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Economics of Self-Measured Blood Pressure Monitoring: A Community Guide Systematic Review

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Abstract

Context—The health and economic burden of hypertension, a major risk factor for cardiovascular disease, is substantial. This systematic review evaluated the economic evidence of self-measured blood pressure (SMBP) monitoring interventions to control hypertension.

Evidence acquisition—The literature search from database inception to March 2015 identified 22 studies for inclusion with three types of interventions: SMBP used alone, SMBP with additional support, and SMBP within team-based care (TBC). Two formulae were used to convert reductions in systolic BP (SBP) to quality-adjusted life years (QALYs) to produce cost per QALY saved. All analyses were conducted in 2015, with estimates adjusted to 2014 U.S dollars.

Evidence synthesis—Median costs of intervention were $60 and $174 per person for SMBP alone and SMBP with additional support, respectively, and $732 per person per year for SMBP within TBC. SMBP alone and SMBP with additional support reduced healthcare cost per person per year from outpatient visits and medication (medians $148 and $3, respectively; median follow-

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[1]Patients with isolated high blood pressure in the medical setting and in the presence of medical personnel are said to have “white coat hypertension.” Patients with controlled blood pressure measured in the clinic and uncontrolled blood pressure when measured outside the clinic are said to have “masked hypertension.”

up, 12–13 months). SMBP within TBC exhibited an increase in healthcare cost (median, $447 per person per year; median follow-up, 18 months). SMBP alone varied from cost saving to a maximum cost of $144,000 per QALY saved, with two studies reporting an increase in SBP. The two translated median costs per QALY saved were $2,800 and $4,000 for SMBP with additional support and $7,500 and $10,800 for SMBP within TBC.

Conclusions—SMBP monitoring interventions with additional support or within TBC are cost effective. Cost effectiveness of SMBP used alone could not be determined.

CONTEXT

High blood pressure (BP) is an important risk factor for cardiovascular disease (CVD) and stroke in the U.S., accounting annually for more than $193 billion in medical care and about $123 billion in lost productivity in 2011–2012.[1] The control of high BP with medication and other treatments can prevent and avert a substantial part of this societal burden,[2] even as costs are projected to increase with hypertension-related outcomes, such as stroke, in a growing and aging population.[3] For example, hypertension control efforts have contributed to the decline in stroke mortality because distributions of population systolic BP (SBP) have shifted.[4]

Self-measured blood pressure (SMBP) monitoring interventions use BP monitoring devices operated by patients to improve the management of high BP. This process provides clinicians with accurate and frequent measurements, increases patient engagement in their own care, and prompts patients to adopt healthful lifestyles. A recent systematic review[5,6] conducted for the Agency for Healthcare Research and Quality showed that SMBP monitoring interventions, typically in the home, were effective in improving BP outcomes in patients with high BP, reducing SBP by 3.2–4.6 mmHg and diastolic BP by 1.3–2.3 mmHg.[7] However, there has been no published review of the economics of these interventions.

The objective of the present paper is to assess the cost and economic benefit of SMBP monitoring interventions based on a systematic review of the literature.

EVIDENCE ACQUISITION

Concepts and Methods

This study was conducted using Community Guide methods for systematic economic reviews, available at www.thecommunityguide.org/about/economic-reviews. A review team (the team) was constituted, including subject matter experts on CVD and hypertension from various agencies, organizations, and academic institutions together with experts in systematic reviews from the Community Guide Branch at the Centers for Disease Control and Prevention. The team worked under the oversight of the Community Preventive Services Task Force.

Interventions with SMBP monitoring involve use of personal BP measurement devices to improve the treatment of high BP. Patients are trained to use these devices in familiar settings, such as their homes. Readings are shared with their healthcare providers during clinic visits, by telephone, or electronically, and are monitored and used in treatment decisions to improve BP control. These interventions also may involve support such as medication and lifestyle counseling, patient education for self-management, and telephone or web-based tools.

Such SMBP interventions often are delivered within team-based care (TBC) for BP control, in which primary care providers and patients work together with other providers to improve the efficiency of care delivery and self-management support for patients.

A novel feature of the present review is the categorization of SMBP monitoring interventions into interventions implementing SMBP alone, SMBP with additional support, and SMBP within TBC. Distinction is drawn between additional support and team-based care because the latter is far more comprehensive and resource intensive than SMBP interventions that add web- or phone-enabled patient support. Further, SMBP alone and SMBP with additional support are both capital intensive, whereas SMBP within TBC is more labor intensive.

Although the focus of the Agency for Healthcare Research and Quality effectiveness review[5,6] of SMBP interventions was on treatment and management of high BP, this economic review also recognizes the diagnostic function of home BP monitors because identification of "white coat hypertension" and masked hypertension[18,9] in a population can have substantial implications for healthcare resource use.[10]

Figure 1 depicts the intervention, the population, and transitions in health status ascribed to the intervention (Intervention Effectiveness), below which appear associated resource use and economic benefits (Economic Outcomes). This economic review takes a societal perspective, which means costs and economic benefits are aggregated regardless of who pays and who benefits. The following research questions are considered based on the economic effects of the intervention illustrated in the Figure 1:

- What is the cost to implement the intervention?
- What is the effect of the intervention on healthcare cost?
- What is the effect of the intervention on productivity of patients at their workplaces?
- What is the net economic benefit of the intervention?
- What is the cost effectiveness of the intervention? In particular, what is cost per quality-adjusted life year (QALY) saved?

The target population of the interventions for this review are patients diagnosed with hypertension in primary care. Studies focused on patients with established CVD, gestational hypertension, and those receiving dialysis were excluded as were those focused on patients with illnesses that prevent them from using the home BP devices. Only published studies of interventions implemented in high-income countries were included. No restrictions were placed on study design. Studies included in the economic review had to contain information that would address one or more of the review's research questions. The measurement and estimation of economic effects associated with each of the research questions are described in detail below.

Intervention cost—SMBP interventions require devices, materials, and labor to implement, which are captured in estimates for intervention cost (Figure 1). The components of intervention cost for SMBP alone interventions are the BP monitoring device, patient training on correct use of the device, any telemetry device to transmit the BP readings, and the cost of generating summary reports for the care provider. SMBP with additional support adds the cost of other devices (e.g., smartphones), staff, development of interactive software, and other information technology necessary to support patient self-care in addition to providers' time to review patients' BP reports to aid counseling and treatment. SMBP within TBC adds the cost of administrative and medical staff engaged in TBC activities. Estimates of intervention cost are considered reasonably complete if they include these components that are cost drivers: the BP device in the case of SMBP alone interventions; the BP device and patient support in the case of SMBP with additional support; and the BP device, patient support, and TBC activities for SMBP within TBC.

Healthcare cost—Figure 1 shows the changes in healthcare resource use expected from the intervention, leading to change in healthcare cost. The components of healthcare cost are outpatient visits, medications, labs, emergency room (ER) visits, and inpatient stays. The effect of SMBP interventions on healthcare cost likely occurs through several channels. Identification of white coat and masked hypertension can alter the number of patients who need treatment. Changes in medication adherence, lifestyle, and BP control related to the intervention have effects on medication utilization, outpatient visits, and labs in the short term and on inpatient and ER visits in the longer term. The directions these changes take are empirical questions. For example, improved adherence to medication may increase refills and medication cost. On the other hand, improved BP control may prompt the provider to reduce medication. In the case of outpatient visits, the expectation is that home-based BP monitoring will reduce clinic visits solely for BP checks. Or it could be that home readings that exceed the threshold may alarm patients and increase contact with the clinic. In the long term, however, the expectation is that these interventions improve BP control and hence avert CVD events, resulting in averted inpatient and ER visits. Therefore, this economic review addresses the interventions' net effect on healthcare cost, both in the short and long term. Based on completeness of reporting in the included studies, estimates of healthcare cost for SMBP alone and for SMBP with additional support interventions were considered reasonable if they included outpatient visits and medication; SMBP within TBC interventions were considered reasonable if they included outpatient visits, medication, and inpatient stays.

Total cost and cost effectiveness—The quantity and quality of years lived increase when CVD morbidity and mortality are averted by effective SMBP interventions. Cost-effectiveness analysis seeks estimates for cost per QALY saved, where cost (total cost) is the sum of intervention cost and change in healthcare cost. An intervention is considered cost effective if the cost per QALY saved is less than a conservative threshold of $50,000.[11,12] The present review translated reductions in SBP to QALYs saved[13] to assess cost effectiveness for studies that reported the change in BP resulting from intervention. Two translations from the published literature were used: Translation (1), for which a reduction of 1 mmHg of SBP=0.009 QALY saved[14]; and Translation (2), for which a reduction of 1 mmHg of SBP=0.093 QALY saved.[15] Estimates based on both translations were evaluated, as a sensitivity measure, because the two equations relating change in SBP to QALYs were based on trial populations that differed in age and in the method used to derive QALY weights. The 20-year cost per QALY saved was based on total cost and increase in QALY per person per year summed over 20 years at a 3% discount rate. For the second formula, the increase in QALY was already reflected over life time of patients.

Productivity in the workplace—Finally, reduced morbidity and mortality related to SMBP interventions translate to higher productivity of patients at their jobs as a consequence of reduced illness and absences, better performance when at work, and increased working years. A complete cost–benefit assessment, as in a cost–benefit ratio, considers changes needed in resources to carry out the intervention, as well as the changes in healthcare cost and worksite productivity.

Economic results and conclusions are presented separately for SMBP alone, SMBP with additional support, and SMBP within TBC. All monetary values are in 2014 U.S. dollars, adjusted for inflation using the Consumer Price Index,[16] and converted from foreign currency denominations using purchasing power parities.[17] All analyses were conducted in 2015.

Search Strategy

The original search strategy from the review of effectiveness,[5,6] available at www.thecommunityguide.org/findings/cardiovascular-disease-self-measured-blood-pressure-with-additional-support, was extended for the economic review. In addition to the original search in MEDLINE and Cochrane, new sources were EconLit and databases maintained at the Centre for Reviews and Dissemination at the University of York. The search period was extended to March 2015 from February 2013, the end of the original search. Studies of interventions that met the definition, were conducted in high-income countries,[18] and contained information on economic cost or economic benefit of intervention were included in the review. Reference lists of included studies were also searched, as were action guides from the Million Hearts Initiative®[19,20] and studies recommended for inclusion by subject matter experts.

EVIDENCE SYNTHESIS

Results

A total of 1,246 papers were screened, yielding 22 studies in 29 papers[21–49] for inclusion (Figure 2). Appendix Table 1 (available online) provides a summary of the study characteristics in terms of design, intervention group size and age, length of intervention, comparison group, setting, and what economic outcomes were actually measured within the study and which were modeled. The substantial majority of the studies were RCTs with usual care as the comparison group, and patient care took place in the primary care setting. The average age of the study patients was about 57 years. Papers that covered the same population and intervention are considered single studies and are identified in Appendix Tables 3–6 (available online). Eight studies[21–31] provided economic evidence for SMBP alone, eight studies[32–39] for SMBP with additional support, and eight studies[22,27,33,40–49] for SMBP within TBC. Although several studies reported intervention cost and effects on healthcare cost, none reported productivity effects. No studies performed a cost–benefit analysis that included productivity effects. Only one[35] study modeled the outcomes to cost per QALY saved. Translated cost per QALY saved estimates were derived for the 11 studies[22–24,27,29–31,33,35,36,38,41,42,44,49] that provided both change in SBP and the total cost of the intervention.

Studies used BP devices as a tool to guide treatment, as a diagnostic tool, or both. Appendix Table 2 (available online) provides additional details on how the home BP devices were used in the interventions and how that may have affected economic outcomes considered in this review. Most studies were of patients with high BP, based on usual clinic measurements. Most of the SMBP alone studies included the diagnostic impact in addition to treatment impact, based on home BP readings. No studies of SMBP with additional support and only one study of SMBP within TBC reported economic outcomes that included the impact of home BP devices used as a diagnostic tool.

Table 1 provides estimates of intervention cost and change in healthcare cost following the intervention. The median cost to implement the intervention increased from $60 per person for SMBP alone, to $174 per person with the addition of patient support, and to $732 per person per year implemented within TBC. A substantial part of intervention cost for both SMBP alone and SMBP with additional support was the cost of the BP monitor. One study[46–48] of SMBP within TBC was excluded as an outlier for intervention cost because it reported a very high cost of intervention that included diabetes case management and telemedicine hardware and software developed specifically for the study. The change in all-cause healthcare cost reported for this study was included in median estimates because hypertension is a major risk factor for CVD and subsequent healthcare utilization for those with diabetes. Individual study details along with components of intervention cost included in the estimate are presented in Appendix Table 3 (available online).

Detailed estimates for change in healthcare cost related to intervention are shown in Appendix Table 4 (available online). Most studies on SMBP alone, and SMBP with additional support, included costs of outpatient visits and medication when estimating the change in healthcare cost. Most studies of SMBP within TBC included outpatient visits, medication, and inpatient stays. The median change in healthcare cost from SMBP alone was a decrease of $148 per person per year (Table 1). All but one[22,27] of the eight estimates[21–27,29–31] showed decreases, indicating SMBP alone was healthcare cost saving, with some of the savings likely from identification of "white coat hypertension." The median change in healthcare cost from SMBP with additional support was a reduction of $3 per person per year, based on six estimates[33,35–39]; individual estimates were mixed, with three estimates[36,37,39] indicating healthcare cost decreased and three indicating healthcare cost increased or was unchanged. For SMBP within TBC, seven[22,27,33,41,46–48] of eight estimates[22,27,33,41,42,44,46–49] reported a positive change in healthcare cost, indicating the intervention was healthcare cost increasing with a median increase of $369 per person per year.

The summary of estimates for intervention cost plus change in healthcare cost attributable to intervention (total cost) is presented in Table 2. Details for individual studies are in Appendix Table 5 (available online). For SMBP-alone interventions, the median total cost was −$72. Five[21,23,24,29–31] of six estimates[21–24,27,29–31] were negative, indicating the intervention was cost saving, with savings likely to include the use of home BP monitors as a diagnostic tool. The median total cost for SMBP with additional support was $44, with five[33,35,36,38,39] of six estimates[33,35–39] being positive, indicating the intervention increased costs. In the case of SMBP within TBC interventions, median total cost was $430, with all seven estimates[22,27,33,41–44,49] positive and, therefore, cost increasing.

Table 2 also summarizes the 20-year cost per QALY saved (based on two methods[14,15] described previously for translating reductions in SBP to QALYs saved). Details for individual studies are shown in Appendix Table 6 (available online). Two studies[23,29] of SMBP alone showed that SBP decreased following intervention and that averted healthcare cost exceeded intervention cost, whereas three studies[22,24,27,30,31] indicated SMBP alone was not cost effective. Of these three studies, SBP was higher at the end of the intervention in two studies,[24,30,31] and the third study[22,27] had a cost per QALY saved >$50,000. For SMBP with additional support, the median costs per QALY saved, based on the two translation methods, were $2,800 and $4,000, with every individual estimate[33,35,36,38] < $50,000, indicating cost effectiveness. Median cost per QALY saved for SMBP within TBC was $7,500 and $10,800, respectively, for the two translation methods, based on six estimates from four[22,27,33,41,42,44,49] studies. Of the six estimates, four estimates from the four studies[22,27,33,41,42,44,49] were <$50,000 and two estimates from one study[42,44,49] were >$50,000; the weight of evidence indicates cost effectiveness.

DISCUSSION

The review of effectiveness found that SMBP monitoring interventions improved BP outcomes based on studies that used the devices as a tool to manage the treatment of high BP.[5,6,50] This economic review included economic outcomes from the use of home BP devices as a diagnostic tool in addition to their use in guiding treatment. This diagnostic feature was prominent only in the SMBP alone studies.

The U.S Preventive Services Task Force recommends confirmation of high BP before beginning treatment, with measurements taken outside the clinic setting using ambulatory or home BP monitoring.[51] Self-measured blood pressure devices could, in practice, be distributed to primary care patients identified with elevated BP by clinic readings and not yet confirmed with ambulatory BP monitoring. In this scenario, the ability of these devices to identify patients with white coat and masked hypertension would have important implications for the economics of SMBP interventions, potentially reducing treatment cost for white coat and increasing treatment cost for masked hypertension. The diagnostic and treatment features of the devices were captured in the subgroup analysis by Arietta et al.,[21] who modeled an SMBP intervention for adult members of a health plan. The savings from the diagnostic and treatment features of SMBP were reflected in a favorable return on investment for young adults, driven by savings from correct diagnosis of hypertension, and favorable return on investment for Medicare members, driven by treatment benefits.

Limitations

A relatively large body of evidence for SMBP alone showed that averted healthcare cost exceeded the cost to implement these interventions. However, healthcare cost in most of the studies did not include inpatient stays or ER visits, and the change in healthcare cost was measured over a relatively short period of about 12 months and also included the use of BP devices as a diagnostic tool. Longer-term outcomes from using SMBP for hypertension treatment, which account for all components of healthcare, are necessary to determine benefits from improved BP control and averted CVD outcomes. Further, two studies[24,30,31] reported increased BP following the intervention. The unfavorable BP outcomes have been ascribed to identical BP thresholds chosen for both intervention and usual care groups instead of a lower threshold for home measurements, as currently recommended.[52] The change in healthcare cost also included savings from identifying patients with white coat hypertension and taking some patients off medication, even as benefits of treating white coat hypertension are still debated.[53] These cost savings were therefore not highlighted for SMBP-alone interventions.

The translation of reduced SBP to QALYs saved was based on two published formulae that are in turn drawn from large longitudinal trials within diabetic populations. Even though it is possible that the overall QALYs may be lower for diabetic patients than hypertensive patients, the relative impact of SBP reduction on the QALYs of diabetic patients compared with that of hypertensive patients is uncertain. Appendix Table 1 (available online) also includes the percentage of the study population that were identified as diabetic, where reported. It may be noted that three included studies explicitly excluded diabetic patients, and 11 did not report any information. For the remaining seven studies, the median and mean percentages of diabetics included in their interventions were 24% and 30%, respectively.

The direct translation of reduced SBP to QALYs saved used in the present review may yet be an oversimplification of the complex processes by which reduced SBP averts CVD outcomes. A related issue is whether there is a lower limit for SBP below which reductions do not produce health benefits[54] nor save QALYs. Current guidelines[55] stipulate a target SBP <140 mmHg for the general hypertensive population, with no consensus about the net benefits of more aggressive treatment to reach a lower target. However, it is likely patients with BP at 160/100 will derive benefit from treatment in moving their BP to 130/80, but might not obtain additional benefit in moving BP to 120/60.[56] Of nine studies where reduction in SBP was translated to QALYs saved, the mean SBP after the effect of intervention was >140 in five studies,[23,33,35,36,38] 135–140 in two studies,[29,41] 120–125 in two studies,[22,27,42,44,49] and <120 in no studies. Based on these means, it is likely that reductions achieved in SBP from the interventions in this review fell within the beneficial range and increased QALYs.

The Community Preventive Services Task Force recommended TBC based on its effectiveness in improving BP control,[57] and also was found to be cost effective.[13] Studies of SMBP within TBC included in the present review do not provide evidence for the contribution of SMBP to the effectiveness or cost effectiveness of TBC because the studies compared SMBP within TBC to usual care. However, SMBP is a common component of

TBC for BP control, as it provides a regular and ongoing activity to engage patients in their own care. SMBP also allows the team of providers to monitor patient response to treatment.

No studies in the present review performed a complete cost–benefit analysis that included improvements in productivity. However, this was partly compensated by cost per QALY estimates computed by the team from translations of reductions in SBP to QALYs saved.

Evidence Gaps

Studies that use SMBP monitoring as a diagnostic tool in addition to treatment should try to separate out their contributing effects on economic outcomes. Although it may be difficult to do this analytically, the diagnostic effect may be approximated, for example, in terms of discontinued or newly initiated treatments. More studies are needed for estimating return on investment for SMBP-alone interventions, capturing longer-term changes in healthcare cost because of changes in morbidity and mortality. There is stronger evidence and greater effectiveness when patient support or TBC is added to SMBP monitoring, but there is no cost-effectiveness evidence for adding various levels of such support, indicating another item for future research.

CONCLUSIONS

When used with additional patient support or within TBC, SMBP monitoring interventions are cost effective. Though short-term healthcare costs averted were greater than cost of intervention, the evidence for cost effectiveness of SMBP interventions when used alone was mixed and inconsistent.

The findings of this economic review, together with the conclusions of the review on effectiveness,[7] support the recommendations for use of SMBP interventions presented by the Community Preventive Services Task Force elsewhere in this issue.[50] These results and findings can contribute to the evidence for SMBP for improved BP management and control as clinical guidelines for the prevention and treatment of hypertension are updated.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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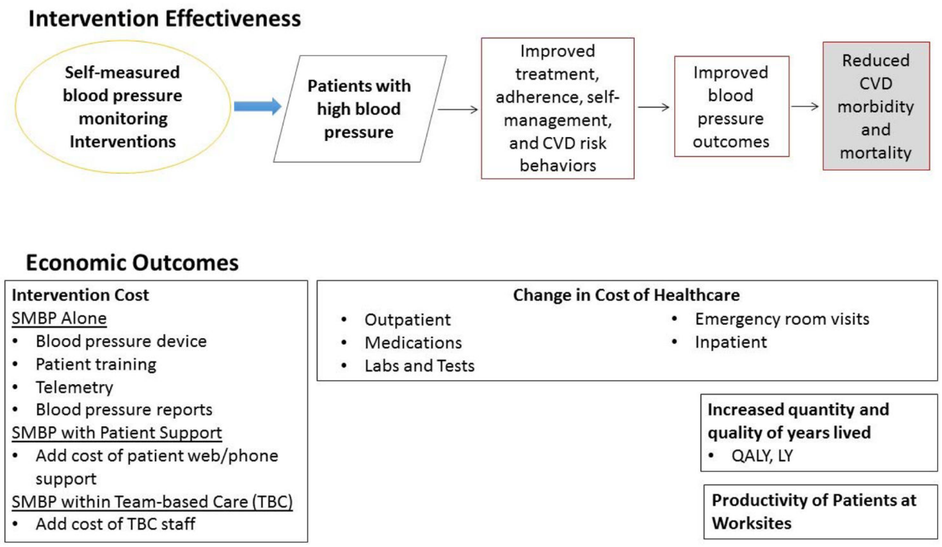

Figure 1.

Economics of SMBP monitoring interventions to improve BP control.

BP, blood pressure; CVD, cardiovascular disease; LY, life years; QALY, quality-adjusted life years; SMBP, self-measured blood pressure; TBC, team-based care

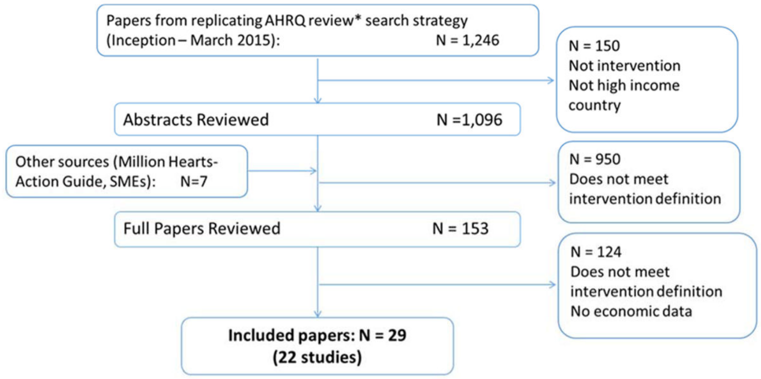

Figure 2.
Economic evidence search yield.
AHRQ, Agency for Healthcare Research and Quality; SME, subject matter expert
*Uhlig K, Patel K, Ip S, Kitsios GD, Balk EM. Self-measured blood pressure monitoring in the management of hypertension: a systematic review and meta-analysis. Ann Intern Med. 2013;159(3):185–194.

Table 1

Intervention Cost and Change in Healthcare Cost

Intervention	Intervention cost Median (IQI) # studies	Change in healthcare cost Median (IQI) # studies	Median time horizon Months	# Modeled studies	Studies with comparison to other than usual care
SMBP alone	\$60 (\$55 to \$74)[a] 7[21–24,27–31]	−\$148 (−\$316 to −\$89) 8[21–27,29–31]	12	2[21,25,26]	Clinic plus ambulatory BP[23]
SMBP with additional support	\$174 (\$63 to \$362)[a] 7[32–36,38,39]	−\$3 (−\$58 to \$62) 6[33,35–39]	9	2[35,39]	None
SMBP within team-based care	\$732 (\$279 to \$946)[b] 6[22,27,33,40–42,44,45,49]	\$369 (\$57 to \$548) 5[22,27,33,41,42,44,46–49]	18	None	None

[a] Per person.

[b] Per person per year.

BP, blood pressure; IQI, interquartile interval; SMBP, self-measured blood pressure

Table 2

Summary Economic Estimates: Total Cost and 20-year Total Cost per QALY Saved

Intervention	Total cost (Intervention cost plus healthcare cost) Median (IQI) # studies	Median time horizon Months	# Modeled studies	Studies with comparison to other than usual care	Total cost per QALY saved; Summed over 20 years Median (IQI) # studies
SMBP alone	−$72 (−$257 to $142)[a] 6[21–24,27,29–31]	12	1[21]	Clinic plus ambulatory BP[23]	Translation (1):[b] Mean $100,000 Translation (2): Mean $144,000 1[22,27] Cost-saving 2[23,29] Ineffective (SBP increased) 2[24,30,31]
SMBP with additional support	$44 ($6 to $250)[a] 6[33,35–39]	9	2[35,39]	None	Translation (1):[b] $2,800 ($525 to $5,100) Translation (2): $4,000 ($756 to $7,400) 4[33,35,36,38]
SMBP within team-based care	$430 ($244 to $1,112)[c] 5[22,27,33,41–44,49]	18	None	Usual care with home BP device[43]	Translation (1):[b] $7,500 ($4,600 to $79,100) Translation (2): $10,800 ($6,600 to $113,900) 4[22,27,33,41,42,44,49]

[a]Per person.

[b]Translation (1): −1 mmHg of SBP=0.009 QALY saved per year[14]; Translation (2): −1 mmHg of SBP=0.093 QALY saved over patient's life time.[15]

[c]Per person per year.

BP, blood pressure; IQI, interquartile interval; QALY, quality-adjusted life year; SBP, systolic blood pressure; SMBP, self-measured blood pressure