts their own medication has been shown to lead to significantly lower BP in hypertension, including in those with higher cardiovascular risk.[6, 7]

The only economic analysis of self-management in the control of hypertension to date demonstrated that tele-monitoring with self-titration in uncomplicated hypertension was highly cost-effective with incremental cost-effectiveness ratios (ICERs) below £5,000 QALY gained for men and women, when modelled over patient lifetime.[8] However subgroup analysis in the main trial suggested that the intervention might not be as effective in those with significant co-morbidities, although patient numbers for this sub-group were small.[7] Therefore, the TASMIN-SR trial was undertaken to determine the effect of self-monitoring with self-titration of antihypertensive medication on systolic BP among hypertensive patients with sub-optimal control and pre-existing cardiovascular disease, diabetes mellitus (DM) and/or CKD, compared with usual care. A model-based probabilistic cost-utility analysis was undertaken as part of this study to assess the long-term cost-effectiveness of the self-management intervention in a 'high risk' patient population, compared with usual care.

Methods

A Markov cohort model, built in TreeAge Pro (TreeAge Software Inc, Williamstown, MA, USA), was developed to estimate the long-term cost-effectiveness of self-management of BP compared with usual care, in patients with hypertension and a history of stroke, coronary heart disease (CHD), DM or CKD. The analysis used the results of the TASMIN-SR trial on BP, extrapolating these to long-term risk of cardiovascular endpoints [see below]. Full details of the trial methods and results have been described in detail elsewhere.[6, 9] The model was run over a lifetime (30 year) time horizon using a six-month time cycle, with results presented from a UK National Health Service (NHS) and Personal Social Services (PSS) perspective.

Study population

The base case analysis considered a cohort of 70 year old patients (39% female) with sub-optimal hypertension, BP ≥ 130/80 mmHg at baseline, combined with a history of stroke, CHD, DM or CKD.[6] Patients had at least one of four main underlying conditions (DM, stroke, CHD and CKD), to be eligible with 15 possible combinations of high risk conditions in total. Further details of the combined risk conditions are available in the supplemental online document, eTable 2.

Interventions

Patients randomised to usual care booked an appointment for a routine BP pressure check and medication review with the study general practitioner (GP). Thereafter, usual care consisted of the participants seeing their GP and or nurse for routine BP measurement and adjustment of medication at the discretion of the health professional. Patients randomised to self-management were trained to self-monitor BP and to self-titrate their antihypertensive medication following a predetermined plan, in two or three sessions, each lasting around an hour. Following training, patients adjusted their antihypertensive medication based on their monthly self-monitored BP readings.[9]

Model structure

A patient entered the model in the "high risk" health state and could move to another health state if they suffered one of three possible cardiovascular (CV) events (stroke, myocardial infarction (MI), unstable angina (UA)), or died from other causes (figure 1). After a CV event, individuals could survive from that event or die within the first 6 months. Those that survived an event subsequently moved to a chronic health state for that condition until death, with no recurrences of CV events. For each chronic health state, an ongoing health care cost was applied every time cycle and quality of life was permanently reduced. Movement between health states was defined by transition probabilities, which represented the risk of experiencing an event within each six-month time cycle.

Model parameters

Patient level data from the TASMIN-SR trial were used to reflect the CV disease history of patients entering the Markov model. The probabilities of suffering a stroke, MI or developing UA were obtained from published literature for hypertensive patients with each of the high risk conditions[10-14] (Table 1). Where the model required probabilities that were not available in the literature (for given age group, gender or combination of high risk conditions), missing values were estimated through extrapolation (see supplemental online document). For patients presenting with two or more high risk conditions, the probability of an event was calculated as the sum of the two individual risk probabilities (supplemental online document, etables 1 and 2).

Systolic BP reductions recorded in the trial at 6 months (11.4mmHg and 5.5mmHg for the intervention and control arms) and at 12 months (15.0mmHg and 5.8mmHg for the intervention and control arms) were extrapolated to age-related risk reductions for CHD (comprising both MI and UA) and stroke, using Law et al[15] (Table 1). Relative risks for

CHD and stroke related to 6 and 12 month BP reductions are reported in Table 1. The model assumed that BP remained static for the first six month cycle of the model, then reduced as per the 6 month trial results for the second model cycle followed by the 12 month trial reductions thereafter with the between groups differences assumed constant in the base case. The probabilities of death from MI and stroke within a year of the event are reported in Table 1 and applied to the first year after an event (first two cycles in the model). Life tables were used to determine overall mortality, dependent on age and gender.[16]

Resource use and costs

Costs are reported in UK pounds at 2011/12 prices. Resource use related to ongoing BP monitoring in primary care, self-management and prescription of antihypertensive was obtained from the TASMIN-SR trial at 12 months follow-up. For self-management, equipment and training costs were annuitized at an annual rate of 3.5% and based on a lifetime of five years.[17] Replacement costs for the equipment and training were included at five yearly intervals over the lifetime of the model (supplemental online document, eTable 3). Equipment used by individuals who died within any five year interval was assumed to be discarded. Unit costs were applied to resource use and mean patient costs per six months were calculated for both randomised groups, and applied to the initial high risk health state. Costs for acute and chronic CV event states were obtained from published studies.[14, 18-20] See Table 1.

Utility values

The primary outcome measure was QALYs. All utility scores used in the model are shown in Table 1. The utility values for the starting 'high risk' health state were obtained from the TASMIN-SR trial where the overall mean EQ-5D score for hypertensive patients at baseline was used to estimate utilities. This was adjusted for age group using weights calculated from Ara et al,[21] which allowed the overall reduction in quality of life with increasing age to be incorporated in the model. Acute events were assumed to happen approximately three months into a six-month cycle and individuals stayed in that acute state for three months before moving into a chronic state. Therefore utilities for the acute state were applied mid-way through the six-month cycle and chronic health state utilities were applied at the start of the subsequent cycle (table 1). Health state utilities for CV events were applied multiplicatively to the age-related 'high risk' health state utility values.

Analysis

A cost-utility analysis was undertaken from a UK NHS and PSS perspective. For the base-case analysis, fifteen separate cost-effectiveness analyses were run, one for each combination of high risk conditions assessed in the model. The final cost-effectiveness results correspond to the trial population-weighted average of costs and quality adjusted life years (QALYs) and are reported in terms of the incremental cost per QALY gained.[22] Analyses were also separately run for men and women. Costs and outcomes were discounted at an annual rate of 3.5%.[23]

Uncertainty in the model results was assessed using sensitivity analyses. Deterministic sensitivity analysis was undertaken around key parameters and assumptions. The time horizon for the model was varied from 30 years (lifetime) to between 1 year and 20 years, to determine whether the intervention was cost effective in the shorter term. The assumption regarding the long-term effectiveness of the intervention was tested by assessing the impact of limiting the additional effect on BP lowering to years of self-management 1, 2, 5 and 10. Additional sensitivity analyses altered long term CV event costs by 30% (up and down). Finally, all analyses were re-run using the un-adjusted trial data which showed marginally smaller reductions in BP (11.4 mmHg and 5.8 mmHg for the intervention and control arms at 6 months and 14.9 mmHg and 6.0 mmHg respectively at 12 months). Where possible, data were entered into the model as distributions in order that a probabilistic sensitivity analysis (PSA) could be undertaken to incorporate parameter uncertainty. Gamma distributions were fitted to all costs obtained from the TASMIN-SR trial and beta distributions were applied to the utility values. The parameters used for these distributions are shown in Table 1. The PSA was run with 10,000 2nd order Monte Carlo simulations and cost-effectiveness planes (CEPs) and cost-effectiveness acceptability curves (CEACs) constructed, to estimate the probability of self-management being cost-effective at different willingness-to-pay thresholds.[17]

Results

In the base-case analysis, self-management of BP was dominant compared to usual care, being cheaper and more effective (Table 2). Self-management was associated with mean cost savings of £830 per patient for the total population (self-management £7,357 vs. usual care £8,187) and a gain of 0.21 QALYs (6.25 vs. 6.03, respectively). This dominance was demonstrated for both men and women (Table 2). In the CEP (Figure 2), all results are in the north-east and south-east quadrants indicating that self-management is always more effective but with greater uncertainty around the difference in costs. The CEAC shows that the probability of self-management of BP being cost-effective compared with usual care was at least 99% if decision makers were willing to pay £20,000 per QALY gained. At a lower threshold of £10,000 per QALY, the probability of the intervention being cost-effective compared with usual care was still high at 97% (Figure 2).

A sensitivity analysis of time horizon demonstrated that self-management is dominant if the horizon is two years or more (Table 3). Similarly, if the impact of self-management on BP is time limited, the cost-effectiveness is reduced – but the intervention is still cost-effective provided that the effect is sustained for one year (first two cycles) (Table 4). Other sensitivity analyses (costs and reduced impact on BP) did not change the overall results (see supplemental online document, etables 4-6).

Discussion

This is the first study to present results of the cost-effectiveness of self-management of BP compared with usual care in a high risk population with sub-optimally managed hypertension and significant CV comorbidity. The base-case analysis suggests that self-management of BP is cost-effective and is likely to be dominant (i.e., it is less costly and produces more QALYs) compared to usual care.

The main driver of this result is the estimated decline in the risk of CV events associated with the observed additional BP lowering achieved with self-management, and this explanation also holds for the greater benefit seen for men. This result was robust to sensitivity analysis unless the time horizon was reduced below two years or the observed BP lowering effect of self-management did not continue beyond a year.

Relationship with other literature

Previous economic studies have evaluated the cost-effectiveness of self-monitoring rather than self-management (self-monitoring plus self-titration of antihypertensive) and only one previous economic analysis of self-management has been undertaken (TASMINH2)[8], which found self-management to be cost-effective (£1,624 and £4,923 per QALY gained for men and women respectively).[8] In this analysis, we found self-management to be even more cost-effective, reflecting the higher number of CV events predicted to have been prevented in the higher risk population, and the slightly greater reductions in BP that were observed in the TASMIN-SR trial.

Strengths and limitations

This study used cost and outcome data of trial participants[6] who may differ from similar patients not taking part in the trial for instance being more adherent and healthier.[24] The strongly positive results however suggest that such an intervention would be cost-effective even in a less compliant population. The costs of long-term and acute care were taken from estimates in the literature and a number of assumptions were made about the annual probabilities of CV events by risk conditions based on best published information. A key assumption was that of the prolonged effectiveness of the intervention. In both TASMINH2 and TASMIN-SR, the difference in BP reduction between trial arms continued to diverge between 6 and 12 months suggesting that the effect may be maintained over time. Indeed, an 18 month post trial follow up of the HSM self-management trial found that BP continued to diverge over time suggesting our assumption of maintenance of effect may even be conservative.[25] The sensitivity analyses showed that even if BP differences lasted only one further year and then returned to the effectiveness of usual care, self-management is still likely to be cost effective. For simplicity, the model did not include subsequent CV events. Given that the main driver of costs was events and the main driver of events was BP, it would be expected that a model including secondary and subsequent events would show self-management to be even more cost-effective than usual care. The model considers patients with co-morbidities and additional risk factors (e.g. age, gender). Arguably, a more complex model such as individual patient level simulation could be more appropriate in this situation, as this type of model can incorporate patient history more efficiently, overcoming the limitations of Markov models.[26] Finally, an assumption has been made regarding the differential effect of BP lowering between the intervention and control groups. Systematic reviews suggests that lowering BP below 140/90 mmHg is as effective as lowering BP to 140/90 mm Hg,[15] but it is fair to say that the evidence of benefit is stronger in stroke and DM than in CHD or CKD.[10, 27-29]

Clinical implications

These results suggest that the benefits of BP reduction seen in the trial can be achieved in a highly cost-effective manner. The up-front costs of implementation of self-management of hypertension in high risk groups are relatively modest (£14.6 equipment and £20.0 training) and are soon repaid by future maintenance of quality of life and reductions in costs from reduced CV events. The very high likelihood of cost-effectiveness from both this and the previous analyses suggests that self-management is a strong candidate for implementation.

Conclusions

The results of this model-based economic evaluation suggest that self-management of hypertension in high risk patients is a cost-effective strategy in the short and long term, resulting in QALY gains and cost-savings. Self-management of BP in high risk patients represents an important new addition to the management of hypertension in primary care.

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Conflict of interest

RJM has received research equipment from Omron and Lloyds Pharmacies.

Table 1 Model parameters

Parameter	Value	Source
Reduction in systolic BP at 12 months (mmHg)		TASMIN-SR trial[6]
Self-management	15.0	
Usual care	5.8	
Reduction in systolic BP at 6 months (mmHg)		TASMIN-SR trial[6]
Self-management	11.4	
Usual care	5.5	
Annual transition probabilities		
CVD events for patients with DM		NICE Diabetes guidelines, Appendix D1[12]
Stroke		
60-69 years old	0.0196	
70-79 years old	0.0262	
80-89 years old	0.0298	
MI (MI)		
60-69 years old	0.0089	
70-79 years old	0.0100	
80-89 years old	0.0111	
UA (UA)		
60-69 years old	0.0041	
70-79 years old	0.0047	
80-89 years old	0.0052	

CVD events for patients with CKD		Kerr et al (2012)[11]
Stroke		
60-69 years old	0.0072	
70-79 years old	0.0147	
80-89 years old	0.0189	
MI		
60-69 years old	0.0051	
70-79 years old	0.0113	
80-89 years old	0.0171	
UA		
60-69 years old	0.0024	
70-79 years old	0.0054	
80-89 years old	0.0081	
CVD events for patients with a previous stroke		PROGRESS (1999) & NICE, Lipid modification guidelines[10, 14]
Stroke		
60-69 years old	0.0348	
70-79 years old	0.0589	
80-89 years old	0.0713	
MI		
60-69 years old	0.0139	
70-79 years old	0.0232	
80-89 years old	0.0232	
UA		

60-69 years old	0.0139	
70-79 years old	0.0232	
80-89 years old	0.0232	
CVD events for patients with CHD		NICE, Lipid modification guidelines[14] and NICE Hypertension guidelines[4]
Stroke		
60-69 years old	0.0359	
70-79 years old	0.0588	
80-89 years old	0.0713	
MI		
60-69 years old	0.0666	
70-79 years old	0.1112	
80-89 years old	0.1112	
UA		
60-69 years old	0.0528	
70-79 years old	0.0881	
80-89 years old	0.0881	
Age-related relative risks at 12 months (95% CI)		TASMIN-SR trial & Law et al (2009)[6, 15]
MI and UA – self-management		
60-69 years old	0.63 (0.60, 0.66)	
70-79 years old	0.68 (0.64, 0.71)	
80-89 years old	0.74 (0.70, 0.78)	
Stroke – self-management		
60-69 years old	0.53 (0.49, 0.57)	
70-79 years old	0.59 (0.55, 0.64)	

80-89 years old	0.74 (0.69, 0.79)	
MI and UA - usual care		
60-69 years old	0.83 (0.81,0.84)	
70-79 years old	0.85 (0.84,0.87)	
80-89 years old	0.89 (0.87,0.90)	
Stroke - usual care		
60-69 years old	0.77 (0.75, 0.79)	
70-79 years old	0.81 (0.79, 0.83)	
80-89 years old	0.89 (0.86, 0.91)	
	Age-related relative risks at 6 months (95% CI)	TASMIN-SR trial & Law et al (2009) [6, 15]
MI and UA – self-management		
60-69 years old	0.71 (0.68, 0.73)	
70-79 years old	0.75 (0.72, 0.77)	
80-89 years old	0.80 (0.76, 0.83)	
Stroke – self-management		
60-69 years old	0.62 (0.59, 0.66)	
70-79 years old	0.68 (0.64, 0.71)	
80-89 years old	0.80 (0.76, 0.84)	
MI and UA - usual care		
60-69 years old	0.83 (0.82,0.85)	
70-79 years old	0.86 (0.85,0.87)	
80-89 years old	0.89 (0.87,0.91)	
Stroke - usual care		
60-69 years old	0.77 (0.75, 0.80)	

70-79 years old	0.81 (0.80, 0.84)	
80-89 years old	0.89 (0.87, 0.91)	
Probability of death for those who have suffered an event		
Fatal stroke	0.23	Bamford et al (1990)[30]
Fatal MI		ONS, Deaths registry (2011) & Kerr et al (2012) [11, 16]
65-74 years old	0.23	
75-84 years old	0.39	
85 and over	0.52	
Costs (UK £)		
Cost for the initial state [a]		TASMIN-SR trial, Curtis L (2012) & BNF 2012[6, 31, 32]
Self-management [b]	183	
Usual care	125	
Costs of acute disease one-off cost		
Stroke	11,020	Youman et al (2003)[20]
MI	5,487	Robinson et al (2004)[19]
UA	3,292	Assumed 60% of MI
Costs for long-term (chronic) disease per year		
Stroke	2,721	Youman et al (2003)[20]
MI	572	NICE, Lipid Modification Guidelines [14]
UA	572	NICE, Lipid Modification Guidelines [14]

Utilities		
Utilities for initial health state		
Self-management and usual care		TASMIN-SR Trial[6]
65-74 years old	0.81	
75-84 years old	0.74	
85 and over	0.71	
Utilities for acute events		NICE, Lipid Modification Guidelines [14]
UA	0.77	
MI	0.76	
Stroke	0.63	
Utilities for long term (chronic) disease		NICE, Lipid Modification Guidelines [14]
UA	0.88	
MI	0.88	
Stroke	0.63	
Dead	0.00	by definition

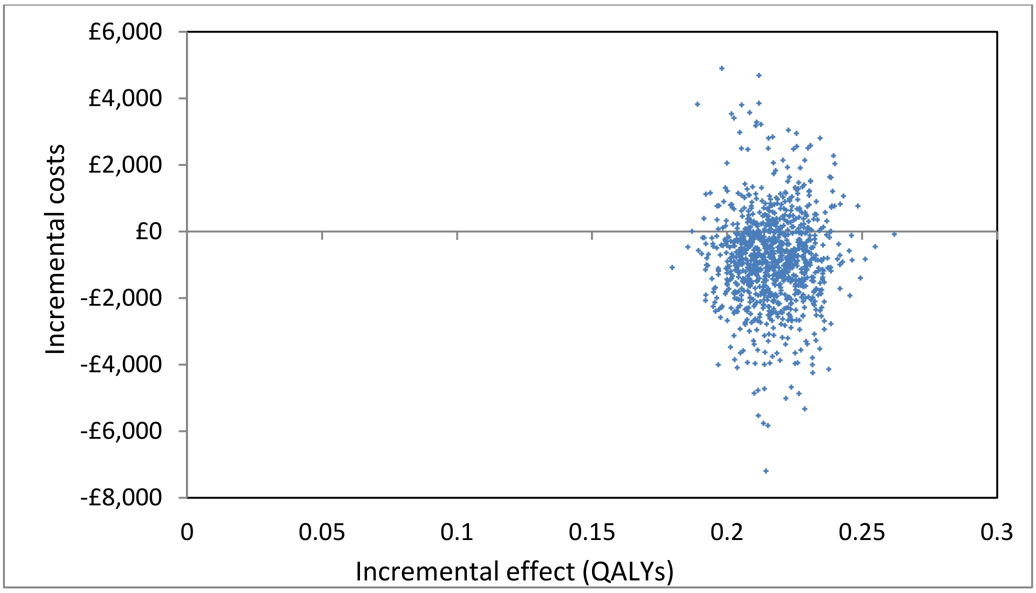
[a] Included annual costs of drugs per patient, average GP and PN cost of consultation(s) and the costs of the intervention. The cost difference between self-monitoring and usual care was driven by the cost of the intervention
[b] For greater detail see supplemental online document

Table 2 Results of cost-effectiveness analysis

	Costs	QALYs	Incremental cost	Incremental QALYs	ICER
Total population					
Usual care	8,187	6.0326			
Self-management	7,357	6.2466	-830	0.2139	Dominant
Women					
Usual care	7,338	6.2467			
Self-management	6,579	6.4456	-759	0.1988	Dominant
Men					
Usual care	8,654	5.9035			
Self-management	7,791	6.1257	-864	0.2221	Dominant

Figure 2 Base-case results

Incremental CEP: self-management against usual care



CEAC for self-monitoring of hypertension

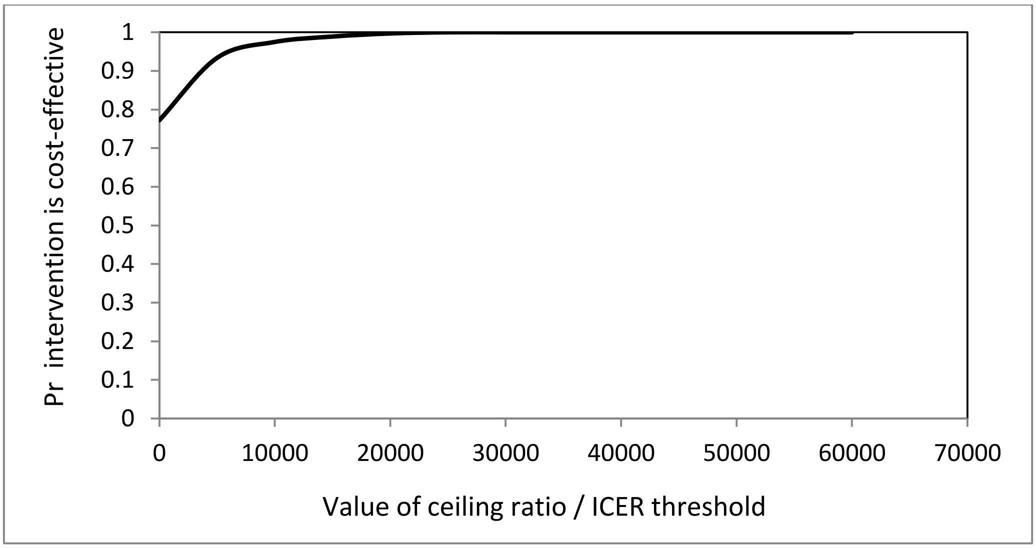


Table 3 Sensitivity analyses: cost-effectiveness by time horizon

	Costs	QALYs	Incremental cost	Incremental QALYs	ICER
20-year					
Usual care	7,709	5.8830			
Self-management	6,919	6.0975	-789	0.2145	Dominant
10-year					
Usual care	5,242	4.7756			
Self-management	4,675	4.9252	-567	0.1496	Dominant
5-year					
Usual care	2,882	3.1178			
Self-management	2,554	3.1742	-328	0.0564	Dominant
3-year					
Usual care	1,690	2.0859			
Self-management	1,535	2.1044	-155	0.0186	Dominant
2-year					
Usual care	1,116	1.4651			
Self-management	1,056	1.4718	-59	0.0067	Dominant
1-year					

Usual care	603	0.7729			
Self-management	625	0.7736	22	0.0006	34,791

Table 4 Sensitivity analyses: cost-effectiveness by reducing the additional effect of self-management to BP lowering at four different time points

Time horizon	Costs	QALYs	Incremental cost	Incremental QALYs	ICER
10 years					
Usual care	8,187	6.0326			
Self-management	7,530	6.2242	-657	0.1916	Dominant
5 years					
Usual care	8,187	6.0326			
Self-management	7,876	6.1623	-311	0.1297	Dominant
2 years					
Usual care	8,187	6.0326			
Self-management	8,259	6.0757	71	0.0430	1,660
1 year					
Usual care	8,187	6.0326			
Self-management	8,382	6.0454	195	0.0127	15,341

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