Evidence-based Practice Center Systematic Review

Project Title: Self-measured Blood Pressure Monitoring

I. Background and Objectives for the Systematic Review

Hypertension has been classified as consistent blood pressure (BP) equal to or greater than 140 mm Hg systolic or 90 mm Hg diastolic in otherwise healthy adults.[1] In 2000, the estimated prevalence of high BP in the adult population globally was 26 percent with a predicted increase by 24 percent in 2025 for developed countries and 80 percent in developing countries.[2] Within the United States, data from the National Health and Nutrition Examination Surveys in 2005–2006 estimated that 29 percent of all adults 18 years and older were hypertensive.[3] More than 65 million adults in the United States are affected. Only 34 percent have their BP under control.[1] Hypertension is also on the rise for children. In children, hypertension is defined as systolic or diastolic BP that is at or above the 95th percentile for age, sex, and height.[4]

Hypertension is a major risk factor for cardiovascular disease and mortality, accounting for an estimated 14 percent of cardiovascular deaths worldwide and 18 percent in high-income countries.[5] There is an increased risk of total mortality due to heart disease, stroke, chronic kidney disease, and heart failure as well as increased morbidity associated with nonfatal cardiovascular disease events.

Vasan and colleagues report a lifetime risk of developing hypertension within adults aged 55–65 years in the United States as greater than 90 percent.[6] Due to the growing number of people afflicted, the burden of its complications, and economic implications, high BP remains a major public health issue. Strategies aimed at the prevention or control of hypertension continue to be a foremost concern for providers and patients, policymakers and governments.

Measuring BP to diagnose hypertension and monitor therapy is problematic. BP as recorded in the office or clinic setting is the most commonly used approach for measurement of BP in routine medical care. Clinic BP measurements have great variability, which can affect accurate classification of patients. Reliable clinic measurements require adequate rest period prior to measurement, observer training, adjustment of the cuff size to the arm circumference, and slow deflation of the cuff. Even when measured according to established guidelines, clinic BP measurements have several limitations. Clinic BP measurements may not represent the usual BP outside of the clinic setting or the burden of BP throughout a day. BP may rise in the clinic in response to the medical environment (referred to as "white coat hypertension") or BP may be normal in the clinic but not outside of the clinic (referred to as "masked hypertension"). Additional problems with clinic BP measurement include terminal digit bias and variability in a small number of readings.[7] To overcome some of these limitations, self and ambulatory BP monitoring have been advocated.

Ambulatory BP monitoring is a noninvasive, fully automated technique in which BP is recorded over an extended period of time, typically 24 hours. A BP cuff is put around the upper

arm and a connected monitor is preprogrammed to intermittently record BP, usually every 15 to 20 minutes during daytime hours and every 20 to 30 minutes during nighttime hours. Patients are instructed to keep an activity log throughout the testing period for evaluation of stress and activity-related BP changes. This method is neither universally available nor practical on a population basis. Ambulatory BP monitoring will not be included in this report since it is not a question of interest and has been studied in a previous report.[8]

Devices for self-measured BP (SMBP) monitoring, also called home BP measurement, provide an opportunity to record BP at home, outside of the artificial setting of the medical office or clinic. Devices used by patients can range from mechanical aneroid gauges (sphygmomanometers) that require self-inflation and self-auscultation, to those that require squeezing a bulb to inflate but display readings automatically, to those that automatically inflate the cuff and display the reading. Commonly, patients use SMBP monitoring to self record their BP at home and to provide written lists of readings to their provider at office visits; however, more recent innovations have enhanced the potential utility of SMBP devices to store and download readings that can be sent directly to the provider.

Although numerous, perhaps hundreds, of SMBP devices are commercially available, very few have been independently validated as recommended by the American Association of Medical Instrumentation and the British Hypertension Society.[9]

SMBP has several potential uses. Repeated measurements, if averaged, can provide a more accurate estimate of BP burden than those obtained in the clinic. These measurements can also be used to monitor BP during treatment and potentially reduce clinic visits by patients. In addition, SMBP has been proposed as a means to improve adherence with treatment and to diagnose treatment-related hypotension.

Summary of Nomination

The nominator is interested in whether the use of SMBP results in sustained outcomes in patients with hypertension, including reductions in BP, coronary events, stroke, and mortality. The nominator questions whether any improved outcomes may be due to the use of the monitoring devices or from additional support provided to the patients. The nominator is also interested in any differences in outcomes if the patient uses an automated, semiautomated, or manual BP cuff. The original nomination states that the nominator is interested in the use of ambulatory BP monitoring; however, after further clarification from the nominator, it was determined that the intervention of interest is only SMBP.

Policy and/or Clinical Context

SMBP is one potential method for improving rates of BP control and reducing cardiovascular morbidity and mortality, yet the effectiveness of this intervention remains unknown. Payers often receive requests to provide BP cuffs to patients. Currently, the cost of a home BP monitor is approximately $30 to $130.[10] Insurance coverage and approval procedures vary. An evidence report addressing the clinical effects of using these devices could be used to inform clinical care (i.e., should providers prescribe or encourage the use of these devices) as well as policy/payer decisions (i.e., should these devices be covered).

II. Key Questions

The Key Questions (KQs) were developed and refined with a panel of Key Informants, including experts in hypertension, general internal medicine, pediatrics, and cardiology as well as representatives from Medicaid programs and the Agency for Healthcare Research and Quality. The draft KQs were posted for public comment and revised based on subsequent input. Based on feedback, we included KQ 2 to examine the impact or using SMBP in combination with additional support for enhancing adherence with SMBP, lifestyle modification, medication or for allowing more frequent patient-provider interactions. Quality of life was added as outcome of interest for KQs 1–4 if measured by validated instruments.

Question 1

In people with hypertension (adults and children), does SMBP monitoring, when compared to usual care or other interventions without SMBP, have an effect on clinically important outcomes?

a. How does SMBP monitoring compare to usual care or other interventions without SMBP in its effect on relevant clinical outcomes (cardiovascular events, mortality, patient satisfaction, quality of life, and adverse events related to antihypertensive agents)?

b. How does SMBP monitoring compare to usual care or other interventions without SMBP in its effect on relevant surrogate outcomes (cardiac measures: left ventricular hypertrophy, left ventricular mass, and left ventricular mass index) and intermediate outcomes (BP control, BP treatment adherence, or health care–process measures)?

Question 2

In studies of SMBP monitoring, how do clinical, surrogate, and intermediate outcomes (including SMBP monitoring adherence) vary by the type of additional support provided?

Question 3

How do different devices for SMBP monitoring compare with each other (specifically semiautomatic or automatic vs. manual) in their effects on clinical, surrogate, and intermediate outcomes (including SMBP monitoring adherence)?

Question 4

In studies of SMBP monitoring, how does achieving BP control relate to clinical and surrogate outcomes?

Question 5

How does adherence with SMBP monitoring vary by patient factors such as demographics, medical or co-morbid conditions, or care settings?

Eligibility Criteria

KQ 1   **Population:**

- Individuals with hypertension:

  o Untreated or treated and partially controlled.
  o Hypertension: in adults >140/90 mm Hg or another valid definition; in children defined as BP above age-sex-height–specific cut-offs.
  o In a primary care or other outpatient setting.

- Exclude studies of individuals on dialysis.
- Exclude studies of women with gestational hypertension.

Interventions:

- SMBP with upper arm BP monitor, adjusted for arm size.
- Include all devices.
- BP measurement of any frequency or averaged over any number of measurements.
- With or without additional interventions.
- Exclude wrist monitors:

  o Except in patients with large arm circumference.
  o Evaluate studies based on whether devices have been certified or approved by the American Association of Medical Instrumentation or the U.S. Food and Drug Administration or another accrediting body.

Comparator(s):

- No SMBP monitoring.
- Usual care: any office/clinic BP monitoring, not including ambulatory BP monitoring.
- With or without additional interventions.
- Any other treatment plan for hypertension, including, but not restricted to, nursing support, medication, lifestyle changes, and other counseling.

- The additional interventions preferentially should be the same in both study groups (both those with and without SMBP monitoring).
- Studies with different additional interventions in both study groups will be considered on a case-by-case basis and will be evaluated separately.

Outcomes:

- *Clinical outcomes* (KQs 1a, 2, 3, and 4)
  - Cardiovascular events (myocardial infarction, new-onset angina, stroke, transient ischemic attack, and peripheral vascular disease diagnosis or events).
  - Cardiovascular disease mortality.
  - All-cause mortality.
  - Patient satisfaction (any measurement tool, including satisfaction specifically with SMBP device).
  - Quality of life (validated and reliable measurement tools only).
  - Adverse events related to treatment with antihypertensive agents (e.g., hypotensive episodes or orthostatic falls).

- *Surrogate outcomes* (KQs 1b, 2, 3, and 4)

  - Cardiac measures

    - Left ventricular hypertrophy
    - Left ventricular mass
    - Left ventricular mass index

- *Intermediate outcomes* (KQs 1b, 2, 3, and 4)

  - BP control (also predictor in KQ 3)

    - Achieving a predefined change in BP (e.g., systolic BP reduction by 10 mm Hg) or a predefined threshold (e.g., systolic BP <140 mm Hg)
    - BP measured the same way in both groups, preferentially performed by a standardized method in the clinic. But not by SMBP monitoring.
    - Change in BP from baseline or achieved (final) BP.
    - Number and dose of hypertension medications.

  - Adherence to hypertension treatment.
    - *Not*: adherence to SMBP monitoring
  - Health care–process measures such health care encounters (visits or calls) or number of medication changes.

Study Design:

- Comparative studies (randomized controlled trials, quasi-randomized controlled trials, and nonrandomized *prospective* studies).
- Longitudinal studies.
- Duration of followup: ≥8 weeks.
- No minimum sample size.

KQ 2   **Population:** same as for KQ 1.

Intervention and Comparator:

- Both study groups must be using SMBP monitoring:

  - As a principal part of the medical intervention.
  - Not just as a device to measure the outcome BP.

- Study abstract and/or title must suggest that SMBP monitoring was used as a principal part of the intervention.
- Not all studies of ancillary interventions will be screened to find those that happen to use SMBP monitoring.
- Study should compare two or more interventions in addition to SMBP monitoring including, but not limited to, training, nursing interventions, physician consultation, et cetera.

Outcomes: same as for KQ 1.

Study Design: same as for KQ 1.

KQ 3   **Population:** same as for KQ 1.

Intervention:

- One type of SMBP monitor:

  - Automatic
  - Semiautomatic
  - Manual
  - Other similar variations, if applicable.

- Same criteria regarding additional interventions to allow a direct comparison of different SMBP monitors.

Comparator: another type of SMBP monitor.

Outcomes: same as for KQ 1.

Study Design: same as for KQ 1.

KQ 4   **Population:** same as for KQ 1.

Intervention: same as for KQ 1.

Comparator: same as for KQs 1, 2, and 3.

Predictor: BP control (effect of SMBP monitoring on BP, as per KQ 1).

Outcomes: same as for KQ 1.

Study Design: same as for KQ 1.

KQ 5   **Population:** same as for KQ 1.

Intervention: same as for KQ 1

Predictors:

- Socioeconomic status
- Race/ethnicity
- Rural versus urban
- Other patient characteristics
- Type of SMBP monitor
- Comorbidities, target-organ damage
- Mental health status, depression, anxiety
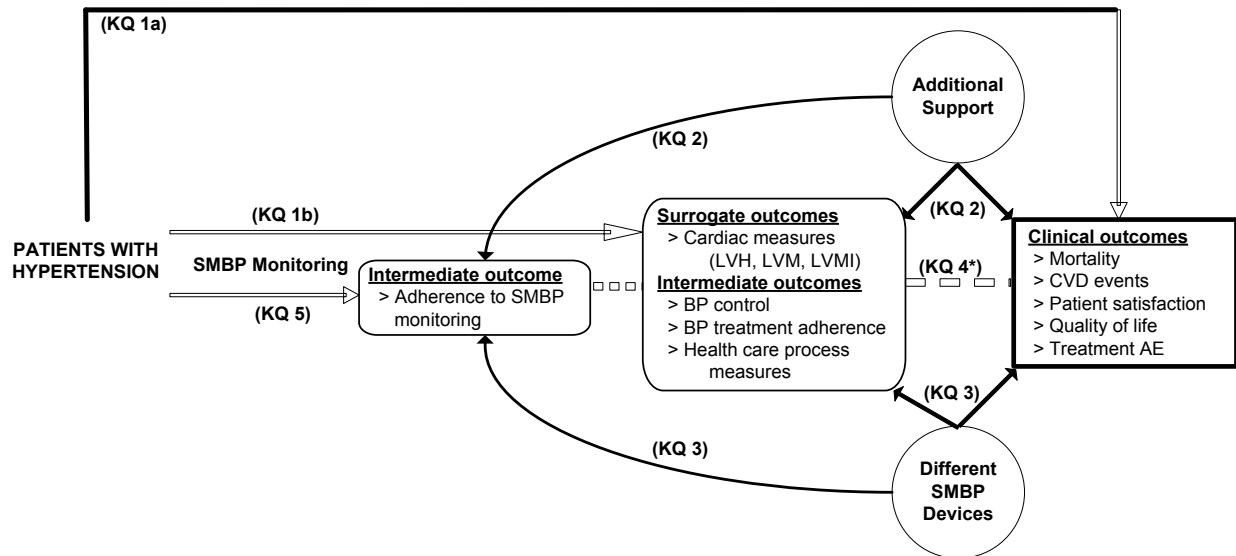- Other factors such as language requirements or literacy

Outcome: adherence with SMBP monitoring (as defined in study; e.g., adherence with a certain percentage of prescribed measurements)

Study Design:

- Prospective longitudinal study
- N ≥ 100 for adults; N ≥ 10 for children
- Duration of followup: ≥8 weeks
- Will not include results in a "case-control" format.
- Studies must evaluate adherence rates based on predictors (e.g., age group ≥65 vs. <65 years old), not predictor values based on adherence (e.g., adherers were on average X years old and nonadherers were on average Y years old).

III. Analytic Framework

* Key Question 4 relates to the link between the specific intermediate outcome of BP control and the health outcomes, in addition to the surrogate outcome cardiac measures.

Abbreviations: AE = adverse events; BP = blood pressure; CVD = cardiovascular disease; KQ = key question; LVH = left ventricular hypertrophy; LVM = left ventricular mass; LVMI = left ventricular mass index; SMBP = self-measured blood pressure.

Alternate Text: This figure depicts the key questions within the context of the PICO described in the previous section. In general, the figure illustrates how use of self-measured blood pressure (SMBP) monitoring may result in changes in surrogate outcomes (cardiac measures), intermediate outcomes (blood pressure control, adherence with antihypertensive treatment, and health care–process measures), and clinical outcomes (mortality, cardiovascular events, patient satisfaction, quality of life, and adverse events related to hypertension treatment). Additional

support and different SMBP devices may impact on the effects of SMBP monitoring. The effect of SMBP monitoring may also be related to adherence to the monitoring. The five key questions are mapped across these various factors.

IV. Methods

A. Criteria for Inclusion/Exclusion of Studies in the Review

We plan to use the eligibility criteria for Populations, Interventions, Comparators, Outcomes, and Study Design as enumerated in Section II (Eligibility Criteria). There will be no language restriction. We plan to search conference abstracts to identify recent, but not yet fully published, studies. We do not expect to contact authors for additional data.

B. Searching for the Evidence: Literature Search Strategies for Identification of Relevant Studies To Answer the Key Questions.

Appendix 1 at the end of this document has our proposed literature search strategy. This search will be conducted in MEDLINE and the Cochrane Central Register of Controlled Trials. Hand searches will not be done. Full-text articles will be retrieved for all potentially relevant articles. These will be rescreened for eligibility. The reasons for excluding these articles will be tabulated. We will ask the technical experts and others to inform us of any potentially missing articles. All suggested articles will be screened for eligibility using the same criteria as for the original articles. If necessary, we will revise the literature search to find similar articles to those missed. When the draft report has been submitted, we will run an updated literature search (using the same search strategy) and will add these to the final report.

C. Data Extraction and Data Management

Each study will be extracted by one experienced methodologist. The extraction will be reviewed and confirmed by at least one other methodologist. Data extraction will be done into standard forms in Microsoft Word. The basic elements and design of the forms will be the same as multiple forms we have used for other comparative effectiveness reviews, technology assessments, evidence reports, and other systematic reviews. Prior to use, the form will be customized to capture all the relevant elements for the KQs. We will use separate forms for questions related to treatment (KQs 1–4) and predictors (KQ 5). We will test the forms on several studies and revise the forms as necessary before full data extraction of all articles is performed.

We will extract basic demographic data such as age, sex, and race; diabetes, cardiovascular disease, or other relevant comorbid conditions; and additional factors that may have a role in effect modification of the intervention-outcome association, including the type of additional support.

D. Assessment of Methodological Quality of Individual Studies

We will use the method for evaluating study quality recommended in Chapter 5 of the Agency for Healthcare Research and Quality *Methods Guide for Comparative Effectiveness Reviews* (hereafter *Methods Guide*). Briefly, we will rate each study as being of good, fair, or poor quality based on their adherence to well-accepted standard methodologies and adequate reporting. The grading will be outcome-specific such that a given study that reports its primary outcome well but did an incomplete analysis of a secondary outcome would be graded of different quality for the two outcomes. Studies of different study designs will be graded within the context of their study design. Thus, randomized controlled trials will be graded as good, fair, or poor and observational studies will separately be graded good, fair, or poor. However, we expect retrospective studies to be of fair or poor quality due to the increased risk of bias with a retrospective study design.

E. Data Synthesis

All included studies will be summarized in narrative form and in summary tables that tabulate the important features of the study populations, design, intervention, outcomes, and results. We will consider performing meta-analyses where there are at least three unique studies that are deemed to be sufficiently similar in population and have the same comparison of interventions and the same outcomes. We expect to require input from domain experts to assess whether studies are too clinically heterogeneous for meta-analysis to be appropriate. We will perform only random-effects model meta-analyses. We will look across trials to qualitatively identify heterogeneity of potential effect-modifying factors, such as age, sex, race, relevant comorbid conditions, and type of additional support. If clinical heterogeneity can be narrowed down to a small number of promising factors, we will consider these for subgroup analyses. For KQ 5, we will search for studies that directly analyze the question of whether any pretreatment patient-level characteristics are associated with adherence with SMBP monitoring. These will be described and discussed in narrative form.

F. Grading the Evidence for Each Key Question

We will follow the AHRQ *Methods Guide for Comparative Effectiveness Reviews* to grade the strength of bodies of evidence for each KQ.[11] Briefly, we will assess the risk of bias, consistency, directness, and precision. For each outcome (or set of outcomes), we will assign a grade for the strength of evidence: high, moderate, low, or insufficient. These will be based on our level of confidence that the evidence reflects the true effect for the comparisons of interest.

V. References

1. Chobanian AV, Bakris GL, Black HR, et al. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report. JAMA 2003;289:2560-72. Erratum in: JAMA 2003;290:197.

2. Kearney PM, Whelton M, Reynolds K, et al. Worldwide prevalence of hypertension: a systematic review. J Hypertens 2004;22:11-19.

3. Yoon SS, Ostchega Y, Louis T. Recent trends in the prevalence of high blood pressure and its treatment and control, 1999–2008. NCHS Data Brief 2010;(48):1-8.

4. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics 2004;114(2 Suppl 4th Report):555-76.

5. Ezzati M, Oza S, Danaei G, et al. Trends and cardiovascular mortality effects of state-level blood pressure and uncontrolled hypertension in the United States. Circulation 2008;117:905-14.

6. Vasan RS, Beiser A, Seshadri S, et al. Residual lifetime risk for developing hypertension in middle-aged women and men: the Framingham Heart Study. JAMA 2002;287:1003-10.

7. Ghuman N, Campbell P, White WB. Role of ambulatory and home blood pressure recording in clinical practice. Curr Cardiol Rep 2009;11:414-21.

8. Appel L, Robinson K, Guallar E. Utility of Blood Pressure Monitoring Outside of the Clinic Setting, Evidence Report/Technology Assessment No. 63 Prepared by the Johns Hopkins Evidence-based Practice Center under Contract No. 290-97-006). Rockville, MD: Agency for Healthcare Research and Quality, November 2002. AHRQ Publication No. 03-E004. Archived at: http://archive.ahrq.gov/downloads/pub/evidence/pdf/utbp/utbp.pdf. Accessed April 7, 2011.

9. British Hypertension Society Web site. NICE/BHS Hypertension Guideline Review 28 June 2006. Available at: http://www.bhsoc.org/NICE_BHS_Guidelines.stm . Accessed December 8 2010.

10. Consumer Reports Health.org Web site. Best blood-pressure monitors. Last reviewed: November 2010. Available at: http://www.consumerreports.org/health/healthy-living/home-medical-supplies/blood-pressure-monitors/blood-pressure-monitor/overview/blood-pressure-monitor-ov.htm. Accessed April 7, 2011.

11. Owens DK, Lohr KN, Atkins D, et al. AHRQ series paper 5: grading the strength of a body of evidence when comparing medical interventions―Agency for Healthcare Research and Quality and the Effective Health-Care Program. J Clin Epidemiol 2010;63:513-23.

VI. Definition of Terms

All terms requiring definition have been addressed in Background and Objectives for the Systematic Review.

VII. Summary of Protocol Amendments

In the event of protocol amendments, the date of each amendment will be accompanied by a description of the change and the rationale.

VIII. Review of Key Questions

For Comparative Effectiveness reviews (CERs) the key questions were posted for public comment and finalized after review of the comments. For other systematic reviews, Key Questions submitted by partners are reviewed and refined as needed by the EPC and the Technical Expert Panel (TEP) to assure that the questions are specific and explicit about what information is being reviewed.

IX. Technical Expert Panel (TEP)

A TEP panel is selected to provide broad expertise and perspectives specific to the topic under development. Divergent and conflicted opinions are common and perceived as health scientific discourse that results in a thoughtful, relevant systematic review. Therefore study questions, design and/or methodological approaches do not necessarily represent the views of individual technical and content experts. The TEP provides information to the EPC to identify literature search strategies, review the draft report and recommend approaches to specific issues as requested by the EPC. The TEP neither does analysis of any kind nor contributes to the writing of the report.

X. Peer Review

Approximately five experts in the field will be asked to peer review the draft report and provide comments. The peer reviewer may represent stakeholder groups such as professional or advocacy organizations with knowledge of the topic. On some specific reports such as reports requested by the Office of Medical Applications of Research, National Institutes of Health there may be other rules that apply regarding participation in the peer review process. Peer review comments on the preliminary draft of the report are considered by the EPC in preparation of the final draft of the report. The synthesis of the scientific literature presented in the final report does not necessarily represent the views of individual reviewers. The dispositions of the peer review comments are documented and will, for CERs and Technical briefs, be published three months after the publication of the Evidence report.

It is our policy not to release the names of the Peer reviewers or TEP panel members until the report is published so that they can maintain their objectivity during the review process.

Appendix 1. Search strategy (updated and run on August 5, 2010)

#	Searches	
1	exp Blood Pressure Monitoring, Ambulatory/	SMBP devices
2	exp Blood Pressure Monitors/	
3	exp Blood Pressure/	
4	exp hypertension/	
5	exp Self Care/	
6	(3 or 4) and 5	
7	((blood pressure or hypertens$) and self and (measure$ or monitor$ or care or manage$)).mp.	
8	1 or 2 or 6 or 7	
9	randomized controlled trial.pt.	Comparative studies (Key Question 1-4)
10	controlled clinical trial.pt.	
11	randomized controlled trials/	
12	Random Allocation/	
13	Double-blind Method/	
14	Single-Blind Method/	
15	clinical trial.pt.	
16	Clinical Trials.mp. or exp Clinical Trials/	
17	(clinic$ adj25 trial$).tw.	
18	((singl$ or doubl$ or trebl$ or tripl$) adj (mask$ or blind$)).tw.	
19	Placebos/	
20	placebo$.tw.	
21	random$.tw.	
22	trial$.tw.	
23	(randomized control trial or clinical control trial).sd.	
24	(latin adj square).tw.	
25	Comparative Study.tw. or Comparative Study.pt.	
26	exp Evaluation studies/	
27	Follow-Up Studies/	
28	Prospective Studies/	
29	(control$ or prospectiv$ or volunteer$).tw.	
30	Cross-Over Studies/	
31	or/9-30	
32	exp cohort studies/ or exp prospective studies/ or exp retrospective studies/ or exp epidemiologic studies/ or exp case-control studies/	Cohort studies (Key Question 5)
33	(cohort or retrospective or prospective or longitudinal or observational or follow-up or followup or registry).af.	
34	case-control.af. or (case adj10 control).tw.	
35	ep.fs.	
36	or/32-36	
37	8 and (31 or 36)	Cross
38	limit 37 to humans [Limit not valid in CCTR; records were retained]	Remove duplicates
39	limit 38 to yr="1888 - 2000"	
40	remove duplicates from 39	
41	limit 37 to yr="2001-current"	
42	remove duplicates from 41	
43	limit 37 to yr="2009-current"	

44	remove duplicates from 43
45	or/40,42,44
46	(home adj20 blood pressure).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
47	or/9-45
48	46 and 47
49	(exp telemedicine/ or exp self-examination/) and (exp Blood pressure/ or exp Hypertension/)
50	47 and 49
51	45 or 48 or 50

Added terms