



# Hypertension in the Consulting Room Versus the Bedroom: Nocturnal Blood Pressure and the Case for Routine Ambulatory Monitoring

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Received: 13 February 2021; Accepted: 22 June 2021; Published: 14 November 2021

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## Abstract

*A single office blood pressure reading is the reference point for most hypertension diagnoses worldwide, yet ambulatory blood pressure monitoring (ABPM) repeatedly shows that the office reading and the 24-hour, out-of-office picture disagree often enough, and in clinically important enough directions, that guideline bodies now recommend confirming a diagnosis outside the clinic before starting treatment. Reverse dipping, not non-dipping in general, carries the excess nocturnal cardiovascular risk; masked hypertension, invisible at the office visit, carries a near-tripling of cardiovascular event odds; and even white-coat hypertension, long treated as reassuring, shows a modest excess risk when untreated that resolves once blood pressure is actually controlled. Home blood pressure monitoring (HBPM) is the practical, guideline-endorsed alternative to ABPM, and it performs comparably for confirming sustained hypertension, but its sensitivity falls to roughly six in ten cases for the two phenotypes, masked and white-coat hypertension, that a single office reading gets wrong. This review sets out the evidence for out-of-office measurement, and closes with the complication that undercuts calling it routine: guideline-preferred ABPM reaches a claimed fraction of one percent of Medicare beneficiaries, a gap in access and reimbursement, not evidence, that a cost-effectiveness case for ABPM has not closed.*

**Keywords:** Ambulatory blood pressure monitoring; Nocturnal blood pressure; Masked hypertension; White-coat hypertension; Home blood pressure monitoring

## Introduction

Hypertension is now the world's most common chronic diagnosis, and it is getting more common, not less: the number of adults aged 30-79 living with hypertension worldwide doubled between 1990 and 2019, from roughly 648 million to more than 1.27 billion, across a pooled analysis of 1,201 population-representative studies covering 104 million participants [15]. Almost every one of those diagnoses rests, at some point, on a blood pressure cuff in a clinic room, a measurement taken in a setting the patient visits rarely, briefly, and usually under some degree of anticipatory stress.

Ambulatory blood pressure monitoring (ABPM) -- a portable cuff that measures blood pressure automatically every 20-30 minutes over 24 hours, capturing sleep as well as waking hours -- exists specifically because that single office reading is an imperfect proxy for the blood pressure that actually accumulates cardiovascular risk over a day and a night. The 2021 US Preventive Services Task Force reaffirmation and the 2018 European Society of Cardiology/European Society of Hypertension guidelines both now recommend obtaining blood pressure measurements outside the clinical setting, by ABPM or home blood pressure monitoring (HBPM), to confirm a hypertension diagnosis before starting treatment [1,2]. ABPM

is described by the USPSTF as offering the most evidence-based risk information of the available methods [1], and a health-economic modelling study across the primary care population found it the most cost-effective diagnostic strategy for both men and women at every age studied [13].

Figure 1 sets out why office and out-of-office readings can diverge so sharply: the same office blood pressure can sit on top of three very different nights. A patient's nocturnal blood pressure fall relative to their daytime average defines a dipping pattern -- dipper (10-20% fall), non-dipper (under 10% fall), extreme dipper (over 20% fall), or reverse dipper, also called a riser, whose blood pressure is actually higher asleep than awake [4] -- and none of that pattern is visible from a daytime office cuff. This review sets out what ABPM and HBPM have shown about which of these out-of-office patterns actually predict cardiovascular events, how well the more accessible home-monitoring alternative substitutes for the ambulatory reference standard, and why, despite guideline endorsement and a favourable cost-effectiveness case, routine out-of-office confirmation remains the exception rather than the rule in most health systems.

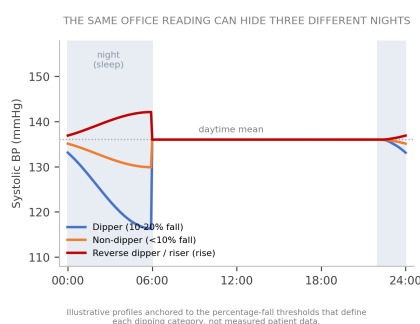


Figure 1: Illustrative 24-hour circadian systolic blood pressure profiles for the three principal dipping patterns, anchored to the percentage-fall thresholds that define each category [4]; not measured trial data.

## Material and Methods

This is a narrative review of published systematic reviews, meta-analyses, guideline documents and health-services research on out-of-office blood pressure measurement, identified through PubMed, guideline-society websites and citation tracking of the sources above, without a pre-registered protocol or systematic search string. Where a study's ABPM protocol is discussed, it follows the measurement, device-validation and reporting standards set out in the European Society of Hypertension's ABPM position paper [14]. Effect estimates are reported exactly as their source studies present them, including original relative risk, odds ratio, or hazard ratio framing, and no numerical value in this review has been invented, estimated, or extrapolated beyond what the cited source itself reports.

## Results

### Reverse dipping, not non-dipping in general, is the pattern that predicts events

The dipping-status literature has long been read as though any attenuation of the normal nocturnal blood pressure fall were dangerous. A 2020 systematic review and meta-analysis pooling seven cohort studies and 10,438 untreated hypertensive patients (7,081 dippers, 3,357 non-dippers) found that the picture is more specific than that [3]. Reverse dippers had substantially higher cardiovascular event risk than dippers (RR 0.47, 95% CI 0.33-0.66, favouring dippers) and higher stroke risk specifically (RR 0.39, 95% CI 0.22-0.72, favouring dippers). When reverse dippers were excluded and non-dippers were compared with dippers alone, the difference in cardiovascular events (RR 0.84, 95% CI 0.61-1.16) and total mortality (RR 0.78, 95% CI 0.53-1.13) was no longer statistically significant [3], and extreme dipping showed no significant difference from ordinary dipping either. A separate review of nocturnal blood pressure and cardiovascular disease reported the same reverse-dipper signal from the International Database on Ambulatory blood pressure in relation to Cardiovascular Outcomes (IDACO): over a median 9.6-year follow-up, reverse dippers had the highest incidence of total mortality (27%), cardiovascular mortality (11%) and cardiovascular morbidity (25%) of any dipping category [5]. The comparative risk chart later in this section places these dipping-status figures alongside the office/ambulatory phenotypes discussed next, on a single axis.

The clinical implication is a narrower one than the field's everyday shorthand suggests: flagging every non-dipper as high-risk overstates the evidence, while the reverse-dipping pattern specifically, easy to miss if a report only records a binary dipper/non-dipper label, is where the excess nocturnal risk actually concentrates.

## Masked and white-coat hypertension show the office visit misclassifies risk in both directions

Masked hypertension -- a normal office reading with an elevated out-of-office reading -- is arguably the more consequential of the two classic office/ambulatory discordances, because it is invisible to the clinician relying on office measurement alone. Up to one-third of patients with a normal office blood pressure meet ambulatory criteria for masked hypertension [6]. A meta-analysis of prospective observational studies (14,729 participants) found masked hypertension carried an odds ratio of 2.91 (95% CI 2.54-3.33) for composite cardiovascular events compared with true normotension (event rates 12.3% versus 5.1%) and an odds ratio of 2.65 (95% CI 2.18-3.23) for all-cause mortality (15.8% versus 7.8%) [6]. White-coat hypertension -- an elevated office reading with a normal out-of-office reading, affecting 15-30% of patients whose office blood pressure reads 140/90 mmHg or higher [18] -- has conventionally been treated as the reassuring counterpart. An individual-participant-data meta-analysis of 25,786 participants with untreated white-coat hypertension or a treated white-coat effect, followed for a mean of 3 to 19 years, complicates that reassurance: untreated white-coat hypertension carried a hazard ratio of 1.36 (95% CI 1.03-2.00) for cardiovascular events and 1.33 (95% CI 1.07-1.67) for all-cause mortality relative to normotension, while the equivalent treated white-coat effect showed no significant excess risk (HR 1.12, 95% CI 0.91-1.39 for cardiovascular events) [7]. Figure 2 sets out how a single office visit's binary normal/elevated classification maps onto these four true, ambulatory-defined categories.

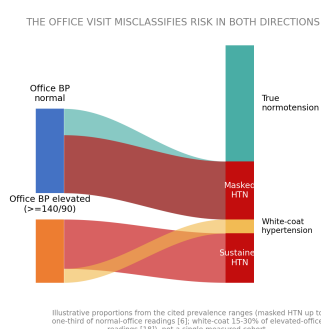


Figure 2: Illustrative reclassification of office blood pressure categories into their true ambulatory-monitoring-defined categories, from the cited prevalence ranges [6,18], not a single measured cohort.

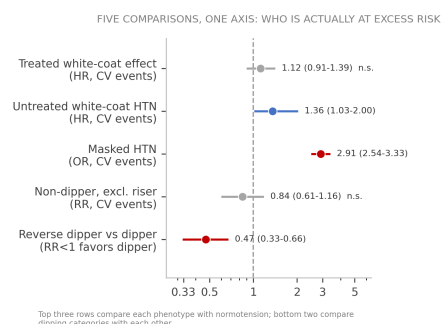


Figure 3: Point estimates and 95% confidence intervals for cardiovascular risk across the phenotypes and dipping comparisons discussed in this review, on a common logarithmic axis [3,6,7].

## Home blood pressure monitoring is the accessible substitute, but it underperforms exactly where it matters most

ABPM is the reference standard, but it is a 24-hour test that many patients tolerate poorly and many practices cannot easily deliver, which makes HBPM -- a patient using a validated device to self-measure blood pressure at home over days to weeks -- the more widely deliverable out-of-office alternative that both the USPSTF and the ESC/ESH guidelines endorse alongside ABPM [1,2]. A direct diagnostic-accuracy comparison of home against ambulatory monitoring found substantial overall agreement for classifying sustained hypertension (89% agreement, kappa 0.79; home-monitoring sensitivity 90%, specificity 89%) [8]. Agreement for white-coat hypertension and masked hypertension looked similarly high by raw percentage (89% and 88% respectively) but far weaker by kappa, which corrects for chance agreement (0.56 and 0.52), and the underlying sensitivity for both phenotypes fell to roughly six in ten cases (white-coat 61%, masked 60%), while specificity stayed high for both (94% and 93%) [8]. Figures 4 and 5 set out the same data two ways: Figure 4 as sensitivity against specificity directly, Figure 5 as raw agreement against kappa, because the gap between the two is exactly the point -- a test can look reliable on a single agreement statistic while its ability to actually catch the case in question is closer to a coin flip weighted slightly in its favour. Table 1 summarizes the dipping-pattern definitions and their associated cardiovascular risk alongside this diagnostic-accuracy picture, since a home-monitoring protocol that only samples daytime readings cannot characterize nocturnal dipping status at all, a limitation ABPM does not share.

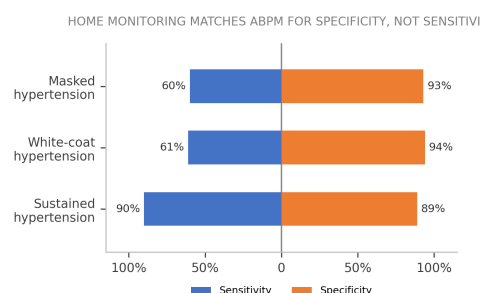


Figure 4: Home blood pressure monitoring's sensitivity and specificity against the ambulatory reference standard, by hypertension phenotype [8].

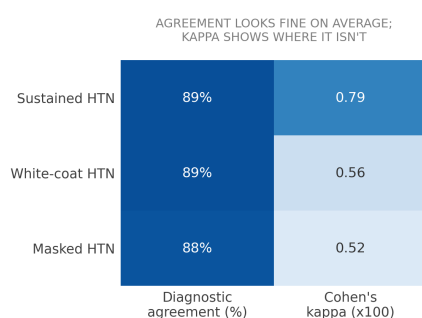


Figure 5: Diagnostic agreement and Cohen's kappa between home and ambulatory blood pressure monitoring, by hypertension phenotype [8].

| Dipping pattern          | Nocturnal BP change | Cardiovascular risk (vs dipper)         |
|--------------------------|---------------------|-----------------------------------------|
| Dipper                   | 10-20% fall         | Reference                               |
| Non-dipper (excl. riser) | <10% fall           | RR 0.84 (0.61-1.16), n.s. [3]           |
| Extreme dipper           | >20% fall           | No significant difference [3]           |
| Reverse dipper / riser   | Rise overnight      | RR 0.47 (0.33-0.66), highest risk [3,5] |

Table 1: Nocturnal dipping pattern definitions and their associated relative cardiovascular risk. RR values are reported exactly as their source states them; "vs dipper" RR<1 favors the dipper category [3,5].

## Despite Grade A guidance and a favourable cost case, routine ambulatory monitoring is barely used

The complication this review closes on is not a clinical one but a delivery one. The USPSTF's recommendation to confirm hypertension outside the clinical setting before treatment carries its highest grade, Grade A [1], and a UK-based modelling study found ABPM the most cost-effective diagnostic strategy for high blood pressure in primary care across sexes and age groups, recommending it be seriously considered for most patients before starting antihypertensive treatment [13]. Real-world uptake does not reflect either the recommendation grade or the cost-effectiveness case. Among Medicare beneficiaries, only 0.1% had a claim submitted for ABPM between 2007 and 2010 [9]. Figure 6 sets that figure directly against HBPM's much higher real-world uptake -- 21.7% of US adults reported home blood pressure monitoring in the past year, and 36.6% of those with hypertension specifically monitored at least monthly [11] -- a gap of roughly two orders of magnitude between the guideline-preferred test and the one patients and clinicians actually use.

Reimbursement and cost sit behind much of that gap. An ABPM device costs roughly \$2,000-2,500 plus software, and CPT code 93784, covering the complete ABPM service, reimburses between \$60 and \$248 depending on payer -- Medicare pays around \$60, commercial insurers \$124-248 -- leaving a practice needing to run roughly 50 tests before recovering a typical \$5,000 start-up cost [10]. Table 2 sets out these reimbursement figures alongside the other structural barriers documented in primary care: staff time for device placement and interpretation, and, internationally, patient-facing barriers including stigma around a visibly worn device, low public awareness of what ABPM is for, and unstable device procurement outside well-resourced health systems [12]. None of this is a case against ABPM's evidence base; it is a case that the evidence base and the delivery system have not been reconciled.

THE GUIDELINE-PREFERRED TEST IS THE ONE ALMOST NO ONE GETS

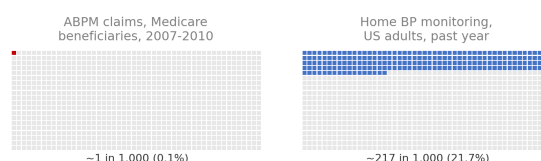


Figure 6: ABPM claims among Medicare beneficiaries, 2007-2010, against home blood pressure monitoring use among US adults in the past year, per 1,000 [9,11].

| Barrier                             | Figure                        | Source |
|-------------------------------------|-------------------------------|--------|
| ABPM device cost                    | \$2,000-2,500 + software      | [10]   |
| CPT 93784 reimbursement range       | \$60-248 by payer             | [10]   |
| Practice break-even                 | ~50 tests on \$5,000 start-up | [10]   |
| Medicare ABPM claim rate, 2007-2010 | 0.1% of beneficiaries         | [9]    |

Table 2: Reimbursement and cost barriers to routine ABPM use in US primary care, alongside the resulting claim rate [9,10].

## Discussion

Taken together, the evidence in this review argues for a more targeted, not a more uniform, expansion of out-of-office measurement. Reverse dipping, masked hypertension and untreated white-coat hypertension each carry real, quantifiable excess cardiovascular risk that a single office reading cannot detect, and international guidelines already endorse out-of-office confirmation at their highest recommendation grade [1,2]. But universal ABPM for every hypertension diagnosis is neither what the delivery system can currently absorb nor necessarily where the marginal benefit is largest. Resistant hypertension is a case in point: in one review, 14.7% of patients with high blood pressure had apparent treatment-resistant hypertension by office criteria, but only 10.3% had genuinely resistant hypertension once pseudo-resistance from unrecognized white-coat effect was excluded by out-of-office measurement [16] -- exactly the population in whom ABPM changes management, as opposed to confirming what was already suspected.

HBPM's role in this picture is pragmatic rather than equivalent. It matches ABPM well for confirming sustained hypertension and, importantly, for ruling out disease when both readings are normal (specificity above 90% for every phenotype in the comparison reviewed here [8]). Its weakness is specifically a sensitivity problem for masked and white-coat hypertension, the two phenotypes where an office reading is already known to mislead -- so a strategy of substituting HBPM for ABPM across the board would preserve much of ABPM's value for the sustained-hypertension majority while quietly re-introducing a meaningful miss rate for exactly the patients ABPM was meant to catch. Emerging cuffless, wearable blood pressure technologies are sometimes proposed as a future solution to the access gap, but the American Heart Association's own 2025 scientific statement on these devices concluded they are not yet validated accurately enough to diagnose or guide treatment of hypertension, and should not be used for that purpose at this time [17]. A defensible near-term strategy, on the evidence assembled here, prioritizes ABPM for patients in whom out-of-office measurement is most likely to change management -- suspected resistant hypertension, discordant office and home readings, and patients whose risk

profile makes a missed masked-hypertension diagnosis most costly -- while treating HBPM as the default, not the compromise, for routine confirmation and monitoring elsewhere.

## Study limitations

This is a narrative review, not a systematic review with a pre-registered protocol, and it draws primarily on evidence from the United States and Europe; the barriers documented in lower-resource settings appear structurally similar but are supported here by a single qualitative study [12]. The relative-risk, odds-ratio and hazard-ratio estimates cited across different source meta-analyses are not directly comparable statistics and are presented on a common axis in Figure 3 for orientation only, not as a formally pooled effect. The Medicare claims-based ABPM utilization figure is more than a decade old [9]; more recent utilization data specific to commercially insured populations could not be independently verified for this review and is not included.

## Conclusion

A single office blood pressure reading can hide a reverse-dipping night, a masked-hypertension day, or a white-coat effect that inflates apparent severity -- and each of those hidden patterns carries a different, quantifiable cardiovascular consequence. Ambulatory blood pressure monitoring remains the evidentially strongest way to uncover them, and it is guideline-endorsed at the highest recommendation grade and cost-effective by formal modelling [1,13]. Yet it reaches a claimed fraction of one percent of Medicare beneficiaries, a gap between what the evidence supports and what the health system actually delivers that no amount of further trial evidence for ABPM's superiority will close on its own. Home monitoring is a reasonable, far more scalable default for most confirmation and follow-up, provided clinicians remember exactly where its sensitivity is weakest -- masked and white-coat hypertension, the very phenotypes an office reading already gets wrong -- and reserve ambulatory monitoring for the patients in whom that blind spot matters most.

The access problem this review describes is not confined to well-resourced health systems, and it is not solved by simply telling clinicians to order more ABPM. The same qualitative work that documented stigma, low public awareness and unstable device procurement as barriers to ABPM adoption in Bangladesh, Pakistan and Sri Lanka also found that clinicians there were often unfamiliar with the test themselves, with little formal training and no established referral pathway once a patient was identified as a candidate [12] -- a workforce and infrastructure gap that sits alongside, rather than instead of, the reimbursement gap documented for US Medicare beneficiaries. Against a global hypertension burden that has

already doubled to more than 1.27 billion adults and continues to grow [15], neither gap will close through stronger evidence for ABPM's prognostic value alone; closing it will require the same deliberate investment in training, device availability and reimbursement policy that any other guideline-recommended, underused diagnostic test would need before it can actually reach the patients it was shown to help.

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Cite this article: Marchetot S, Nystrand A, Pavlek L. Hypertension in the Consulting Room Versus the Bedroom: Nocturnal Blood Pressure and the Case for Routine Ambulatory Monitoring. *J Heart Cardiovasc Sci.* 2021; 2: 001-006.