

Estimated Prevalence of Hypertension and Undiagnosed Hypertension in a Large Inpatient Population: A Cross-sectional Observational Study

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BACKGROUND

Hypertension is a major cause of morbidity and mortality. In community populations the prevalence of hypertension, both in diagnosed and undiagnosed states, has been widely reported. However, estimates for the prevalence of hospitalized patients with average blood pressures (BPs) that meet criteria for the diagnosis of hypertension are lacking. We aimed to estimate the prevalence of patients in a UK hospital setting, whose average BPs meet current international guidelines for hypertension diagnosis.

METHODS

We performed a retrospective cross-sectional observational study of patients admitted to adult wards in 4 acute hospitals in Oxford, United Kingdom, between March 2014 and April 2018.

RESULTS

We identified 41,455 eligible admitted patients with a total of 1.7 million BP measurements recorded during their hospital admissions. According to European ESC/ESH diagnostic criteria for hypertension,

21.4% (respectively 47% according to American ACC/AHA diagnostic criteria) of patients had a mean BP exceeding the diagnostic threshold for either Stage 1, 2, or 3 hypertension. Similarly, 5% had a mean BP exceeding the ESC/ESH (respectively 13% had a mean BP exceeding the ACC/AHA) diagnostic criteria for hypertension, but no preexisting diagnostic code for hypertension or a prescribed antihypertensive medication during their hospital stay.

CONCLUSIONS

Large numbers of hospital inpatients have mean in-hospital BPs exceeding diagnostic thresholds for hypertension, with no evidence of diagnosis or treatment in the electronic record. Whether opportunistic screening for in-hospital high BP is a useful way of detecting people with undiagnosed hypertension needs evaluation.

Keywords: blood pressure; hospital measurements; hypertension; undiagnosed hypertension

doi:10.1093/ajh/hpab070

BACKGROUND

Hypertension is a major cause of morbidity and mortality.¹ Early detection and management of hypertension is key to preventing end-organ damage.² However, in the early stages, hypertension is usually asymptomatic. In the UK healthcare setting, hypertension is typically identified either opportunistically or through the National Health Service (NHS) Health Check in primary care.^{3,4} However, only half of those invited attend these health checks⁵ and 12% of the English adult population have undiagnosed hypertension.⁶ Internationally, hypertension awareness varies widely from

40% to 80% among high-income nations, with awareness and treatment rates of younger people being lower than older age groups.⁷ Furthermore, the Global Burden of Disease Study of 2013 estimated hypertension causes over 10 million deaths worldwide annually.⁸ Therefore, current approaches to identifying people with hypertension are not adequate and innovative approaches need to be considered to improve the detection of hypertension.

The inpatient hospital setting, in which multiple blood pressure (BP) measurements are performed for each admitted patient may provide an opportunity to detect

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Initially submitted April 12, 2021; accepted for publication May 4, 2021; online publication May 22, 2021.

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people with undiagnosed hypertension. However, research in this field has so far, focused on the prevalence of hypertension in the emergency department setting and has largely excluded patients admitted to hospital.⁹

OBJECTIVES

The primary objective of this study is to estimate the prevalence of hypertension and undiagnosed hypertension in a UK hospital inpatient setting using a large hospital database of 1.7 million BP measurements. We also identify patient characteristics of those who appear to be at greatest risk of undiagnosed hypertension.

METHODS

Study design

This study is a retrospective cross-sectional analysis of in-hospital BP for adult hospital patients meeting the eligibility criteria described below.

Study setting

Patients were admitted between March 2014 and April 2018 to adult wards in 3 tertiary and 1 secondary referral centers in the Oxford University Hospitals NHS Foundation Trust, United Kingdom.

Participants

We included patients from all adult wards, with the exception of the maternity and intensive care units, of the 4 acute hospitals in the Oxford University Hospitals (OUH) NHS Foundation Trust. We included the first admission of each patient during which at least 3 BP measurements were recorded, with at least 1 being recorded during the nighttime (midnight to 5:59 AM) and at least 1 recorded during the daytime (10:00 AM to 7:59 PM), with 2 of these observations being at least 24 hours apart. Hospital day and night periods were defined in accordance with standard practice in the literature.¹⁰

Data sources

Patients had their vital observations, including heart rate and systolic and diastolic BP recorded using the System for Electronic Notification and Documentation (SEND). SEND is a software application that links vital sign monitoring devices including BP monitors, with a tablet computer for the manual recording of vital signs in patients.¹¹ All vital-sign equipment used within the study was purchased and maintained (including regular calibration) in accordance with the Oxford University Hospitals NHS Foundation Trust Medical Devices Management Policy. Other data (date of birth, sex, ICD-10 codes and prescription information) were obtained from the Patient Administration System (PAS) in the hospitals' electronic patient record (EPR) system, Cerner Millennium (<https://www.cerner.com/>, North Kansas City, MO).

Sample size

We examined all patients aged 16 years and over who were admitted between March 2014 and April 2018 with observations recorded electronically using the SEND system for eligibility.

Quantitative variables

Each patient's BP data were averaged by hour of the day over their whole admission period, such that each individual only contributed averaged data for a maximum of 24 individual hourly periods. The computational details of this procedure have been described in our previous article.¹²

Classification of inpatients meeting clinic and ambulatory (daytime, nighttime, and 24 hours) hypertension diagnostic thresholds were made according to published guidelines for hypertension diagnosis and management from Europe (ESC/ESH guidelines of 2018¹³) and America (ACC/AHA guidelines of 2017¹⁴). The definitions of the corresponding hypertension diagnostic thresholds can be found in [Supplementary Tables ST-1](#) and [ST-2](#) online.

Undiagnosed hypertension was defined as having a mean BP above the diagnostic thresholds and no previous ICD-10 codes for hypertension ([Supplementary Table ST-4](#) online) nor any of the prescribed antihypertensive medications listed by British National Formulary ([Supplementary Table ST-3](#) online).¹⁵

In line with published diagnostic criteria, we define patients meeting the criteria for isolated nocturnal hypertension as

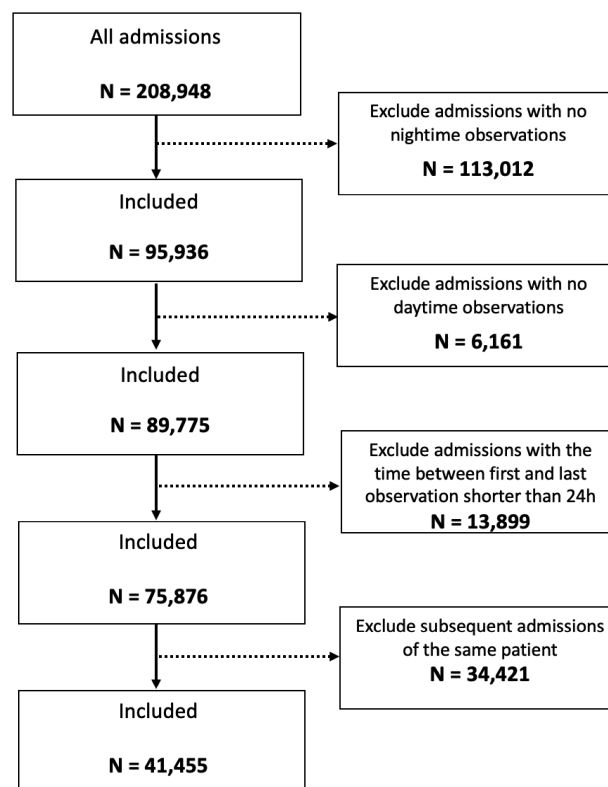


Figure 1. Inclusion/exclusion criteria flowchart.

Table 1. Patient demographics

	Patients	Age	LOS	Number of BP measurements	SBP	DBP
	Percentage of total	Mean (SD)	Median (IQR)	Median (IQR)	Mean (SD)	Mean (SD)
All	41,455 (100%)	64 (19)	4.7 (7.4)	27 (34)	127 (16)	69 (9)
Sex						
Men	20,169 (49%)	64 (19)	4.9 (7.5)	28 (34)	128 (15)	70 (9)
Women	21,286 (51%)	65 (20)	4.6 (7.2)	26 (33)	126 (17)	67 (9)
Age groups						
18–29	2,833 (7%)	24 (4)	2.8 (3.9)	17 (19)	118 (12)	66 (8)
30–39	2,722 (7%)	35 (3)	3.2 (4.5)	19 (23)	119 (14)	69 (9)
40–49	3,714 (9%)	45 (3)	3.6 (5.1)	22 (26)	122 (14)	71 (10)
50–59	5,674 (14%)	55 (3)	4.1 (5.8)	25 (28)	125 (15)	71 (9)
60–69	7,071 (17%)	65 (3)	4.5 (6.4)	27 (32)	127 (15)	69 (9)
70–79	8,680 (21%)	74 (3)	5.2 (7.9)	30 (35)	130 (16)	68 (8)
80–89	7,861 (19%)	84 (3)	6.8 (10.9)	34 (44)	132 (17)	68 (9)
90+	2,714 (7%)	91 (1)	7.5 (12)	34 (45)	133 (18)	68 (9)
NHS Admission Method						
Emergency	26,290 (63%)	66 (21)	5.1 (8.9)	26 (37)	125 (14)	67 (8)
Elective	13,490 (33%)	61 (17)	3.9 (4.7)	27 (26)	128 (17)	69 (9)
Other	1,675 (4%)	64 (18)	9.8 (11.9)	46 (48)	126 (16)	68 (9)
NHS Specialty						
Medical	18,113 (44%)	69 (19)	4.9 (8.9)	25 (36)	127 (18)	69 (10)
Surgical	22,543 (54%)	60 (19)	4.6 (6.3)	28 (31)	127 (15)	68 (8)
Other	792 (2%)	66 (15)	5.5 (9.8)	27 (41)	125 (16)	68 (9)

Abbreviations: BP, blood pressure; DBP, diastolic BP; IQR, interquartile range; LOS, length of stay; SBP, systolic BP. “Other” in NHS Admission Method refers to any admission method, that is not Emergency or Elective (e.g., maternity admissions or transfer from other hospital provider other than in an emergency); “other” in NHS Specialty refers to any specialty that is not Medical or Surgical.

Table 2. Estimated prevalence of “clinic” hypertension

	Patients	Age	LOS	Number of BP measurements
	% of total	Mean (SD)	Median (IQR)	Median (IQR)
Hypertension category (ESC/ESH)				
Normotensive	32,788 (79%)	62 (20)	5 (7)	27 (34)
Stage 1	7,504 (18%)	72 (15)	5 (8)	27 (35)
Stage 2	1,297 (3%)	74 (15)	4 (6)	23 (29)
Stage 3	144 (0.4%)	72 (18)	2 (3)	19 (15)
Hypertension category (ACC/AHA)				
Normotensive	24,158 (58%)	60 (20)	5 (7)	27 (34)
Stage 1	10,858 (26%)	68 (17)	5 (8)	27 (34)
Stage 2	7,504 (18%)	72 (15)	5 (8)	28 (35)
Stage 3	1,417 (3%)	74 (15)	4 (6)	23 (28)

Estimated prevalence (%) of patients meeting the criteria for clinical hypertension stratified by stages of hypertension together with the corresponding mean age (years), median length of stay (days), median number of blood pressure observations according to European ESC/ESH and American ACC/AHA guidelines ([Supplementary Table ST-1](#) online). Abbreviations: BP, blood pressure; IQR, interquartile range; LOS, length of stay.

elevated nighttime BP (average nighttime systolic BP ≥ 120 or diastolic BP ≥ 70) in the presence of normal daytime BP (average daytime systolic BP < 135 and diastolic BP < 85).

As a proxy for the ambulatory BP monitoring, we applied these diagnostic criteria to patients’ 24-hour BP signature as explained above.

Table 3. Estimated ABPM daytime, ABPM nighttime, and ABPM 24-hour hypertension

ABPM SBP/DBP ≥	ESC/ESH						ACC/AHA					
	Daytime		Nighttime		24 hours		Daytime		Nighttime		24 hours	
	135/85		120/70		130/80		130/80		110/65		125/75	
	M	F	M	F	M	F	M	F	M	F	M	F
Overall	29	28	73	65	43	40	42	38	95	90	59	53
Age groups												
18–29	15	4	55	31	23	8	28	10	93	79	44	17
30–39	20	8	65	36	30	12	33	13	95	81	48	21
40–49	26	15	74	47	37	20	39	22	97	87	55	33
50–59	29	22	76	59	43	31	43	33	97	91	60	45
60–69	31	29	74	66	45	41	44	40	97	91	60	55
70–79	31	35	76	74	47	50	43	47	96	92	62	64
80–89	34	39	76	80	51	58	46	51	94	95	64	70
90+	31	41	77	82	49	61	43	52	94	95	62	72
NHS Admission method												
Elective	26	22	71	55	41	32	40	32	96	87	57	45
Emergency	30	31	74	70	45	45	43	41	95	92	60	57
Other	26	29	70	65	40	41	38	38	94	91	56	51
NHS Specialty												
Medical	29	31	72	69	43	45	40	41	94	91	57	56
Surgical	29	25	74	61	43	37	43	35	96	90	60	50
Other	28	23	72	60	41	36	40	34	95	88	54	49

Estimated prevalence (%) of patients meeting the criteria for “clinic,” daytime, nighttime, and 24-hour hypertension stratified by sex, age groups, NHS Admission Method, and NHS Specialty according to the European ESC/ESH and American ACC/AHA guidelines (Supplementary Table ST-2 online). Abbreviations: DBP, diastolic blood pressure; F, female; M, male; SBP, systolic blood pressure. *Daytime SBP (DBP)* is the mean systolic (diastolic) blood pressure measurements taken during daytime hours (10:00 AM to 7:59 PM). *Nighttime SBP (DBP)* is the mean systolic (diastolic) blood pressure measurements taken during night hours (midnight to 5:59 AM).

We investigated the prevalence of elevated BP in predefined patient subgroups according to (i) sex as recorded in the EPR, (ii) age, (iii) elective vs. emergency admission, and (iv) medical vs. surgical admission. We classified patients according to whether their electronic record did not contain previous ICD-10 codes for hypertension (Supplementary Table ST-8 online) or record of the antihypertensive drugs listed by British National Formulary¹⁵ (Supplementary Table ST-7 online).

RESULTS

Descriptive data

Between March 2014 and April 2018, 208,948 patients 16 years of age and over were admitted to Oxford University Hospitals NHS Foundation Trust and had their BP recorded using the SEND system. After excluding patients with no nighttime observations (113,012), those with no daytime observation (6,161), those in whom the time between first and last observation was less than 24 hours (13,899), and any subsequent admissions of the same patient (34,421), 41,455 patients were eligible for inclusion in the study (see

Figure 1 for an inclusion/exclusion criteria flowchart). A total of 1,701,812 BP measurements were recorded for these patients. Patient demographics are shown in Table 1. Mean patient age was 64 years (SD 19) and 51% were female. Median length of stay was 4.7 days (interquartile range 7.4) and 63% were admitted as an emergency, whilst 33% were admitted electively and 4% classified as “other” (e.g., transfer from other hospital provider other than in an emergency).

Prevalence of patients meeting criteria for hypertension

According to the European ESC/ESH diagnostic criteria for clinical hypertension, 18% patients had a mean BP equal to or greater than the diagnostic thresholds for Stage 1 hypertension, 3% had a mean BP equal to or greater than the diagnostic thresholds for Stage 2 hypertension, and 0.4% equal to or greater than the thresholds for Stage 3 hypertension (Table 2). Using the (lower) American ACC/AHA guidelines, the proportions of patients meeting the diagnostic thresholds for Stage 1, 2, and 3 hypertension were 26%, 18%, and 3%, respectively (Table 2). The prevalence of patients meeting the criteria for isolated nighttime hypertension was 39% according to ESC/ESH (45% according to ACC/AHA)

Table 4. Estimated undiagnosed ABPM daytime, ABPM nighttime, and ABPM 24-hour hypertension

ABPM	ESC/ESH						ACC/AHA					
	Daytime		Nighttime		24 hours		Daytime		Nighttime		24 hours	
	135/85		120/70		130/80		130/80		110/65		125/75	
	M	F	M	F	M	F	M	F	M	F	M	F
Overall	9	8	29	25	14	12	15	12	42	42	22	18
Age groups												
18–29	13	3	50	28	20	6	25	8	86	74	39	15
30–39	13	5	52	30	22	8	25	9	79	71	37	16
40–49	14	9	50	34	22	12	23	14	69	67	35	22
50–59	12	11	36	34	18	16	20	18	50	58	28	25
60–69	9	10	26	28	14	16	14	16	36	43	20	23
70–79	7	8	19	21	10	14	10	12	25	29	15	18
80–89	6	7	16	17	10	11	9	10	21	21	13	14
90+	6	7	19	17	11	11	10	9	25	20	15	15
Admission method												
Elective	8	8	29	24	14	11	15	12	42	46	22	18
Emergency	10	8	30	26	15	13	16	14	42	41	23	19
Other	6	6	20	19	9	9	9	9	28	32	15	13
Specialty												
Medical	8	8	24	24	12	12	12	12	35	38	18	18
Surgical	10	8	33	26	16	12	17	13	46	46	25	19
Other	11	11	34	28	17	15	17	16	49	49	24	21

Estimated undiagnosed hypertension prevalence (%) in-hospital population stratified by sex, age category, NHS Admission Method, and NHS Specialty according to the European ESC/ESH and American ACC/AHA guidelines ([Supplementary Table ST-2](#) online). Abbreviations: DBP, diastolic blood pressure; F, female; M, male; SBP, systolic blood pressure. *Daytime SBP (DBP)* is the mean systolic (diastolic) blood pressure measurements taken during daytime hours (10:00 AM to 7:59 PM). *Nighttime SBP (DBP)* is the mean systolic (diastolic) blood pressure measurements taken during night hours (midnight to 5:59 AM).

guidelines. The prevalence of those meeting criteria for isolated systolic hypertension according to ESC/ESH thresholds was 19% (31% according to ACC/AHA thresholds). The prevalence for isolated diastolic and daytime hypertension was low ([Supplementary Table ST-5](#) online). The prevalence of patients meeting the Ambulatory Blood Pressure Monitoring (ABPM) for daytime, nighttime, and 24-hour diagnostic thresholds ([Supplementary Table ST-2](#) online) is stratified further by sex, age groups, NHS admission method, and NHS specialty and presented in [Table 3](#).

Estimated undiagnosed hypertension in the hospital setting

The prevalence of patients meeting the diagnostic criteria for clinic hypertension and no previous or existing ICD-10 codes for hypertension nor any of the prescribed antihypertensive drugs listed by British National Formulary (referred to here as “undiagnosed hypertension”) was 5% for men and for 5% women according to European ESC/ESH (140/90 threshold) and 14% men and 12% for women according to American ACC/AHA (130/80 threshold)

guidelines. The analogous estimated prevalence of undiagnosed hypertension using the ABPM thresholds stratified by sex, age, NHS admission method, and NHS Specialty is given in [Table 4](#).

The prevalence of those meeting the criteria for “undiagnosed” isolated nighttime hypertension was 17% according to ESC/ESH (22% according to ACC/AHA). The prevalence for those meeting the criteria for “undiagnosed” isolated systolic hypertension was lower at 5% according to ESC/ESH (9% according to ACC/AHA). The prevalence for undiagnosed isolated diastolic and daytime hypertension was nearly zero ([Supplementary Table ST-6](#) online).

Estimated age-dependent trends of hypertension

The estimated age-dependent prevalence of hypertension trends for men and women according to the European ESC/ESH and American ACC/AHA definitions of thresholds is shown in [Figure 2](#), with underlying numbers in [Table 3](#). The analogous estimated prevalence trends for undiagnosed hypertension, shown in [Figure 3](#), with the underlying data presented in [Table 4](#).

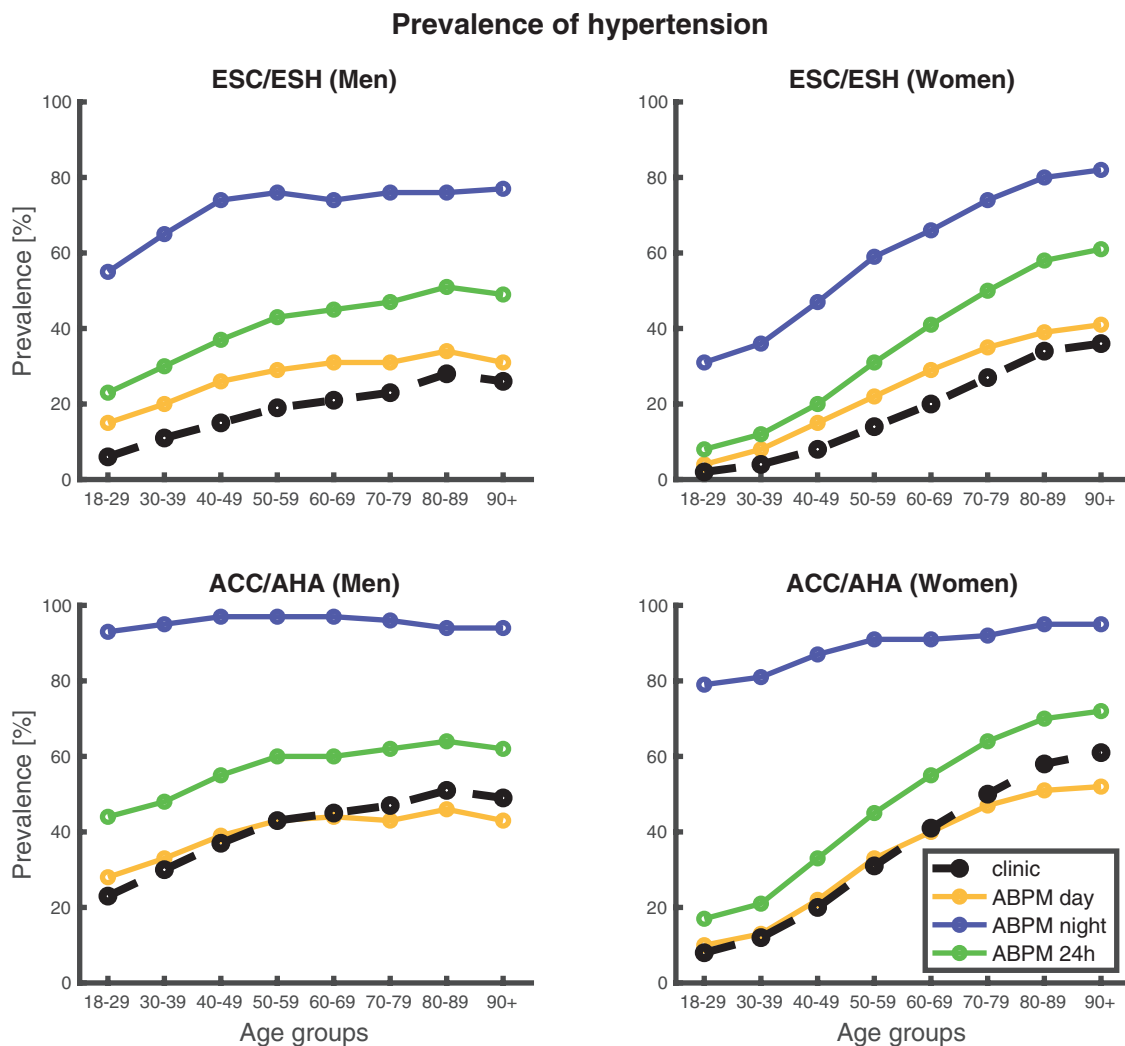


Figure 2. Estimated age-dependent hypertension trends. Estimated prevalence trends of patients meeting the criteria for “clinic,” ABPM day, ABPM night, and ABPM 24-hour hypertension for different age groups according to the European ESC/ESH (top panel) and American ACC/AHA (bottom panel) guidelines (Supplementary Tables ST-2 online).

DISCUSSION

Key results

We estimated the prevalence of patients with average in-hospital BP meeting criteria for hypertension and undiagnosed hypertension according to the European 2018 ESC/ESH guidelines¹³ and American 2017 ACC/AHA guidelines,¹⁴ using a large hospital database of 1.7 million BP measurements. The proportion of patients meeting the diagnostic criteria for Stage 1, 2, or 3 hypertension was 21.4% when the European guidelines were applied and 47% when the American guidelines were applied. Overall, the proportion of patients meeting diagnostic criteria for hypertension increased with age, whilst number with “undiagnosed” hypertension decreased with age.

Interpretation

Although the prevalence of hypertension and specifically undiagnosed hypertension in the community has been well established, it is rarely reported in the hospital setting. Literature regarding the prevalence of elevated in-hospital BP in the absence of a diagnosis of hypertension and its diagnostic ability and association with a persistently raised BP postdischarge and the future development of hypertension are also lacking; a recent systematic review that investigated the extent to which elevated in-hospital BP can predict undiagnosed hypertension identified 12 studies of emergency department populations but none of inpatient populations.⁹

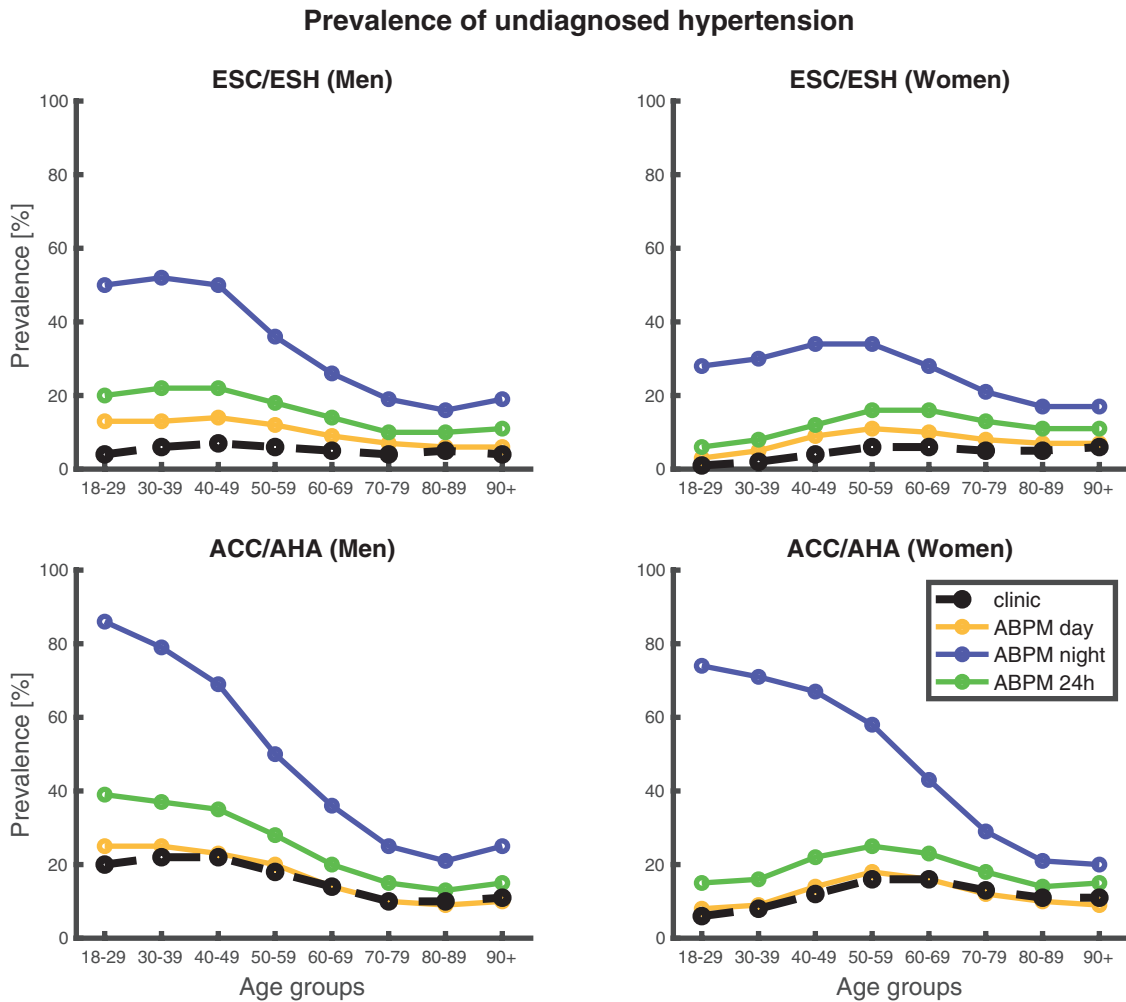


Figure 3. Estimated undiagnosed age-dependent hypertension trends. Estimated prevalence of undiagnosed hypertension trends for different age groups according to the European ESC/ESH (top panel) and American ACC/AHA (bottom panel) guidelines.

Prevalence of hypertension The prevalence of undiagnosed hypertension in emergency departments has been reported to be about 3%–15% of adult patients, of which nearly 50% being categorized as having Stage 1 hypertension, 25%–36% Stage 2 hypertension, and 12%–30% Stage 3 hypertension.¹⁶ In comparison, the current study shows that the estimated prevalence of patients undiagnosed hypertension (see Methods section for a definition) was 5% using ESC/ESH and 13% using ACC/AHA criteria. We note that using lower ABPM daytime, nighttime, and 24-hour thresholds yields higher estimated prevalences (Table 4).

Screening for hypertension in hospital Hospital admission allows for opportunistic screening of BP and potential identification of undiagnosed hypertension. The accumulation of multiple measurements during hospital admission may also allow more accurate detection of patients who have hypertension. The prevalence of nocturnal high BP suggests a single normotensive screening measurement obtained in a primary care appointment might falsely classify some

patients reaching hypertension criteria in hospital as being normotensive.

Figure 2 shows that the prevalence of elevated BP increases with age. This patient group includes those with and without an existing diagnosis of hypertension. Although many of those with diagnosed hypertension had elevated BP in hospital, this may result from decreased antihypertensive treatment during the hospital stay, rather than reflecting uncontrolled hypertension in the community.

Figure 3 illustrates that there is a decrease in prevalence of patients meeting criteria for “undiagnosed” hypertension with advancing age. It is unlikely that this is solely attributable to physiological aging and may reflect increased pick-up as age increases. The marked prevalence of patients meeting criteria for “undiagnosed” hypertension suggests in-hospital screening may be worthwhile.¹⁷ Whilst elevated or labile BP in hospital may be attributed to stress and anxiety, previous studies have suggested increased BP lability under stress is a predictor of future cardiovascular events.¹⁸

A particularly interesting aspect of hospital screening is the finding that 17% patients met the ESC/ESH (22% ACC/AHA) criteria for undiagnosed isolated nighttime hypertension. These patients would not be identified for 24-hour ABPM by office measurements, but may have increased cardiovascular risk.¹⁹

Present guidelines on the management of elevated BP in hospital are only applicable to patients who have markedly elevated BP in the emergency department setting.²⁰ Internationally, hypertension guidelines provide diagnostic criteria for the clinic, home, or ambulatory setting (Supplementary Tables ST-1 and ST-2 online) but do not suggest diagnostic thresholds for the in-hospital setting. This may be owing to a lack of studies upon which hospital thresholds could be defined. Indeed, the emergency department guidelines draw on evidence from few studies which are limited in sample size and representativeness.⁹ However, studies conducted in Emergency Departments suggest that between 25% and 76% of those with high BP in the emergency department meet criteria for the diagnosis of hypertension in the community.⁹ As our hospitalized patients contributed more BP readings than patients with brief hospital attendances in the emergency departments studies⁹ classification of BP using in-hospital measurements may prove more predictive.

Study limitations

This was a retrospective study with inherent limitations. The study used measurements recorded on the wards by nursing staff as part of their regular observations of in-hospital patients. This poses 2 potential limitations. Firstly, patients who have longer hospital stays will contribute more data to a hospital database of vital-sign observations. We compensated for this by generating 1 24-hour BP profile per patient, regardless of their length of hospital stay with details of this procedure described in ref. 12. Secondly, the question of selection bias arises. The patients who are clinically less stable may have their BP taken more frequently during nighttime hours. However, observations may also be measured at night as a result of admission time or clinical protocols. Our pre-defined inclusion criteria based on earlier work in which we defined a method for 24-hour BP profiling of patients meant we excluded the majority of patients admitted to hospital. The greatest number of patients was excluded due to having no nighttime BP measurements. This may have caused us to underestimate the prevalence of daytime hypertension.

This study included patients from 4 hospitals (3 tertiary and 1 secondary) within a single University Hospital Trust in the United Kingdom. Further work is needed to discover whether our results are generalizable to hospitalized patients in different regions of the world. Finally, our work includes only in-hospital BPs. Further research investigating the diagnostic performance of in-hospital BP measurements for reliably detecting community hypertension is required.

A substantial number of hospitalized patients have an average in-hospital BP that exceeds international criteria for the diagnosis of hypertension, with many demonstrating isolated nocturnal hypertension that are unlikely to be picked up with clinic or home BP measurements. In-hospital BPs

may present an opportunity to detect patients with previously undiagnosed hypertension.

SUPPLEMENTARY MATERIAL

Supplementary data are available at *American Journal of Hypertension* online.

FUNDING

The research was supported by the National Institute for Health Research (NIHR) Oxford Biomedical Research Centre and by an EPSRC grant (EP/EP/N024966/1—Intelligent Wearable Sensors for Predictive Patient Monitoring).

ACKNOWLEDGMENTS

The views expressed are those of the authors and not necessarily those of the National Health Service (NHS), the National Institute for Health Research, or the Department of Health. This research would not have been possible without the help of Dr Marco Pimentel, who was instrumental in compiling the anonymized patient data.

ETHICAL APPROVAL

This study was approved by the Oxfordshire Research Ethics Committee (reference: 16/SC/0264), with Confidential Advisory Group approval to process patient data without consent (reference: 16/CAG/0066).

DISCLOSURE

A.M. was funded by an EPSRC grant (EP/EP/N024966/1—Intelligent Wearable Sensors for Predictive Patient Monitoring). L.C.A. is funded by a Wellcome Trust Doctoral Research Fellowship [203921/Z/16/Z]. For the purpose of open access, the author has applied a CC BY public copyright license to any Author Accepted Manuscript version arising from this submission. L.T. is a nonexecutive Director of Sensyne Health and holds share options in the company. P.W. was Chief Medical Officer for Sensyne Health and holds shares in the company.

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