

**Mini-Review**

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# The Role of Home Blood Pressure Telemonitoring for Blood Pressure Control

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**Key Words**

Hypertension · Blood pressure control · Home blood pressure telemonitoring · Self-measurement of blood pressure · Remote physician care

**Abstract**

Despite improvements in hypertension awareness and treatment, the blood pressure (BP) control rate still remains at around 50%. One of the major determinants of low BP control results from therapeutic inertia of the physician and suboptimal compliance of the patients. Home BP self-measurement and monitoring improves patients' awareness and helps the management of hypertension. Recent technological advances are allowing for accurate measurement and telemonitoring of home BP, with a number of randomized clinical trials demonstrating the efficacy of telemonitoring for BP control. Home BP telemonitoring combined with self-adjustment based on prespecified treatment algorithms has been shown to improve BP control. Additionally, telemonitoring with active intervention by medical professionals has been shown to improve drug compliance and increase the target BP achievement rate. Although nothing can replace the tried and tested doctor-patient relationship in the office, telemonitoring of home BP will be an important tool for treating hypertension in the future.

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**Introduction**

Hypertension is the most prevalent risk factor for cardiovascular disease [1]. Blood pressure (BP) control to below the target BP level is important for improving cardiovascular prognosis [2]. However, despite the improvement of hypertension control rate over the past several decades, the BP control rate still remains low at around 50% [1, 3]. Important factors

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for the low BP control rate are therapeutic inertia of the attending physician and suboptimal medication compliance of the patient [4]. Home BP self-monitoring may be one way to improve both adherence and BP control. In a systemic review and meta-analysis reported by Agarwal et al. [4], there was a significant improvement in both systolic BP (SBP,  $-2.63$  mm Hg; 95% confidence interval, CI,  $-4.24$  to  $-1.02$  mm Hg) and diastolic BP (DBP,  $-1.68$  mm Hg; 95% CI  $-2.58$  to  $-0.79$  mm Hg) with home-based BP compared with clinic-based measurements (control group). Home BP monitoring led to significant reduction in antihypertensive medications (relative risk, RR, 2.02; 95% CI 1.32–3.11) along with less therapeutic inertia (RR for unchanged medication, 0.82; 95% CI 0.68–0.99) [4]. However, self-measurement of home BP without some forms of active monitoring by medical personnel may not be enough to improve BP control. In the Treatment of Hypertension Based on Home or Office Blood Pressure (THOP) trial, a randomized study that compared BP control rate in 203 subjects whose BP medication was adjusted according to home BP compared to 197 control subjects, medication adjustment according to home BP measurements led to less intensive drug treatment but with less BP control [5]. This demonstrates that home BP telemonitoring, behavioral modification as well as algorithm for medication adjustment are needed for improvement in BP control. In this mini-review, we will discuss recent data regarding the effectiveness of home BP telemonitoring for BP control.

### **Telemonitoring of Home BP: Its Effectiveness in Improving BP Control Rate**

The recent development of wireless technologies along with mobile telephone-based transmission systems allows for collection of home BP measurement data into the remote computer server of the health care provider [6]. These recent technological innovations have resulted in telemonitoring that can provide advices regarding adjustments in medications as well as behavioral alterations, both through intervention by medical professionals as well as by self-adjustment based on a prespecified algorithm [7–9]. In contrast to self-monitoring of home BP, telemonitoring of home BP improves BP control. In a meta-analysis by Omboni et al. [10], despite the high level of heterogeneity among the analyzed studies, there was a significant reduction in office BP (SBP, 5.64 mm Hg; 95% CI 3.36–7.92; DBP, 2.78 mm Hg; 95% CI 1.62–3.93;  $n = 4,389$ ) and a significant reduction in ambulatory SBP in the home BP telemonitoring group (SBP, 2.28 mm Hg; 95% CI 0.24–4.32;  $n = 655$ ). The telemonitoring group had a 31% higher target BP achievement at a cost of significant increase in the use of antihypertensive medications [10]. However, to have a significant BP lowering effect, the telemonitoring needed to be combined with some sort of intervention, be it a self-titration protocol or intervention by a health care professional. In another meta-analysis of 23 randomized trial by Omboni et al. [11], home BP telemonitoring improved office SBP by 4.71 mm Hg (95% CI 3.24–6.18,  $p < 0.001$ ) and office DBP by 2.45 mm Hg (95% CI 1.57–3.33,  $p < 0.001$ ), with a larger proportion of patients achieving BP below the target BP (RR, 1.16; 95% CI 1.04–1.29;  $p < 0.001$ ). However, this was associated with significantly increased health care costs (+662.92 EUR per patients; 95% CI 540.81–785.04) [11].

### **Effectiveness of Active Intervention by Medical Personnel Based on Home BP Telemonitoring**

The effectiveness of home BP telemonitoring combined with self-management based on a titration algorithm was determined in the Telemonitoring and Self-Management in the Control of Hypertension (TASMINH2) trial, which enrolled 527 participants and randomized

them to self-management of their anti-hypertensive medications ( $n = 263$ ) or control ( $n = 264$ ). The intervention by the research group based on the telemonitored home BP was limited to checking for the patient's compliance to the safety advice for high or low readings [12]. The results showed that mean SBP at 6 months decreased by 3.7 mm Hg (95% CI 0.8–6.6;  $p = 0.013$ ) in the self-management group compared to control. The mean SBP at 12 months also was significantly decreased by 5.4 mm Hg (95% CI 2.4–8.5;  $p = 0.0004$ ) in the self-management group compared to control [12]. Based on these studies, self-management of BP medications based on prespecified algorithm and/or based on recommendations from medical personnel seems to improve BP control. What about the effectiveness of BP reduction when active intervention by medical personnel is done based on home BP telemonitoring? The Hypertension Intervention Nurse Telemedicine Study (HINTS) was a trial evaluating the effectiveness of three telemonitoring-based interventions [13]. All patients were provided a home BP monitor (model UA-767PC; A&D Medical Digital Blood Pressure, Tokyo, Japan) and a wireless home BP telemonitoring device (model 102; Carematrix Inc., Chicago, Ill., USA). The study subjects were randomized to (1) usual care; (2) nurse administered behavioral management; (3) nurse administered, physician directed medication management, and (4) combined interventions of both medication and behavioral managements [13]. At 12 months, both the behavioral management and physician-directed medication management groups showed significant improvements in BP control compared to the usual care group at 12.8% (95% CI 1.6–24.1) and 12.5% (95% CI 1.3–23.6), respectively. In addition, the subgroup analyses of those with poor baseline BP control revealed that the combined intervention decreased SBP by 14.8 mm Hg (95% CI –21.8 to –7.8) at 12 months and 8.0 mm Hg (95% CI –15.5 to –0.5) at 18 months, compared to usual care [13]. Similarly, in a randomized study of 401 subjects with uncontrolled hypertension aged 29–95 years, telemonitoring of home BP by the attending nurses and physicians with automated patient decision support was compared to control for 6 months. The clinicians were allowed to contact the participants if needed to arrange changes in the medications. The results show that the intervention group had a significant reduction of both daytime ambulatory SBP (4.3 mm Hg; 95% CI 2.0–6.5,  $p = 0.0002$ ) and daytime ambulatory DBP (2.3 mm Hg; 95% CI 0.9–3.6;  $p = 0.001$ ) [8].

In a study by Green et al. [14], 778 participants with uncontrolled hypertension aged 25–75 years were randomized to either usual care, home BP monitoring with patient website training or home BP monitoring, and secure patient website training with pharmacist care management. The results showed that web-based pharmacist care was associated with a significantly increased percentage of patients with controlled BP (56%; 95% CI 49–62) compared to both usual care (31%; 95% CI 25–37;  $p < 0.001$ ) and home BP monitoring with web training only (36%; 95% CI 30–42;  $p < 0.001$ ). In patients who had baseline SBP of higher than 160 mm Hg, web-based pharmacist care was associated with a significant net reduction of both SBP (–13.2 mm Hg; 95% CI –19.2 to –7.1;  $p < 0.001$ ) and DBP (–4.6 mm Hg; 95% CI –8.0 to –1.2;  $p < 0.001$ ) [14]. Similarly, a cluster randomized trial of 450 adults with uncontrolled hypertension were randomized to either usual care ( $n = 222$ ) or telemonitoring intervention and pharmacist management ( $n = 228$ ) [15]. The results showed that the proportion of subjects with composite BP control at both 6 and 12 months was significantly greater in the intervention arm (57.2 vs 30.0%;  $p = 0.001$ ) (table 1; reproduced from Margolis et al. [15], with permission from the American Medical Association). In addition, the BP control rate at 6, 12, and 18 months was significantly higher in the intervention arm as well (table 1). Compared to the usual care group, there was a significant decrease in SBP at 6 months (–10.7 mm Hg; 95% CI –14.3 to –7.3;  $p < 0.001$ ), 12 months (–9.7 mm Hg; 95% CI –13.4 to –6.0;  $p < 0.001$ ), and 6 months (–6.6 mm Hg; 95% CI –10.7 to –2.5;  $p = 0.004$ ). The effectiveness of the intervention arm 6 month after the end of the trial (18th month of the trial) again demonstrates the sustained effect of telemedicine after the end of the active monitoring [15].

**Table 1.** Composite and BP control by telemonitoring intervention or usual care (reproduced from Margolis et al. [15], with permission from the American Medical Association)

	Telemonitoring intervention		Usual care		Differential change from baseline, % (95% CI)	p value <sup>a</sup>
	Pa-tients, n	% (95% CI)	Pa-tients, n	% (95% CI)		
Composite BP control						
At 6 and 12 months	113	57.2 (44.8–68.7)	58	30.0 (23.2–37.8)	27.2 (13.4–40.0)	0.001
At 6, 12, and 18 months	96	50.9 (36.9–64.8)	42	21.3 (14.4–30.4)	29.6 (13.1–46.0)	0.002
BP control						
At 6 months	148	71.8 (65.6–77.3)	89	45.2 (39.2–51.3)	26.6 (19.2–33.1)	<0.001
At 12 months	141	71.2 (62.0–78.9)	102	52.8 (45.4–60.2)	18.4 (7.9–27.0)	0.005
At 18 months	135	71.8 (65.0–77.8)	104	57.1 (51.5–62.6)	14.7 (7.0–21.4)	0.003

<sup>a</sup> Study group difference for composite BP control and at each individual time point.

What about the effectiveness of telemonitoring with remote, web-based management by the attending physician? Recently, we performed a study to determine the effectiveness of remote patient monitoring and physician care for treatment of hypertension. A total of 374 hypertensive patients aged 20 years and over were randomized into three groups: (1) control, patients received usual clinical care with home BP monitoring; (2) patients were remotely monitored and received office follow-up, and (3) patients received remote monitoring with out-of-office physician care using the remote monitoring device, respectively [9]. The results did not show any significant difference between the three groups for the primary endpoint, adjusted mean sitting SBP (group 1,  $-8.9 \pm 15.5$  mm Hg; group 2,  $-11.3 \pm 15.9$  mm Hg; group 3,  $-11.6 \pm 19.8$  mm Hg;  $p = \text{n.s.}$ ). However, achieving the target BP at the 24th week of follow-up was significantly higher in group 2 compared to group 1. In addition, subgroup analysis of subjects aged over 55 years showed a significant decrease in adjusted mean sitting SBP in groups 2 and 3 compared to the control. The study demonstrated that remote monitoring combined with remote physician care was efficacious and safe for reducing BP in patients with hypertension as usual care [9]. Table 2 summarized the study population, outcome, and major findings from all studies mentioned in this mini-review (table 2). From all evidence mentioned previously, it seems that home BP telemonitoring improves BP control when compared to usual care.

Nonetheless, whether home BP telemonitoring improves the BP control rate compared to home BP monitoring alone is not clear. In a meta-analysis by Uhlig et al. [16], 52 prospective studies comparing self-measured BP (SMBP) with or without additional supportive care with usual care were analyzed. The study found that SMBP monitoring with additional supportive care lowers SBP by  $-3.4$  to  $-8.9$  mm Hg and DBP by  $-1.9$  to  $-4.4$  mm Hg at up to 12 months. However, the same study did not find any evidence that SMBP plus additional supportive care lowers BP better than SMBP alone [16]. When considering the evidence at hand, more data is needed to show the benefit of home BP telemonitoring with or without additional care in improving both BP control and prognosis compared to usual care. Until that time, home BP self-monitoring should still be the out-of-office BP monitoring of choice in the management of hypertension [17]. Though, the evidence suggests that home BP telemonitoring may be useful in selected circumstances such as in sparsely populated areas where medical care access is not readily available and in cases of natural or man-made disasters. For example, during the aftermath of the devastating tsunami in Tohoku, Japan, investigators have

**Table 2. Summary of self-monitoring or telemonitoring of BP trials**

First author	Study population	Intervention group	Follow-up period	Outcome	Major findings
Staessen et al. [5]	400 participants with DBP >95 mm Hg	(1) Adjustment of antihypertensive drug treatment based on self-measured home BP	12 months	Office BP, home BP, 2-hour ambulatory BP, intensity of drug treatment	Less intensive drug treatment, but less BP control by treatment based on home BP
McManus et al. [7]	552 patients with at least 1 of the high-risk conditions and BP >130/80 mm Hg	Self-monitoring BP with self-titration of medication following a predetermined plan	12 months	Difference in SBP between intervention and control groups	SBP was 9.2 mm Hg lower in the intervention group than control group
McKinstry et al. [8]	401 participants with mean daytime ambulatory measurement $\geq$ 135/85 mm Hg	(1) Self-measurement and transmission of BP, reviewed and feedback by the attending nurse or doctor	6 months	Change in mean daytime systolic ambulatory BP	4.3 mm Hg of mean daytime SBP reduction in the intervention arm
Kim et al. [9]	374 participants with hypertension	(1) Home BP monitoring with no remote monitoring (2) Remote home BP monitoring with in-office physician care but no remote physician care (3) Remote home BP monitoring and remote physician care without in-office physician care	24 weeks	Change of SBP at 24 weeks compared with the baseline	Changes of SBP were not different between three groups at 24 weeks. Participants aged over 55 years in groups 2 and 3 showed a significant decrease in SBP compared to group 1
McManus et al. [12]	527 participants with BP >140/90 mm Hg despite antihypertensive treatment	(1) Self-monitoring of BP and self-titration of antihypertensive drugs, combined with telemonitoring of home BP measurements	12 months	Change in mean SBP	17.6 mm Hg of mean SBP reduction in the self-management group
Bosworth et al. [13]	593 participants with inadequate BP control (>140/90 mm Hg) on antihypertensive medication	Telephone-based BP monitoring with (1) nurse-administered, behavioral management intervention (2) nurse-administered, physician-directed medication management using a validated clinical decision-making system (3) combined behavioral management and medication intervention	18 months	Percentage of the improvement of BP control	At 12 months, the improvement of BP control in the behavioral management group, medication management group, and combined group was 12.8, 12.5, and 8.3%, respectively, relative to usual care. At 18 months, only the combined group showed an improvement of BP control of 7.7%
Green et al. [14]	778 participants with uncontrolled essential hypertension	(1) Home BP monitoring and secure patient website training only (2) Home BP monitoring and secure patient website training plus pharmacist care management through Web communications	12 months	Control of SBP to <140 mm Hg and DBP to <90 mm Hg	Adding web-based pharmacist care to home BP monitoring significantly increased patients with controlled BP compared to the usual care and home BP and web training only
Margolis et al. [15]	450 participants with uncontrolled BP	Home BP telemonitoring and adjustment by pharmacists according to transmitted BP data	18 months (6 months after intervention stopped)	Control of SBP to <140 mm Hg and DBP to <90 mm Hg	The proportion of BP controlled patients was significantly greater in the telemonitoring group at 6 and 12 months, and its effect persisted during the 6-month postintervention period compared with usual care



developed a web-based Disaster Cardiovascular Prevention (DCAP) network to monitor cardiovascular risk factors in the survivors of the tsunami and to promote preventive behaviors [18]. In the future, with ever improving technological advances, application of telemonitoring for treatment of chronic diseases, such as hypertension, will only increase. We as clinicians should be ready for the upcoming changes.

## Conclusion

The treatment of hypertension based on measurement of office BP once every few months may be a thing of the past. Home BP monitoring is a cost-effective way to assess for white coat hypertension, masked hypertension, and 24-hour BP control while increasing patient awareness and treatment adherence. Therefore, home BP should be the ideal out-of-office BP measurement for routine management of hypertension patients [19]. At present, when considering the evidence and the cost-effectiveness, co-intervention, including teletransmission or health care professional co-management, should be limited to selected cases. However, technological advances are allowing for accurate measurement and telemonitoring of day-to-day home BP. Also, active intervention of medical personnel through the use of BP telemonitoring is helpful for improving drug compliance and achieving target BP. Although nothing can replace the tried and tested doctor-patient relationship in the office, telemonitoring of home BP will be an important tool for treating hypertension in the future.

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## Disclosure Statement

The authors have no financial conflict of interests that are related to this subject.

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