The Impact of a Multidisciplinary Information Technology–Supported Program on Blood Pressure Control in Primary Care

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Background—Hypertension is a leading mortality risk factor yet inadequately controlled in most affected subjects. Effective programs to address this problem are lacking. We hypothesized that an information technology–supported management program could help improve blood pressure (BP) control.

Methods and Results—This randomized controlled trial included 223 primary care hypertensive subjects with mean 24-hour BP $>130/80$ and daytime BP $>135/85$ mm Hg measured with ambulatory monitoring (ABPM). Intervention subjects received a BP monitor and access to an information technology–supported adherence and BP monitoring system providing nurses, pharmacists, and physicians with monthly reports. Control subjects received usual care. The mean (±SD) follow-up was 348 (±78) and 349 (±84) days in the intervention and control group, respectively. The primary end point of the change in the mean 24-hour ambulatory BP was consistently greater in intervention subjects for both systolic (−11.9 versus −7.1 mm Hg; $P<0.001$) and diastolic BP (−6.6 versus −4.5 mm Hg; $P=0.007$). The proportion of subjects that achieved Canadian Guideline target BP (46.0% versus 28.6%) was also greater in the intervention group ($P=0.006$). We observed similar BP declines for ABPM and self-recorded home BP suggesting the latter could be an alternative for confirming BP control. The intervention was associated with more physician-driven antihypertensive dose adjustments or changes in agents ($P=0.03$), more antihypertensive classes at study end ($P=0.007$), and a trend toward improved adherence measured by prescription refills ($P=0.07$).

Conclusions—This multidisciplinary information technology–supported program that provided feedback to patients and healthcare providers significantly improved blood pressure levels in a primary care setting. (Circ Cardiovasc Qual Outcomes. 2009;2:170-177.)

Key Words: hypertension ■ blood pressure ■ blood pressure monitoring, ambulatory

Only 25% of North American hypertensive patients have adequate blood pressure (BP) control.¹ Reasons for lack of control in treated subjects include nonadherence, lower BP goals, monotherapy, and clinician “inertia” or inadequate management.²⁴ Suboptimal flow of information between primary healthcare providers may also be a contributing factor.⁵ The involvement of pharmacists, nurses, or communication technologies to enhance hypertension management may improve BP; however, most studies that tested interventions to optimize patient follow-up, pharmacotherapy, and adherence were small and none combined these approaches in a randomized design or used 24-hour ambulatory blood pressure monitoring (ABPM) to assess outcomes.⁶⁻¹⁴ Our multidisciplinary research group developed an information technology (IT)-supported management program to facilitate BP and adherence data circulation between patients and primary care healthcare providers, without the need for high intensity and costly personnel interventions. We tested the hypothesis that this multifaceted program would improve mean 24-hour BP levels.
WHAT IS KNOWN

• Although hypertension is a leading mortality risk factor, effective programs to address poor BP control are lacking.

• We hypothesized that a primary care information technology–supported management program could help improve BP control.

WHAT THE STUDY ADDS

• Following a mean (±SD) of 348 (±78) and 349 (±84) days in the intervention or control group, respectively, the change in the mean 24-hour ambulatory BP was consistently greater in intervention subjects for both systolic (−11.9 versus −7.1 mm Hg; P=0.001) and diastolic BP (−6.6 versus −4.5 mm Hg; P=0.007), and the proportion of subjects that achieved target BP (46.0% versus 28.6%) was also greater in the intervention group (P=0.006).

• Although the number of physician visits was similar in both groups (P=0.32), the intervention was associated with more physician-driven antihypertensive dose adjustments or changes in agents (P=0.03), more antihypertensive classes at study end (P=0.007), and a higher median adherence composite index (1.36 versus 1.00; P=0.008).

• This multidisciplinary information technology–supported program that provided feedback to patients and healthcare providers significantly improved BP levels in a primary care setting without increasing the number of visits to physicians.

Methods

Study Design

The study was a randomized controlled trial (ClinicalTrials.gov, NCT00374829; ISRCTN75436659) using a prospective, randomized, open-label, blinded end points design, as used in a number of hypertensive trials15–17 when blinding is impractical. As this study did not include hard clinical end points, such as mortality, myocardial infarctions, etc., no data safety and monitoring board (DSMB) was felt to be necessary. An external advisory and blinded end point committee was created to monitor study progress and analyze and adjudicate results without knowledge of the study group to which subjects were assigned.

Participants

Consecutive subjects aged ≥18 years with an office diagnosis of hypertension according American and Canadian guidelines18–20 followed by one of 21 physicians from 8 primary care clinics in the city of Laval, Quebec, Canada and who filled their prescriptions at one of 32 participating pharmacies were offered to participate in the trial by their physician. Subjects unlikely to complete the study, with chronic atrial fibrillation, pregnant, or those participating in another trial were excluded. Physicians involved in the study had no previous experience with telemedicine technology or hypertension management programs. Subjects were followed at their usual point of care by their primary care physician throughout the study period; however, ABPMs were conducted at the regional ambulatory hospital by study staff. Only subjects with hypertension confirmed by a mean 24-hour BP ≥130/80 and daytime BP ≥135/85 mm Hg measured by ABPM were randomized. Institutional Review Board (IRB) of the Centre de santé et de services sociaux de Laval (Laval, Quebec, Canada), the regional health center, granted ethical approval for all 8 clinics involved in the study. The IRB of the Centre Hospitalier de l’Université de Montréal (Montréal, Quebec, Canada), where the study was designed, also provided research and ethics approval. Declaration of Helsinki principles were followed, and all patients read and signed informed consent forms approved by the Centre de santé et de services sociaux de Laval IRB.

Study Groups

Intervention subjects were provided with an educational booklet, a digital home BP monitor (Omron HEM-711AC), a log book and access to a telephone-linked IT-supported management program. The system collected self-recorded BP and self-assessed adherence data (with the Morisky questionnaire)20 weekly from intervention subjects and merged these data with actual pharmacy medication refill data and generated reports, which were faxed monthly to physicians, pharmacists, and study nurses. Based on a predefined algorithm, the system also e-mailed study nurses in the event of poor BP control after 4 weeks or reports of nonadherence. Nurses could subsequently contact subjects to inquire about BP or adherence difficulties and to deal with them or refer subjects to their physician or pharmacist as specified in the study algorithm. Control subjects received usual care and educational materials. Participating pharmacies were provided software so that they could actively transmit data on antihypertensive prescription refills and changes in medication from both study groups to the IT-supported central system.

Outcomes

The primary end point was the change in mean 24-hour systolic blood pressure (SBP) and diastolic blood pressure (DBP) over the planned study duration of 1 year (±30 days) measured by ABPM. Secondary end points included: changes in daytime and nocturnal SBP and DBP measured by ABPM; change in office SBP and DBP, measured by a digital BP monitor (Omron HEM-907); the proportion of subjects that achieved target BP; the number of physician-driven medication changes, the number of antihypertensive agents used; and adherence from pharmacy data collected electronically and validated after on site pharmacy database monitoring. Adherence was expressed as continuous medication availability (CMA) and measures of gaps (CMG) scores calculated from actual pharmacy data, which estimate the proportion of time that subjects have or do not have medication available.22 Given that self-reported adherence data were only assessed in the intervention group, it was not used as an outcome measure.

Sample Size Calculation

Although the primary end point was the change in mean 24-hour SBP and DBP, we elected to determine sample size based on adherence scores, because we hypothesized it would be the most likely determinant of BP control to be impacted by the intervention. A sample size of 250 patients per group would have a power of 80% to detect a difference in compliance rates of 5% (effect size of 0.25) at a standard deviation of 20%.22,23 This sample size had more than 99% power to detect a difference in 24 hour SBP or DBP change from baseline (the primary end point) larger than 3.5 mm Hg (with standard deviations up to 7 mm Hg).24

Randomization

Nurses telephoned a central automated randomization system and provided 2 stratification factors: (1) newly diagnosed, pharmacologically untreated versus uncontrolled pharmacologically treated hypertension; and (2) pharmacologically treated concomitant disease(s) or not. The randomization system assigned subjects to 1 of the 2 treatment groups using randomly permuted blocks for each stratification factor. Study nurses informed subjects as to which treatment group they were assigned.
Statistical Methods

Baseline descriptive statistics to characterize the study population include means ± SD for continuous variables and frequency distributions for categorical variables. All primary and secondary end point analyses were performed using the intent-to-treat principle including all randomized subjects. Missing data were estimated using the last-value-carried-forward technique. Subjects lost to follow-up or refusing the final ABPM were attributed the same BP as at the beginning. Subjects lacking pharmacy data were assigned a CMA score of 0 and CMG score of 1. Subjects that withdrew before completing 1 year had CMA and CMG scores calculated as if they had completed 1 year in the study. Additional sensitivity analyses were performed: the first involved no data imputation and was conducted only on subjects who completed follow-up ABPM and study visits for the primary end points only. The second involved multiple imputation analyses on the full sample size for the primary end points.

The change from baseline between groups in primary and secondary BP end points were assessed by an ANOVA model that included treatment and the stratification factors mentioned above and are presented as least square means ± SE. All other secondary end points are expressed as medians (interquartile range), and differences between groups were tested by the Wilcoxon rank-sum test. The normality assumption was assessed by examining histograms of the residuals and normal probability plots. The proportion of subjects that achieved target BP was analyzed using a logistic regression model adjusted for the same stratification factors.

Two additional ancillary analyses were performed. To estimate the impact of adherence and numbers of medications taken, a posthoc adherence composite index, the multiple of the CMA value with the number of antihypertensive agents taken at the end of the study was calculated and compared between groups. We also estimated the mean slope of the decline in self-recorded SBP and DBP using a mixed model procedure.

All statistics were performed on a locked and cleaned dataset by independent statistical programmers at the data coordination center. All probability values reported are 2-sided. Mean 24-hour ABPM systolic and diastolic BP were considered the coprimary end points and were analyzed at the 0.025 significance level. All other end points were predefined secondary end points and were analyzed at the 0.05 significance level, without adjustment for multiple comparisons.

Results

Recruitment and Participant Flow

A total of 371 subjects were referred between May 2004 and March 2007 (Figure 1), of which 15 refused to participate, 13 did not meet inclusion criteria, and 120 did not meet the ABPM criteria. This 39.9% rate of ineligibility significantly delayed recruitment. The Steering Committee requested an unplanned blinded interim analysis by the Advisory Committee who recommended that recruitment be stopped because of significant differences in BP levels between groups. All 51 subjects that had not completed the 1 year study follow-up were called to have their final visit even if 1 year follow-up was not completed.

Analyses included all 223 randomized subjects, 111 in the intervention and 112 in the control group. The mean (± SD) follow-up was 348 (± 78) days in the intervention and 349 (± 84) days in the control group. All patients were followed a minimum of 4.9 months. Of all randomized subjects, 1 died (intervention), 14 (12.6%) patients in the intervention and 18 (16.1%) in the control group did not have physician follow-up visits, and 1 was withdrawn by their physician for nonadherence (intervention). A marginally larger proportion of patients in the control than in the intervention group did not
undergo a final ABPM (25/112 or 22.3% versus 17/111 or 15.3%, respectively, \(P=0.18\)).

### Baseline Characteristics

Subjects from both groups had similar baseline demographic and clinical characteristics as well as uncontrolled hypertension at the time of recruitment. The number and proportion of subjects taking medications to treat concomitant disease was also similar (Table 1).

#### Information Technology–Supported Interventions

The system generated 4617 telephone calls to collect BP and self-reported adherence data, corresponding to 42 (±15) answered calls per intervention subject throughout the study. Nurses made 209 contacts in response to e-mail alerts generated by the system for self-reported uncontrolled BP, poor adherence, or hospitalization (an equivalent to 4.5% of all system calls to the patients), which corresponds to 1.9 (±2.4) contacts per intervention subject. Nurses then provided further education on hypertension and adherence or recommended the subject contact their doctor. Mean duration of these calls was 7.5 (±4.9) minutes.

#### Outcomes

### Blood Pressure

Figure 2 illustrates 24-hour measurements, daytime and nocturnal ambulatory BP, and office BP measurements at baseline and study end. Changes and incremental differences between groups in these levels are presented in Figure 3. For the coprimary end points, the mean (±SE) change in 24-hour SBP was \(-11.9 (±1.0)\) versus \(-7.1 (±1.0)\) mm Hg (\(P<0.001\)) and the change in 24-hour DBP was \(-6.6 (±1.1)\) versus \(-4.5 (±1.1)\) mm Hg (\(P=0.007\)) in the intervention and control subjects, respectively. A consistent favorable effect of the intervention was observed on all secondary BP end points.

As a larger proportion of controls did not have a final ABPM, sensitivity analyses were conducted on subjects who underwent ABPMs at study end. Without data imputation, the change in 24-hour SBP was \(-13.9 (±1.1)\) and \(-9.0 (±1.1)\) mm Hg in the intervention and control groups, respectively (\(P=0.002\)). Similarly, the change in 24-hour DBP was \(-7.7 (±0.6)\) and \(-5.6 (±0.6)\) mm Hg in intervention and control subjects, respectively (\(P=0.02\)). After multiple imputation parameter estimates for the primary end points, differences between treatments in the change in 24-hour SBP and DBP were \(4.22 (±1.6)\) mm Hg and \(2.05 (±0.86)\), respectively, in favor of the intervention group (\(P=0.009\) and \(P=0.01\)).

The mean change in office SBP was \(-18.7\) and \(-13.8\) mm Hg in intervention and control subjects, respectively (\(P=0.05\)). Similarly, the mean change in office DBP was \(-9.1\) and \(-5.6\) mm Hg, in intervention and control subjects, respectively, (\(P=0.02\)). The proportion of subjects who achieved American and Canadian Guideline target office BP (\(<140/90\)) was significantly greater in the intervention group (46.0% versus 28.6% for controls, \(P=0.006\)).

Ancillary analyses of self-recorded BP by intervention subjects throughout the study revealed significant slopes (±SE) of \(-0.025 (±0.003)\) mm Hg/d, \(P<0.001\) and \(-0.014 (±0.002)\) mm Hg/d, \(P<0.001\), for SBP and DBP, respectively. The resulting mean (±SD) decline of \(-10.7 (±18.8)\) and \(-6.1 (±10.9)\) mm Hg in self-recorded SBP and DBP over the study duration was of similar magnitude as those observed using ABPM but not office BP.

#### Medications Taken, Refill Adherence, and Physician Visits

The number of physician-driven antihypertensive medication additions or dosage adjustments was significantly higher among intervention subjects (\(P=0.03\); Table 2). At the study end, intervention subjects took a median of 2.0 antihypertensive drug classes, which was higher than the median of 1.0 drug taken by control subjects (\(P=0.007\)). There was a trend toward an increase in the total number of different classes of antihypertensive medications dispensed to subjects throughout the study in the intervention group (\(P=0.07\)). There was also a trend toward improved drug adherence measured with pharmacy data (CMA) in intervention subjects (\(P=0.07\)), and the median posthoc adherence composite index was 1.36 and 1.00 in intervention and control subjects, respectively (\(P=0.008\)). The smaller sample size reduced the power to
detect a difference between groups in CMA rates to 43% using the Wilcoxon rank sum test. The number of physician visits was similar in both groups ($P=0.32$). The interval (in days) between randomization and the first physician follow-up visit ($P=0.39$) was also similar.

### Adverse Events

As this trial assessed the impact of an IT-supported subject management system, there were no adverse events that can be associated with the intervention per se. During the study, 1 subject (0.4%) died of cancer (intervention group) and 14

![Figure 2](image1.png)

**Figure 2.** Impact of the information technology–supported program (Intervention) vs usual care (Control) on blood pressure levels (ABPM and in office). Data are presented as means with standard error of the means. Probability values are from analyses of variance comparing differences in the change in blood pressure from baseline to study end after adjustment for stratification factors. The BP scale varies from 1 graph to the other, to highlight differences. DBP indicates diastolic blood pressure; IT, information technology; SBP, systolic blood pressure.

![Figure 3](image2.png)

**Figure 3.** Changes from baseline in blood pressure in subjects receiving the information technology–supported program (Intervention) versus usual care (Control) and their differences. Changes are presented as least squares means, adjusting for stratification factors. Differences between groups are presented graphically along with their corresponding 95% CI and probability value. DBP indicates diastolic blood pressure; IT, information technology; SBP, systolic blood pressure.
supports the argument that technology coupled with home measurement of BP and follow-up by a health care professional is more likely successful in achieving improved blood pressure control rather than a single component on its own.

A marginally larger proportion of control (25/112 or 22.3% versus 17/111 or 15.3% in the intervention group, P=0.18) patients refused the final ABPM, with the usual justification of not having perceived the value of coming back to the ambulatory clinic, which was not their usual point of care. In spite of this, both the sensitivity analyses for the primary end points, which excluded patients who did not have a final ABPM, and the multiple imputation parameter estimates for the primary end points did not change our results.

ABPM measurements were consistently lower than office BP readings, as reported previously.25 The benefits of ABPM are well documented.26–28 We were able to identify subjects that were either normotensive or who had well controlled hypertension (“white coats”) before randomization. The long-term risk of events in patients with sustained hypertension has been shown to be twice that of normotensive or white coat patients,27 which further strengthens the argument for the routine use of techniques to screen for hypertension control in primary care. We also observed highly significant negative slopes in self-recorded BP and similar mean BP declines for both ABPM and self-recorded home BP. Such findings support the recent recommendations to use self-recorded BP taken with reliably calibrated home BP monitors in the real-life condition of the patient’s home rather than rely on BP readings taken in the clinic setting.29,30 Home BP monitoring may therefore prove to be an inexpensive alternative to ABPM.

Over 70% of hypertensive patients are uncontrolled (BP ≥140/90) and, even in large trials, lowering SBP under 140 mm Hg was achieved in less than one fourth of patients.27,31 The proportion of subjects with controlled BP (46%) was significantly higher with the IT-supported intervention. The additional 4.8-mm Hg decrease in SBP achieved with the intervention was much higher than previously reported using other IT-supported interventions.12,14 The incremental decrease in SBP observed with the intervention, if sustained, can be projected to result in risk reductions of 30% to 35% for stroke and a 20% to 25% for MI.27
Generalizability of our results is supported by the low intensity of interventions required to achieve BP control. The majority (95.5%) of outbound calls that collected adherence and BP data and generated reports to healthcare providers did not elicit nurse support. The average per patient number of calls (1.9) and time spent on these calls by nurses was extremely modest compared to the 42 IT contacts throughout the study. Therefore, a fairly simple intervention supported by technology that consumed very little human resources can be highly effective in primary care settings.

Our study had several limitations, the first of which was the reduced versus planned sample size. Although the final sample size had more than 90% power to detect the prespecified effect size on 24-hour BP, the primary end point, we lacked power to demonstrate the impact of the program on drug adherence, which was our intention when planning the sample size. Antihypertensive agent adherence is usually between 50% and 70% in the North American population. In addition to possible interference with adherence by technology that consumed very little human resources can be extremely modest compared to the 42 IT contacts throughout the study. Therefore, a fairly simple intervention supported by technology that consumed very little human resources can be highly effective in primary care settings.

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In summary, our IT-supported multidisciplinary management program significantly improved BP levels and control in primary care. These results were achieved through regular automated patient contact, nursing support as needed, and monthly feedback to physicians and pharmacists, which led to more medication dosage adjustments, changes or additions, a larger number of antihypertensive classes at study end, and a trend toward improved adherence. Our results clearly support the need for further investigation on innovative approaches that can improve the management of hypertension and other chronic diseases.

Appendix

Steering Committee

Advisory and Blinded End Point Committee
D. Drouin, A. Milot (Université Laval) and R. Tamblyn (McGill University).

Data Management and Statistical Analyses
D. Johnson, PhD, M.-C. Guertin, PhD, A. Nozza, Y. Ssuto, and A. Brunelle from the MHICC were responsible for independent statistical analysis of the data. The MHICC received financial compensation as the data management and statistical analysis subcontractor. The MHICC was responsible for randomization and stratification, production of case report forms, data entry, and management and the analysis and interpretation of the data.

Study Staff
C. Tremblay, C. Mayrand, R. Jolicoeur, M.R. Guertin, L. Julien, and A. Peirce were study employees.

Participating Physicians
C. Ricard, MD, G. Lalonde, MD, M.J. Poulin, MD, L. Trudelle, MD, Méd-Centre Chomedey; M. Breton, MD, Centre Médical Laval; H. Chénard, MD, C. Saucier, MD, Polyclinique Médicale Concorde; M. Beauchamp, MD, B. Emond, MD (posthumously), M. Cardin, MD, M. Ouellette, MD, Centre Médical Laval Ouest; M.T. Lussier, MD, MSc, A. Turcotte, MD, A. Desfossés, MD, J. Giroux, MD, B. Millette, MD, UMF/GMF Cité de la Santé de Laval; M. Pilon, MD, S. Meagher, MD, C. Lortie, MD, Le Carrefour Médical; D. Chabot, MD, E. Chabrol, MD, CLSC-CHSLD Ste-Rose; J. Rivest, MD, Clinique L’Envolée. Participating physicians were paid a small honorarium for referral of subjects that qualified, were randomized, and completed the study.

Participating Pharmacists

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**Disclosures**

Members of the advisory and blinded end point committee were not paid for their participation and had no conflicts of interest. No other potential conflict of interest relevant to this article was reported.

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