Title

Examining the Influence of Care Processes and Clinical Engagement on Disparities in Blood Pressure Control

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Examining the Influence of Care Processes and Clinical Engagement on Disparities in Blood Pressure Control

by
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DEDICATION AND AKNOWLEGDEMENTS

This dissertation is dedicated first and foremost to my best friend and soulmate, **Karim Azar** –

فما جاوزتهم الا قليلا حتى وجدت من تحبه نفسي

It is also dedicated with all my love to our three beautiful boys – my boys - **Bendely, Elias and Nikitas** – always believe there is good in this world and BE THE GOOD. You **will** change this world with love, compassion and perseverance.

It is dedicated to my parents **– Elias and Laura Jadelrab** – "You raised me up so I can walk on mountains" And to my second parents – **Bendely (Bill) and Nadia (Nina) Azar** – "And I think to myself, what a wonderful world". It is further dedicated to my grandparents who now and forever have had a deep and profound effect on my life and who I will become in this world – **Hanna and Wedad Jadelrab** & **Dimitri and Dolores Kaidy.** May their memories be eternal.

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EPIGRAPH

"The idea that some lives matter less is the root of all that is wrong with the world."

-Dr. Paul Farmer

Examining the Influence of Care Processes and Clinical Engagement on Disparities in Blood Pressure Control

Kristen M.J. Azar

ABSTRACT

Nearly half of all adults in the United States (U.S.) have high blood pressure (BP) and despite the availability of effective and affordable medications, it is often very challenging for people to achieve BP control this in turn raises the risk of stroke, myocardial infarction and heart failure. This dissertation examines the role that healthcare inequities can play for historically marginalized patient groups that experience persisting disparities in BP control. It is unclear how suboptimal care as it related to care processes involved in the treatment of hypertension (HTN), or healthcare inequities, may differentially impact observed disparities in BP control. Our goal for these analyses will be both descriptive and inferential. We will aim to conduct an in-depth examination of contributors to disparities in uncontrolled hypertension from the perspective of healthcare processes and clinical care management. We use electronic health record data from real-world health systems to examine, first, factors associated with high performing clinical sites for BP control among Black individuals. Next, we examine how different patients may engage with primary care and what that might mean for their BP control outcomes. Finally, we examine whether clinical engagement trajectories most closely resembling the established paradigm for sequential "diagnosis, treatment and control" more or less likely among historically marginalized patient groups, at 24-months post-diagnosis. While upstream societal and social inequities undoubtedly play a major role in healthcare inequities and health disparities, health care plays a crucial role in addressing disparities in BP control as it is a system that can be modified and optimized by leveraging existing quality improvement infrastructure within a healthcare system and the greater healthcare ecosystem.

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LIST OF ABBREVIATIONS

AHA	American Heart Association
AI/AN	American Indian/ Alaska Native
AMA	American Medical Association
ASWw	Average silhouette width weighted
BMI	Body Mass Index
BP	Blood Pressure
CAD	Coronary Artery Disease
CDC	Centers for Disease Control and Prevention
CHF	Congestive Heart Failure
CMS	Centers for Medicare and Medicaid Services
COPD	chronic obstructive pulmonary disease
CVD	Cardiovascular Disease
DBP	Diastolic Blood Pressure
ED	Emergency Department
EHR	Electronic Health Record
ESRD	End Stage Renal Disease
FFS/HMO	Fee for service/Health Maintenance Organization
HC	Hubert's C
HG	Hubert's Gamma
HPI	Healthy Places Index
HTN	Hypertension
ICD	International Classification of Diseases

IQR	Interquartile Range
JNC	Joint National Committee
KPNC	Kaiser Permanente Northern California
LTFU	Loss to follow-up
NH	Non-Hispanic
NHA	Non-Hispanic Asian
NHANES	National Health and Nutrition Examination Survey
NHB	Non-Hispanic Black
NHO	Non-Hispanic Other
NHPI	Native Hawaiian/Pacific Islander
NHW	Non-Hispanic White
NQF	National Quality Forum
OB/GYN	Obstetrics and gynecology
OCM	Optimal blood pressure care management
OM	Optimal Matching
OR	Odds Ratio
PBC	Point Biserial Correlation
PCORnet	Patient Centered Outcomes Research Network
REAL	Race, Ethnicity, Ancestry, Language
SBP	Systolic Blood Pressure
SCM	Suboptimal blood pressure care management
SD	Standard Deviation
SH	Sutter Health

T2DM	Type 2 Diabetes Mellitus
UCM	Unknown blood pressure care management
UCSF	University of California San Francisco
US	United States
UTD	Up to date

CHAPTER 1

Clinical Site Characteristics Associated with Superior Blood Pressure Control among Non-Hispanic Black Adults in Ambulatory Healthcare Settings

1.1 ABSTRACT

Background: Uncontrolled blood pressure (BP) causes almost half a million deaths per year in the United States (US), making it a leading preventable cause of death. Despite the availability of effective and affordable medications, BP control rates remain sub-optimal and are substantially lower in Black patients than in patients of other race/ethnicities.

Study Objective: We used the BP Control Laboratory Surveillance System (BP Track), an ongoing serial cross-sectional study of BP control across the US using electronic health record (EHR) data, to explore patient sociodemographic and clinical site-level characteristics associated with BP control with the goal of identifying factors associated with high performing clinical sites for BP control among Black individuals.

Methods: We fitted multivariable logistic regression models to estimate the effect of each clinical site on predicted probability of blood pressure control among Black adult patients with hypertension (primary outcome), adjusting for patient sociodemographic, care process quality metrics and site-level characteristics. We used an external benchmark for performance (>=70% BP control) to define positively deviant clinics, or clinics that exceeded the benchmark for reasons that were not explainable by known characteristics or measured quality metrics.

Results: Among 73 clinics, BP control among Black adult patients was 62.8% +/- 10.9%, with 13 clinics exceeding the 70% control benchmark for high performance. Sociodemographic patient mix characteristics were more predictive of clinic performance than established care process quality metrics, but even in fully adjusted models, residual variability was high.

Conclusion: We quantitatively identified positively deviant, high performing clinics with performance that we could not explain with established quality process metrics or patient mix. The variation in clinic performance for BP control among Black patients that was unexplained by care process metrics or patient mix elucidates an important opportunity to further examine practices within clinics identified as high performing clinics identified based on the fully adjusted model. Further investigation is warranted to understand how these clinics are able to achieve better blood pressure control for their Black patients than other clinics.

1.2 INTRODUCTION

Uncontrolled blood pressure (BP) causes over 450,000 deaths per year in the United States (US), making it a leading preventable cause of death.[1,2] Despite the availability of effective and affordable medications, BP control rates remain sub-optimal in the US overall, estimated to be 43.7% among those with hypertension between 2017-2018, and are substantially lower in Black patients than in patients of other race/ethnicities.[3]

Clinical settings and local processes of care delivery play a crucial role in influencing whether patients with hypertension ultimately achieve and maintain BP control. System-wide attempts to implement comprehensive, evidence-based best practices have had some success in certain healthcare systems. For example, in the year 2000 Kaiser Permanente Northern California (KPNC) implemented a large-scale hypertension management program and realized a significant increase in hypertension control (from 44% to 90%) between 2000-2013, but whether BP control improved in Black patients is unclear (race/ethnicity was not reported).[4,5] A similar program was implemented at 12 safety-net clinics in the San Francisco Health Network with significant success, but a considerable gap in BP control between Black and White individuals with hypertension remained.[6] National studies have demonstrated persistent disparities in diagnosis, treatment and control in Black individuals with hypertension[3] and lower control rates among Black patients diagnosed with hypertension at health systems across the US.[7]

While disparities overall persist, electronic health record-based surveillance has identified substantial variability across health systems for Non-Hispanic Black patients[7], with relatively high rates of control in some health systems and clinical sites. High performing clinical sites achieving high rates of BP control among patients with hypertension and across race/ethnic patient subgroups offer an opportunity to identify best practices. A positive deviance approach[8,9], whereby clinical sites with high performance are identified in order to analyze and share effective strategies, can be a mechanism for change and quality improvement both within and across larger healthcare organizations.[10]

We used the BP Control Laboratory Surveillance System (BP Track), an ongoing serial cross-sectional study of BP control across the United States using electronic health record (EHR) data[11], to explore

patient sociodemographic, clinical care process metrics and clinical site-level characteristics associated with BP control among non-Hispanic Black individuals with diagnosed hypertension. Our goal was to identify factors associated with high performing clinical sites for BP control among Black individuals and describe residual variability in performance that might indicate successful strategies with potential for dissemination.

1.3 METHODS

BP Track conducts surveillance of BP control and BP-related process metrics from EHR data collected by the National Patient-Centered Clinical Research Network (PCORnet). PCORnet is a national network-of-networks developed to conduct patient-centered outcomes research, using a common data model to enable rapid access to clinically and sociodemographically diverse patient populations for pragmatic clinical trials and epidemiological research.[12] We used data from BP Track to identify and analyze patient and site-level characteristics and BP control metrics for non-Hispanic Black (hereafter referred to as Black) adults from 1/1/2017 to 3/31/2020 among participating clinical sites with > 100 eligible Black adults with hypertension. This study was approved by the UCSF Institutional Review Board and was conducted according to Health Insurance Portability and Accountability Act standards.

Study Design and Data Source

BP Track is a serial cross-sectional study that collects counts, descriptive statistics and quality metrics using EHR data from health systems participating in PCORnet, with data reported out aggregated at the site (i.e. clinic) level. Details regarding the PCORnet Blood Pressure Control Laboratory platform study and methods are published elsewhere.[7,11] For this analysis, we used BP Track Wave 6, which includes data from 27 participating healthcare systems (i.e. PCORnet datamarts), 10 of which also provided results for specific clinical sites within those health systems. We limited our present analysis to the clinical sites within health systems with data from >100 eligible hypertensive individuals with Black race/ethnicity as recorded in their EHR data.[7] For Wave 6, data were collected from clinical sites for 1-year measurement

periods on a rolling quarterly basis from January 2017 through December 2020 (Appendix 1). Data were collected at the clinical-site level in aggregate, cross-classified by several sociodemographic characteristics (i.e. race/ethnicity, age group and sex) for a given clinical site.

We limited our analysis to the measurement period ending in March 2020 so as not to include disruptions from the COVID-19 pandemic. Only BP measurements associated with ambulatory visits are analyzed, as specified in the National Quality Forum (NQF) 0018[13] Controlling High BP. To be included in analyses (as specified in NQF 0018), patients had to (1) be 18 to 85 years of age through the end of a measurement period, (2) have at least one visit during the measurement period at the health system, and (3) have a diagnosis of hypertension according to International Classification of Diseases, Ninth and Tenth Revision (ICD-9, ICD-10) codes during the first 6 months of the measurement period or at any time before the measurement period. Patients were excluded if (1) they received hospice services during any measurement period; (2) had a diagnosis or evidence of end-stage renal disease, dialysis, or renal transplant during or before any measurement period; (3) had a diagnosis of pregnancy during any measurement period; or (4) were receiving care based on an institutional special needs plan or were residing in a long-term care facility during any given measurement period.

In the event >1 BP measurement was recorded during a visit, the lowest measurement was retained. Each metric described below was calculated for each clinical site, then separately for subgroups defined by age, sex, and race/ethnicity. The SAS code used to generate metric results (for the BP Track parent study) is available on GitHub (https://github.com/markjpletcher/Blood-Pressure-Control-Laboratory).

Patient Sociodemographic Characteristics

Variables for patients' age group, sex and race/ethnicity were derived from aggregate counts of the combinations of those characteristics. Age was classified as 18-44, 45-64 and ≥65 years old as the oldest category. Race and ethnicity were defined jointly using information about Hispanic identity and race group as recorded in the patient's medical record, in 5 mutually exclusive and exhaustive categories: Hispanic of

any race, non-Hispanic White (White), non-Hispanic Black (Black), non-Hispanic Asian (Asian) or Other/Unknown.

Clinical Site Characteristics

Clinical site size was defined by the total number of eligible patients with hypertension. For all clinical sites, we extracted aggregate patient demographic and clinical information, including proportions of patients in different categories of age, sex and race/ethnicity and with different comorbid conditions. Comorbid conditions included coronary artery disease (CAD), chronic obstructive pulmonary disease (COPD), depression, type 2 diabetes mellitus (T2DM) and congestive heart failure (CHF) based on ICD-9/ICD-10 codes.

Clinical Site Quality Metrics

For each clinical site, BP Track queries produce a set of BP-related quality metrics derived from EHR data that track the healthcare processes linked to improving care for patients with hypertension.[14] The BP Track process metrics examined in this analysis are based on recommendations in currently available guidance,[15,16] and include confirmatory repeated blood pressure measurement, medication intensification (addition of a new class of antihypertensive medication after uncontrolled BP), repeat visit in 4 weeks after uncontrolled BP, use of a calcium channel blocker or thiazide or thiazide-like diuretic among Black patients prescribed at least one medication, prescription of a fixed-dose combination medication among patients prescribed at least 2 classes of medications, and whether the BP measure recorded ended in a zero, which sometimes indicates inappropriate rounding. We also performed a sensitivity analysis for care process metrics among Black patients only. Detailed metric definitions have been published elsewhere[11] and technical specifications for all metrics can be found in Appendix 2.[7]

Primary Outcome

Our primary outcome of interest was the probability that a Black adult patient would have blood pressure in the controlled range for a given clinical site. The primary outcome in the regression models is an individual-specific binary indicators of BP control. BP control was defined as a most recent BP measurement of <140/<90 mmHg during the measurement period. This overall measure of BP control implements NQF 0018[13], which defines BP Control as the percent of patients with hypertension for whom the last BP measurements at an ambulatory care visit were at goal, defined as systolic BP (SBP) < 140 mmHg and diastolic BP (DBP) < 90 mmHg. Per this definition, we exclude those with end stage renal disease (ESRD), dialysis, renal transplant before or during the measurement period or pregnancy during the measurement period. Individuals who are age 65 years or older Institutional Special Needs Plans or residing in long-term care with POS code 32, 33, 34, 54, or 56 any time during the measurement period are also excluded. The fitted model is then used to estimate the site-specific marginal control probabilities, adjusting for covariates derived from aggregate measures.

Statistical Methods

For all clinical site-level covariates, we generated a mean across clinical sites using data from the most recent cross-sectional timepoint (i.e. the last available quarterly, rolling 1-year period from 1/1/2017 to 3/31/2020). We also calculated the standard deviation and range for each covariate. We calculated the mean number of eligible patients (i.e. patients with hypertension), and site percent BP control both overall and among Black patients. Finally, we calculated the interquartile range (IQR) and distribution statistics for care process metrics across clinical-sites.

We converted the aggregate data into an individual patient-level dataset including three patient-level sociodemographic characteristics (i.e. age group, sex and race/ethnicity) for each individual using the cross-classified aggregate data for those covariates, along with the clinic-level variables described above.

We fitted logistic models to estimate clinic-specific predicted probabilities of blood pressure control among Black adult patients with hypertension (primary outcome), adjusting for patient sociodemographic

and clinical site-level characteristics. Three nested models were fitted, first including only clinical site indicators as fixed effects (Unadjusted Model), next adding the measured site-level BP-related quality care process metrics for BP management (Primary Model), and then finally adding patient baseline characteristics and site-level characteristics (Fully Adjusted Model). We included season (i.e. fall, winter, spring, summer) in all models to account for seasonal variation in BP control known to occur[17,18] and previously described in the BP Control Lab.[7] Each model was used to estimate the marginal predicted probability that patients at each clinic achieved BP control, with variability summarized using 95% confidence limits based on robust standard errors for site-specific correlation. These estimates are interpreted as the predicted probability of BP control for each clinic, averaging over the joint distribution of included covariates.

To identify sites with high performance that cannot be attributed to the influence of our measured covariates, we ranked clinical sites according to their predicted probability of BP control from the Primary Model. We categorized them as clinical sites with high performance (i.e. positive deviants[9]) if the lower bound of the 95% confidence intervals for the probability of control for a given site was above 70%, a benchmark of high performance per the American Heart Association(AHA)/ AMA Target BP recognition program.[19] An external benchmark for performance was used to define positively deviant clinics that exceeded the benchmark for reasons that were not explainable by known characteristics or measured quality metrics. We repeated these analyses, stratifying by clinical sites with the highest quartile of performance compared to those with the lowest quartile of performance. Statistical analyses were performed using Stata version 16.0 (College Station, Texas).

1.4 RESULTS

Of the 27 health systems participating in BP Track Wave 6, 10 included clinical site-level data representing a total of 171 clinical sites with data available for analysis. Of these, 73 clinical sites (from 9 different healthcare systems) included data with >100 Black qualifying adults, with a total of 388,327 adults overall with hypertension and, of whom, 57,567 were Black (Figure 1). The number of 1-year measurement

periods contributed per clinical site varied from 1 to 10 (mean 8.6), after applying the exclusion due to low number of qualifying adults. Clinical site-level characteristics are summarized in Table 1. Clinical sites ranged in size from 136 to 78,963 eligible patients with hypertension (all race/ethnicities), with between 1% and 80% Black patients (range 101 to 5501 patients).

On average across all available time periods, BP control was lower among Black patients (62.8% [SD, 10.9]) compared to White individuals (69.5% [11.6]) or the overall patient population with hypertension (66.9 % [11.8]). Clinical sites treated more women than men overall (55.2% vs 44.8% respectively) with a wide range across clinics; some clinical sites had no male patients. There was also a high level of heterogeneity regarding race/ethnic composition and age groups across sites, with wide ranges across all race/ethnic groups except non-Hispanic Asian, which made up <11% of the patient population across all clinics. Over one-third of individuals with hypertension also had type 2 diabetes (T2DM; 34.4%). Clinical care process metrics also varied across sites, with substantial room for improvement nearly across the board, except for the prescribing of calcium channel blocker or thiazide or thiazide-like diuretic for Black patients, where the average performance was generally high (74.8% [7.6]). Mean proportion of eligible patients meeting the criteria for care process metrics across clinics ranged from 13.4% for medication intensification (SD = 7.5) to 19.3% for prescription of a fixed dose combo medication (SD= 8.8). The IQR across metrics (Table 2) was 9.3% (0-42.9) for medication intensification and 12.5% (8.2-46.4) for those prescribed a fixed dose combo. Of note, the proportion of patients with terminal digit zero, an indicator of sub-optimal care quality, was relatively frequent, with a mean of 19.1% (SD = 11.6) across clinics and an IQR of 12.4% (8.2-46.4). In the model adjusted for clinical care process metrics (Primary Model), we observed substantial unexplained variability in BP control among Black patients (Figure 2). Of the 73 clinical sites, 15 (20.5%) were identified as high performers, with predicted probabilities of BP control > 70% (Figure 2, B). Nearly two-thirds (63%; n = 46) had a predicted probability of BP control that was less than 70%, our benchmark for high performance. The Unadjusted Model shows a very similar pattern of deviation (Figure 2, A), with all high performing clinics in the Primary Model appearing to be high performers in the Unadjusted Model. Adjustment for measured care process quality metrics had little

impact on deviance estimates, though adjusting for more factors in Primary Model reduced the precision of the predicted probability estimates (Figure 2, A vs. B).

Patient demographics and clinical site characteristics had stronger influences on likelihood of BP control; adjusting for these factors substantially altered our estimates of clinic performance (Figure 2, C). Three clinical sites identified as high performers after adjustment for care process metrics no longer met our criteria based on the Fully Adjusted Model (Figure 2, B vs C). These clinics had high performance for BP control among Black patients (range 76.2% - 78.2%) based on unadjusted proportion in control at the most recent timepoint. One of the clinics had a much lower eligible population size (n = 290) compared to the other two and also compared to the mean across all clinical sites (n= 5319.5 [12075.3]). This clinic also had a very high proportion of Black patients (80%) compared to the mean across clinical sites (32.3% [23.0]). Conversely, one of the clinics identified had a very high proportion of White patients (90.8%) compared to the mean across clinical sites (57.2% [23.3]). This clinical site also had a higher proportion of patients with diagnosed coronary artery disease (71.1%) compared to the mean (21.1% [13.8]) as well as a much higher proportion of patients over the age of 65 (74.9% vs 47.2% [14.5]).

Further, three clinical sites identified as low performers with adjustment for care process metrics were identified as high performers in the Fully Adjusted Model (Figure 2, B vs C). These clinics had lower performance for BP control among Black patients (range 62% - 67.1%). One of these clinics had a higher proportion of White patients (82.8%) compared to the mean, but all had lower proportion of Black patients (6.7%, 14.9% and 22.3%, respectively).

When we examine predicted probabilities for clinics in the top quartile of performance and lowest quartile, the fully adjusted model, which included patient-level and site-level predictors, influenced predicted clinical site performance more prominently than the care process metrics alone (Figure 3). Care process metrics had more influence on clinics in the lowest performance quartile.

Finally, a substantial portion of the clinic-level variation in BP control among Black patients is unexplained by either measured clinical care processes or the patient sociodemographic and clinical site-level characteristics that we measured. When stratifying by the highest vs lowest quartile of performance,

the variation that is explained by adjustment is more clearly visible, where variability in predicted probabilities is decreased in the unadjusted vs fully adjusted models for both the highest quartile performers (Figure 3, Panel A vs C) and the lowest quartile performers (Figure 3, Panel D vs F). While less, there is still variation in predicted probability of BP control by clinic in each of these quartiles, which remains unexplained.

1.5 DISCUSSION

In examining clinical site characteristics that are associated with BP control, specifically among Black individuals with hypertension, we found that sociodemographic patient characteristics with variables related to patient mix were more influential in comparative clinic performance than care process metrics. Some clinics consistently outperformed others in terms of BP control for their Black patients; in some cases this performance was explained by measured characteristics, but most of the variability remained unexplained.

Barriers to hypertension control occur at the patient, physician, health system and even societal level. Some evidence suggests that physician-level factors, and specifically treatment intensification, may be more influential than system-level processes or patient-level behaviors (i.e. adherence) in controlling hypertension.[20,21] We found that patient mix within a clinical site greatly influences blood pressure control for Black individuals. This is not surprising giving the large body of evidence demonstrating the influence of social drivers and societal inequities that contribute to disparities in blood pressure management and preventive care behaviors at the individual level.[22] Despite accounting for these factors, there remained substantial variation in clinic performance and physician-level factors as well as health system-level factors may be underappreciated as key targets in need of improvement and optimization.

The American Medical Association's (AMA) MAP framework (Measure accurately, Act rapidly and Partner with patients) identifies treatment inertia, defined as the failure to establish appropriate targets and escalate treatment to achieve treatment goals, as a key obstacle to improving BP control.[14] While Aggarwal et al. (2021) found that treatment rates are comparable, concerns have been raised regarding

differential treatment where discrimination may increase treatment inertia.[23] Overall, the care process metrics did not account for as much variation in clinic performance as other clinical-site characteristics such as patient mix and clinic size. It is important to note that across all clinics examined, the care process metrics were suboptimal with less than 20% of eligible patients receiving medication intensification (13.4%) and/or a follow-up visit within 4 weeks (16.1%) as examples. Also, there was limited variation in performance of these metrics across clinics making it difficult to interpret their influence given that even high performing clinics did poorly in terms of care process metrics. More work is needed to better understand the influence of these processes on BP control outcomes. Overcoming treatment inertia may, therefore, be a key approach to improving blood pressure management and reducing disparities. Optimization and improvement in care management processes for clinics could improve the overall influence on achieving BP control among patients at a given clinic. The unexplained variation could also be indicative of different care models and other physician or system – level processes that have differential effectiveness in facilitating optimized outcomes specifically for Black patients.

Over two decades ago KPNC implemented a successful, large-scale hypertension management program which included a comprehensive hypertension registry, development and sharing of performance metrics, evidence-based guidelines, medical assistant visits for BP measurement, and preference for single-pill combination pharmacotherapy. While the changes implemented via the KPNC approach are highly effective, they require extra staff and a reorganization of the way services are delivered, changes which many open health systems, especially those with limited resources, cannot easily implement or replicate. Previous results from the BP Control Lab[7] demonstrate substantial room for improvement in BP control (<140/90 mm Hg), which was 63% among Black patients, and in the clinical processes relevant for BP control.[7]

Of note, the KPNC program included hypertension control reports generated every quarter for each KPNC medical center and distributed to the center directors as well as a central hypertension management team who identified successful practices and disseminated effective strategies to the medical centers.[4] While many aspects of Kaiser's intervention are challenging to translate to dissimilar settings, this intentional

sharing and spreading of best practices was a key feature of their success and harkens to a positive deviance approach to process optimization. Positively deviant groups or individuals within health systems are high performers who do things differently.[8] Bradley et al (2009)[9] proposed a four stage process for healthcare organizations to conduct positive deviance analyses (Figure 4).[8,9] The first stage involves initial identification of positive deviants, which can be the result of either qualitative or quantitative analysis.[8,9,24] In this analysis, we have completed this step and have identified clinics that are high performers in both an absolute sense (they meet an objective benchmark) and a comparative sense (they are performing substantially better than other clinics in our sample). Little variation was explained by the variables included in the model. This presents an opportunity, as a next step, for qualitative and mixed methods to characterize strategies used to achieve the results (i.e. Stage 2 in a classic positive deviance analysis). These methods can then be empirically tested (i.e. Stage 3) and, if feasible, disseminated (i.e. Stage 4). A positive deviance approach can be a mechanism for change and quality improvement both within and across larger healthcare organizations that span wide geographies and serve diverse populations, and can be applied at the clinic, department, or system level. Additionally, while intra-institutional efforts may result in optimizing BP control within large integrated health systems, we must not overlook opportunities for inter-institutional efforts as well. The ongoing BP Track project presents an example of how inter-institutional data may be leveraged to operationalize a learning health network of institutions to identify positive deviants and, in some cases, test them on a national scale.

We defined and identified high performing clinical sites based on the predicted probability of having controlled BP for Black patients with hypertension receiving care at a given clinical site, after adjustment for covariates. Disparities in blood pressure control have persisted for Black patients for decades[3], where BP control rates are substantially lower for individuals self-identifying as Black compared to those who identify as White (39.2% vs 49% respectively, age-adjusted).[23] A recent analysis using National Health and Nutrition Examination Survey data between 2013 and 2018 reported that Black adults have higher hypertension prevalence, similar awareness and treatment rates, but lower BP control compared to White adults.[23] Given that Black adults in the United States have five times higher mortality risk from

hypertension compared to their White counterparts[23,25], there is an urgent need to better identify contributors that may influence BP control for Black patients, particularly in clinical settings. As mentioned previously, we used an external benchmark for performance to define positively deviant clinics, or clinics that exceeded the benchmark for reasons that were not explainable by known characteristics or measured quality metrics. The AHA/ AMA Target BP recognition program defines clinics achieving "Gold Status" BP control if the average BP control is ≥70% across a 12 month measurement period. Among nearly 1200 organizations participating in the program, representing over 8 million patients with hypertension across 46 states, nearly half achieved BP control rates of at least 70% amongst their patient populations in 2019.[19] Benchmarking programs such as this are helpful in elucidating a need for improvement and action, but do not account for important differences due to patient mix; and, as we have demonstrated in this analysis, these have enormous influence over overall clinic performance for blood pressure control.

1.6 LIMITATIONS

This study had several limitations. First, there are additional potential unmeasured confounders which could influence clinic-level blood pressure control among individuals who self-identify as Black, including additional patient-level factors, physician characteristics and neighborhood characteristics. We were not able to include patient-level data other than age, sex and race/ethnicity, limiting information regarding patient, provider, or system characteristics that may be relevant to BP control, including healthcare utilization, co-occurring conditions and other risk factors for high BP. Further, neighborhood factors and the social determinants of health have been shown to be highly influential in blood pressure control among minoritized patients.[22] We are not able to ascertain whether these are primary care clinics or specialty clinics, an important distinction which could influence clinic performance in BP management. EHR data are primarily collected to facilitate clinical care and promote more accurate billing and are not necessarily optimized for data analysis upon entry.

1.7 CONCLUSION

We quantitatively identified positively deviant, high performing clinics with performance that we could not explain with established quality process metrics. Further investigation is warranted to understand how these clinics are able to achieve better blood pressure control for their Black patients than other clinics.

1.8 FIGURES AND TABLES

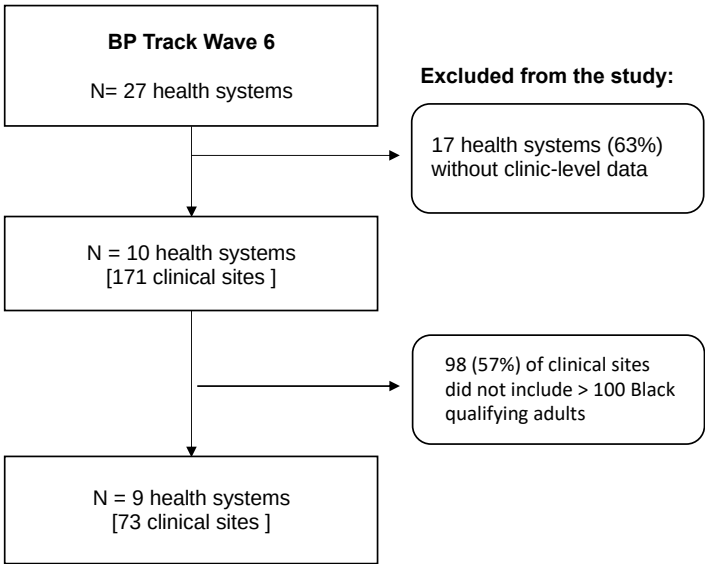


Figure 1.1. Cohort Flowchart
This figure provides a description of the inclusion/exclusion criteria for clinical sites included in the analysis.

Table 1.1. Summary of clinic-level characteristics* across clinical-sites for patients with hypertension

	Clinical Sites (n = 73)	
	Mean (SD)	**Range**
Total number of patients with HTN, N	5319.5 (12075.3)	136.0 – 78963.0
Number of Black patients with HTN, N	788.6(894.7)	101.0– 5501.0
% Overall BP Control	66.9 (11.8)	35.2 – 92.8
% BP Control for Black patients with HTN	62.8 (10.9)	37.9 – 86.5
% BP Control for White patients with HTN	69.5 (11.6)	35.0– 93.4
Clinical Site Sex Distribution		
% Male	44.8 (11.3)	0.0 – 63.5
%Female	55.2 (11.3)	36.5 – 100.0
Clinical Site Race/Ethnic Distribution		
% Non-Hispanic White	57.2 (23.3)	7.7 – 95.4
% Non-Hispanic Black	32.3 (23.0)	1.0 – 80.0
% Non-Hispanic Asian	1.6 (1.7)	0.0 – 10.5
% Hispanic	5.6 (10.1)	0.7 – 73.6
% Other/Unknown Race	3.3 (3.2)	0.0 – 11.7
Clinical site Age Distribution		
% Age < 45 y	11.0 (5.5)	2.0 – 38.2
% Age 45-64 y	41.8 (11.4)	23.1 – 70.6
% Age >=65 y	47.2 (14.5)	14.3 – 74.9
Clinical Site Distribution of Patient Clinical Characteristics		
% on >= 1 BP med	84.4 (6.6)	64.7 – 97.0
% with CAD	21.1 (13.8)	7.1 – 71.1
% with COPD	9.0 (7.2)	2.2 – 45.6
% with Depression	18.4 (8.1)	7.1 – 65.4
% with T2DM	34.4 (12.1)	18.5 – 99.4
% with CHF	12.6 (13.7)	2.5 – 88.7
Clinical Care Process Metrics		
% eligible with Medication Intensification	13.4 (7.5)	0.0 – 42.9
% of eligible with Confirmatory BP	14.1 (18.0)	0.0 – 83.2
% of eligible with Fixed Dose Combo	19.3 (8.8)	0.6 – 38.2
% of eligible with Visit in 4 weeks	16.1 (9.8)	0.0 – 43.2
% of eligible with CCBthiazide	74.8 (7.6)	38.8 – 85.3
% of eligible with Terminal Digit Zero	19.1 (9.9)	8.2-46.4

*At most recent measurement period

HTN = Hypertension; CHF = Congestive heart failure; COPD = Chronic obstructive pulmonary disease; CAD = coronary artery disease; T2DM = type 2 diabetes; CCBthiazide = calcium channel blockers or thiazide diuretics

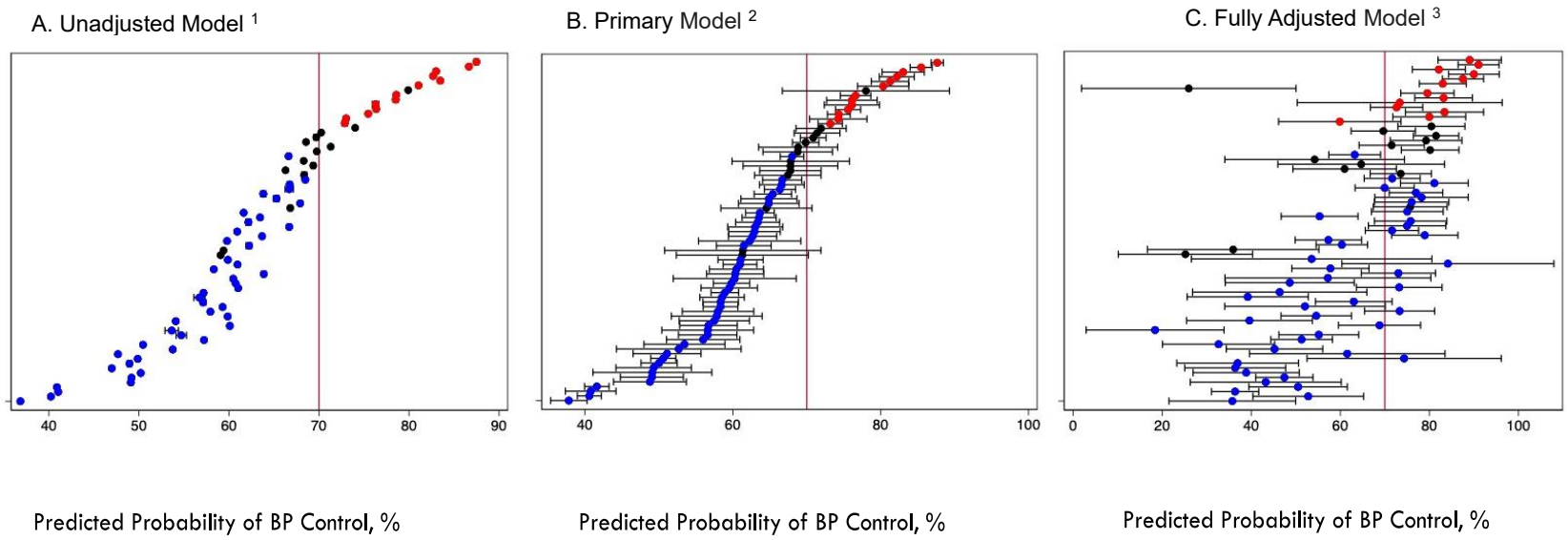
This table shows the summary of clinic-level characteristics* across clinical-sites for patients with hypertension

Table 1.2. Distribution of Care Process Metrics

	Mean [SD]	25th Percentile	75th Percentile	IQR	Range
Clinical Care Process Metrics*					
% eligible with Medication Intensification	13.4 (7.5)	8.6	17.9	9.3	0.0 – 42.9
% of eligible with Confirmatory BP	14.1 (18.0)	0	24.5	24.5	0.0 – 83.2
% of eligible with Fixed Dose Combo	19.3 (8.8)	13.7	26.2	12.5	0.6 – 38.2
% of eligible with Visit in 4 weeks	16.1 (9.8)	15.7	20.8	11.7	0.0 – 43.2
% of eligible with CCBthiazide	74.8 (7.6)	76.7	79.6	9.1	38.8 – 85.3
% of eligible with Terminal Digit Zero	19.1 (9.9)	11.6	24.0	12.4	8.2 – 46.4

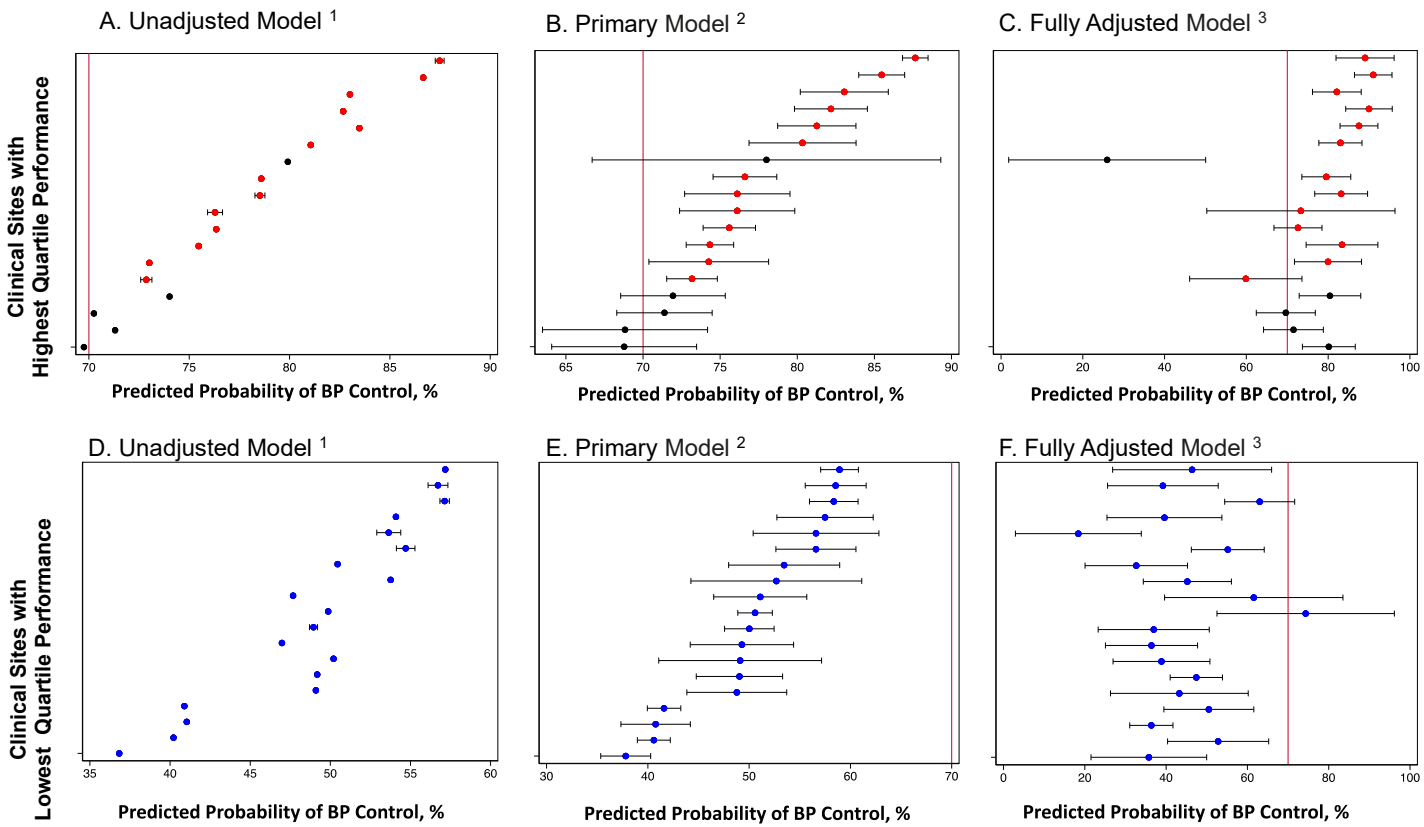
*At most recent measurement period
IQR = Inter quartile range

This table shows the distribution of care process metric occurrence for the study cohort



*Facility order is consistent across panels and based on rank of predicted probability of BP control from Primary Model; Blue marker = Clinical sites identified as negative deviants based on predicted probability < 70% for Primary Model; Red marker = Clinical sites identified as positive deviants based on predicted probability > 70% for Primary Model
[1]Unadjusted Model = includes time-period
[2] Primary Model = Unadjusted Model + Care Process Metrics
[3]Fully Adjusted Model = Primary Model + patient-level and site-level characteristics

Figure 1.2. Predicted probability of BP control* among NHB patients by clinical – site with and without adjustment for measured patient and site-level characteristics with 95% Confidence Interval
This figure shows the predicted probability of the percent of patients with blood pressure control by clinic based on unadjusted and adjusted models



*Facility order is consistent across panels and based on rank of predicted probability of BP control from Primary Model; Blue marker = Clinical sites identified as negative deviants based on predicted probability < 70% for Primary Model; Red marker = Clinical sites identified as positive deviants based on predicted probability > 70% for Primary Model

[1]Unadjusted Model = includes time-period

[2] Primary Model = Unadjusted Model + Care Process Metrics

[3]Fully Adjusted Model = Primary Model + patient-level and site-level characteristics

Figure 1.3. Predicted probability of BP control* among NHB patients by clinical – site with and without adjustment for measured patient and site-level characteristics with 95% Confidence Interval comparing highest and lowest quartiles of performance

This figure shows the predicted probability of the percent of patients with blood pressure control by clinic based on unadjusted and adjusted models comparing clinics in the highest to lowest quartiles of performance

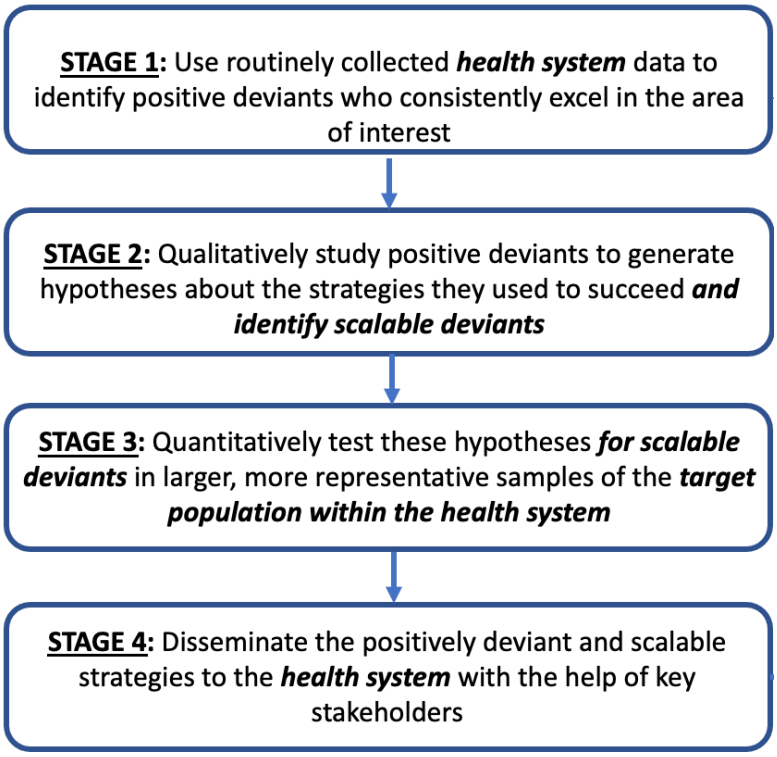
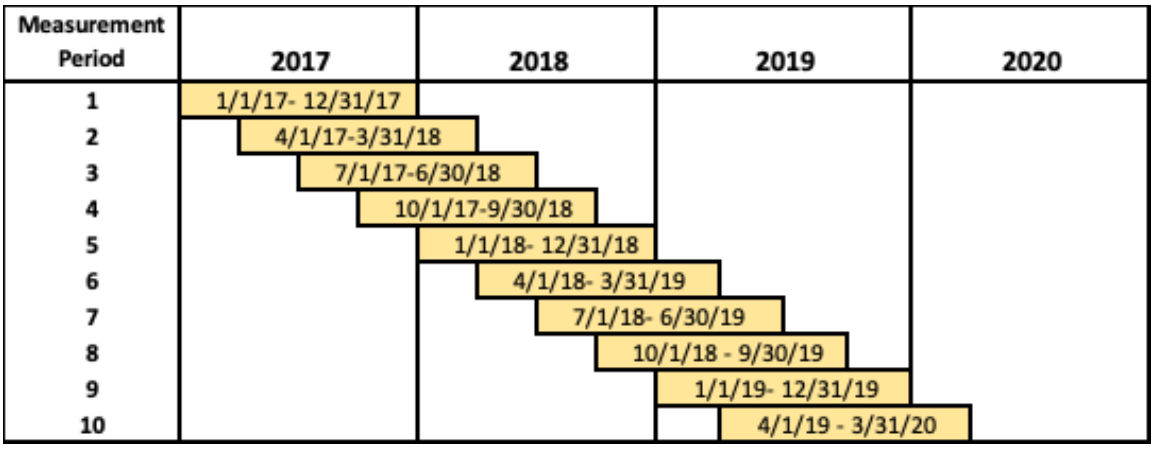


Figure 1.4. Positive Deviance Process for Learning Healthcare Organizations
This figure was adapted from Bradley et al (2009) paper entitled " Research in action: using positive deviance to improve quality of health care" published in Implementation Science that describes the steps to conducting positive deviance analysis in healthcare.

1.9 APPENDICES

Appendix 1:

Measurement Periods Included in BP Track



Each BP Track measurement period is a full year in duration, starting at the beginning of each quarter of the calendar year (3 months apart). In the current manuscript, BP Control metrics from up to 10 measurement periods were assessed from each participating datamart, depending on data availability. Data availability is limited by electronic record system factors and data latency, which varies by datamart within PCORnet®

Appendix 2:
PCORnet Blood Pressure Control Laboratory
Blood Pressure Control Metrics, v1.5, approved 4/7/2020

The goal of the PCORnet Blood Pressure Control Laboratory is to facilitate research and quality improvement efforts designed to improve control of blood pressure (BP) in patients with hypertension. To support this goal, the Data Core of the BP Control Lab will develop and maintain a set of aggregate BP Control Metrics, calculated for participating healthcare institutions using SAS-based queries of data in the PCORnet Common Data Model, and provide back to participating institutions in the form of BP Control Reports. These metrics include both measures of a target health state (BP control) and process measures that help clinicians understand where processes might be improved to attain a target health state.

This document includes the names, descriptions, and specifications for the metrics that will be supported by the Data Core and included in BP Control Reports. A Glossary defining key terms used in the specification statements is also included. A Notes section describing key programming details is also included.

Metric Specifications

1) Medication intensification, % of visits

This process measure captures the proportion of visits where BP is uncontrolled where a medication is ordered that is of a different class of medication than had previously been used. Note that this explicitly does not give credit for ordering a simple refill or medication dose increase, or use of a different medication in the same class.

Denominator Statement (Definition 2a): *Visit with uncontrolled BP*

A Visit is considered to be a *visit with uncontrolled BP* if it meets all of the following criteria:

- Visit made by a patient that is *hypertensive and eligible for BP control* (Definition 1a)
- Visit occurred in months 10-12 of the Measurement Period
- Visit was a Visit at the Clinical Unit of interest (as per Glossary)
- The lowest SBP measurement at the visit is ≥ 140 mmHg, or the lowest DBP measurement at the visit is ≥ 90 mmHg

Numerator Statement (Definition 2b): *Visit with medication intensification*

A visit is considered to be a *visit with medication intensification* if it meets all of the following criteria:

- *Visit with uncontrolled BP* (Definition 2a)
- At least one BP medication was prescribed at (or up to 7 days following) the qualifying *Visit with uncontrolled BP*
- The class of one or more BP medications prescribed was not prescribed to the patient in the 12 months prior to the prescribing date (see the Glossary for details on BP medication classes)

2) Confirmatory repeated blood pressure measurement, % of visits

This process measure is designed to capture the practice of repeating a blood pressure measurement in the same visit when the first measurement done in clinic is high (SBP≥140 mmHg or DBP≥90 mmHg).

Denominator Statement (Definition 3a): *Visit with a high BP measurement*

A Visit is considered to be a *visit with a high BP measurement* if it meets all of the following criteria:

- Visit made by a patient that is *hypertensive and eligible for BP control* (Definition 1a)
- Visit occurred in months 10-12 of the Measurement Period
- Visit was a Visit at the Clinical Unit of interest (as per Glossary)
- At least one SBP measurement at the Visit is ≥140 mmHg, or at least one DBP measurement at the Visit is≥90 mmHg

Numerator Statement (Definition 3b): *Visit with more than one BP measurement*
A Visit is considered to be a *visit with more than one BP measurement* if it meets all of the following criteria:

- *Visit with a high BP measurement* (Definition 3a)
- More than one SBP measurement is recorded during that Visit, OR more than one DBP measurement is recorded during that Visit

3) Use of fixed dose combination product among patients taking 2 or more classes of medications, % of patients

Use of fixed dose combination medications helps with adherence, promotes rational combinations of medications, and increases likelihood of achieving BP control. This metric, which is limited to patients taking more than one medication class, describes the prevalence of fixed dose combination pill use.

Denominator Statement (Definition 6a): *Hypertensive patient taking 2 or more different classes of medications*
A patient is considered to be a *hypertensive patient taking 2 or more classes of medications* if they meet all of the following criteria:

- Patient is *hypertensive and eligible for BP control* (Definition 1a)
- Patient has a prescription for 2 or more medications in two or more different classes of BP medications that was placed during the Measurement Period (see the Glossary for details on BP medication classes)

Numerator Statement (Definition 6b): *Hypertensive patient taking a fixed dose combination product*
A patient is considered to be a *hypertensive patient taking a fixed dose combination product* if they meet all of the following criteria:

- Patient is *a hypertensive patient taking 2 or more different classes of medications* (Definition 6a)
- Patient has a prescription for a fixed dose combination product that was placed during the Measurement Period

4) Use of a CCB or thiazide or thiazide-like diuretic among African-American patients on at least one medication, % of patients

Use of calcium channel blockers (CCB) OR a thiazide or thiazide-like diuretic medication classes is recommended to treat black or African American patients as first line monotherapy due to increased efficacy. This metric, which is limited to African-American patients with a diagnosis of hypertension taking at least one medication class, describes the prevalence of those receiving the recommended drug class.

Denominator Statement (Definition 7a): *African-American hypertensive patient taking at least one medication*
A patient is considered to be an *African-American hypertensive patient taking at least one medication* if they meet all of the following criteria:

- African-American race
- Patient is *hypertensive and eligible for BP control* (Definition 1a)
- Patient has prescribing record for at least one class of BP medication during the Measurement Period

Numerator Statement (Definition 7b): *African-American hypertensive patient taking a calcium channel blockers (CCB) or thiazide or thiazide-like diuretic*
A patient is considered to be an *African-American hypertensive patient taking a calcium channel blocker (CCB) or a thiazide or thiazide-like diuretic* if they meet the following criteria:

- Patient is an *African-American hypertensive patient taking at least one medication* (Definition 7a)
- Patient has a prescription for a calcium channel blocker (CCB) or thiazide or thiazide-like diuretic during the Measurement Period

5) Terminal digit = zero, % of measurements

Inappropriate rounding of blood pressure measurements (usually to zero) leads to measurement error and worse treatment decisions. This metric is designed to catch this behavior, which would lead to a terminal digit of zero of greater than 10% (if an automated BP monitor is used) or greater than 20% (if a manual BP monitor is used with recommended rounding to even digits). Unlike most of our metrics, lower is better, down to an ideal value of 10-20%, which would be expected if no rounding were occurring.

Denominator Statement (Definition 8a): *Qualifying SBP measurement*

A SBP measurement is considered a *qualifying SBP measurement* if it was recorded during a visit that meets the following criteria:

- The SBP measurement is for a patient who is *hypertensive and eligible for BP control* (Definition 1a)
- The SBP measurement is recorded during months 10-12 of the Measurement Period
- The SBP measurement is recorded at a Visit occurring at the Clinical Unit of interest

Numerator Statement (Definition 8b): *Terminal digit = zero*

The SBP measurement is considered to have a *terminal digit = zero* if it meets all of the following criteria:

- The SBP measurement is a *qualifying SBP measurement* (Definition 8a)
- The final digit of the SBP measurement is equal to zero.

Note that more than one *qualifying SBP measurement* may occur at a given visit. All *qualifying SBP measurements* are included.

6) Repeat visit in 4 weeks after a visit with uncontrolled HTN, % of visits

This process measure captures the proportion of persons who had uncontrolled HTN who made a subsequent visit within the following 4 weeks.

Denominator Statement (Definition 9a): *Visit with uncontrolled BP with time for a repeat Visit*

A Visit is considered to be a *Visit with uncontrolled BP with time for a repeat Visit* if it meets all of the following criteria:

- Visit made by a patient who is *hypertensive and eligible for BP control* (Definition 1a)
- Visit occurred in months 9-11 of the Measurement Period
- Visit was a Visit at the Clinical Unit of interest (as per Glossary)
- The lowest SBP measurement at the Visit is ≥ 140 mmHg, or the lowest DBP measurement at the Visit is ≥ 90 mmHg

Numerator Statement (Definition 9b): *Repeat visit in 4 weeks*

A Visit is considered to be a *repeat visit in 4 weeks* if it meets all of the following criteria:

- Visit made by a patient who had a *Visit with uncontrolled BP with time for a repeat Visit* (Definition 9a)
- The Visit occurred within 4 weeks of the "Denominator" Visit (*Visit with uncontrolled BP with time for a repeat visit*)
- At least one SBP or DBP measurement was recorded at the Visit

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CHAPTER 2

Examining the Influence of Clinical Care Management Practices at the Time of Incident Hypertension Diagnosis on Timely Blood Pressure Control

2.1 ABSTRACT

Background: Nearly half of adults in the U.S. have high blood pressure (BP). Despite the availability of effective and affordable medications, BP control is often not achieved. Healthcare inequities in the optimization of care processes for historically marginalized patient subgroups may contribute to persisting disparities in HTN control. Several evidence-based hypertension clinical care processes have been identified as crucial for achieving BP control among patients diagnosed with hypertension (HTN). We hypothesized that after adjusting for measured sociodemographic, healthcare utilization, clinical comorbidities, neighborhood factors and clinical-site characteristics, evidence-based care management practices would increase the odds of BP control at 15-months post-diagnosis.

Methods: We use patient-level data from a large, integrated healthcare system in Northern California, to examine the influence of several BP care management practices among patients (n= 40,469) with newly diagnosed hypertension on probability of achieving BP control at 15-months post diagnosis. We used multivariable logistic regression models to estimate the individual effect of care process metrics (primary predictor variables) on BP control at 15-months (Primary outcome) across patient self-identified racial/ethnic subgroups. In addition to estimates based on the entire sample, we also fitted models to estimate effects in race/ethnicity subgroups.

Results: The range across racial/ethnic groups for percentage in control at 15-months was 53.3% (NHB)-58.4% (Hispanic). Of the four care-management practices assessed, having a clinical encounter within 8 weeks of diagnosis was statistically significantly associated with increased odds of BP control across all racial/ethnic groups for both the unadjusted and fully adjusted models. Having a follow-up visit within 8 weeks of diagnosis of HTN was statistically significantly associated with greater odds of BP control at 15-months, with odds ratios of 2.28 [2.12-2.45] (NHW), 2.91 [2.19-3.87] (NHB), 2.45 [2.12-2.83] (NHA) and 2.15 [1.8-2.55] (Hispanic).

Conclusion: These findings underscore the high importance of patient engagement and close clinical follow-up for ensuring timely BP control among those with newly diagnosed HTN.

2.2 INTRODUCTION

Nearly half (47.3%) of adults in the U.S. have high blood pressure (BP), defined as systolic BP >= 130 mmHg and/or diastolic BP >= 80 mmHg[1], and prominent racial disparities persist. The age-adjusted prevalence of hypertension (HTN) among NH Black people, based NHANES 2015 to 2018 data, was 56.6% among males and 55.3% among females, compared to 49.4% and 38.1% among NH white males and females respectively.[1] In response to the worsening national crisis, in October 2020, the Surgeon General issued a Call to Action to Control Hypertension[2] which articulated three goals to improve control rates in the U.S., which are (1) Make hypertension control a national priority, (2) Ensure that the places where people live, learn, work, and play support hypertension control, and (3) Optimize patient care for hypertension. Patient care and clinical care management practices play a crucial role in helping individuals diagnosed with HTN to achieve and maintain BP control.[3] These practices and processes can be defined as strategies and interventions employed by healthcare professionals to manage and maintain healthy BP levels in patients.

The American Medical Association's MAP framework (Measure accurately, Act rapidly and Partner with patients) identifies treatment inertia, defined as the failure to establish appropriate targets and escalate treatment to achieve treatment goals, as a key obstacle to improving BP control. Despite the availability of effective and affordable medications, multiple rounds of adjustment and intensification are typically required to manage BP, and BP control is often not achieved.[4,5] There are several evidence-based hypertension clinical care processes that have been identified as crucial for achieving high clinic-level BP control among patients diagnosed with HTN. These include prescription and management of antihypertensive medications, scheduled timely follow-up appointments, and regular monitoring of BP to allow healthcare providers to assess the effectiveness of treatment plans. However, it is unclear how implementation of these care management practices may influence the likelihood of achieving timely BP control among individuals who are newly diagnosed with HTN in a real-world setting.

Further, healthcare inequities in the optimization of care processes for historically marginalized patient subgroups may contribute to persisting disparities in HTN control. Discrimination and unconscious

bias may influence care management practices for some patient subgroups compared to others. Identifying care management practices that are more influential than others for patient subpopulations may help us to determine the most influential practices that should be emphasized or more vigilantly followed to reduce disparities in BP control.

In this study, we use clinical data from a large, integrated healthcare system in Northern California to examine the comparative influence of several BP care management practices, among patients newly diagnosed with HTN, on the probability of achieving BP control at 15-months post diagnosis, especially for patients who self-identify as a members of historically marginalized or minoritized racial/ethnic groups compared to other racial/ethnic groups. Our hypothesis is that, after adjusting for measured sociodemographic, healthcare utilization, clinical comorbidities, neighborhood factors and clinical-site characteristics, the increased implementation of evidence-based care management practices will increase the probability of BP control at 15-months post-diagnosis. Further, we hypothesize care process metrics will be especially influential for patient racial/ethnic subgroups with persisting disparities in BP control.

2.3 METHODS

Setting

This study was conducted at Sutter Health (SH), a large not-for-profit integrated health system in Northern California. SH provides comprehensive medical services in 22 counties across 130 ambulatory clinics and 24 acute-care hospitals, with approximately 11 million outpatient visits, 850,000 emergency department (ED) visits, and 200,000 hospital discharges, annually. SH provides services in geographies with some of the greatest diversity in the country, in both urban and rural settings. The Epic electronic health record (EHR - Epic Systems Corporation; Verona, Wisconsin) is fully integrated across all sites throughout SH. SH has collected patient self-reported race, ethnicity, ancestry, and language (REAL) data since 2010. As of 2023, SH patients self-identified as 41.4 percent non-Hispanic white (NHW), 17.5 percent Hispanic, 16.5 percent non-Hispanic Asian (NHA), 4.8 percent non-Hispanic Black (NHB), and 20.1 percent non-Hispanic Other (NHO - American Indian/Alaskan Native, mixed race, declined-to-state, and unknown). We use the designation

"Hispanic", instead of "LatinX", for consistency with U.S. census categories[6] and SH self-report data collection. Data were retrospectively extracted from the Sutter EHR for the study period between January 1, 2010 to December 31, 2019. This study was approved by Sutter's Institutional Review Board and was conducted according to Health Insurance Portability and Accountability Act standards.

Cohort Identification

Data were extracted from the SH EHR for adult patients (age 18+ years old as of the first encounter) with at least one SH in-person visit to primary care (i.e. family medicine, internal medicine, OB/GYN) within the observation period (January 1, 2012 to December 31, 2019) and 2 visits to primary care within the two-year period prior (i.e. washout period) to the observation period. We defined the index encounter as the first primary care encounter with an International Classification of Diseases, Ninth and Tenth Revision (i.e. ICD 9 401.0, 401.1 and 401.9; 796.2 or ICD 10 [I10, Essential hypertension] diagnosis code documented in the EHR in the observation period (see Figure 1). For the analytic cohort in the present analysis, we further exclude individuals 1) with evidence of pregnancy at any point during the observation period and 2) whose SBP was < 140 mmHg and DBP < 90 mmHg) at the index visit (i.e., BP controlled). We exclude those who are pregnant during the study period because the pathophysiology of hypertension in the perinatal and postpartum period is distinct.

To study individuals with incident diagnosed and documented HTN, we excluded individuals who had evidence of HTN during the two-year washout period prior to the observation period on two methods of identification of pre-existing hypertension. First, we excluded individuals who had an ICD code for HTN as described above. Second, we excluded those with clinical evidence of HTN but no diagnosis, defined as at least two clinic measured BP values, at least 30 days apart, in the Stage 1 or higher hypertensive range in accordance with the timing of the measurement (see Appendix 1). For measurements occurring in the EHR prior to 2017, we applied the JNC7 criteria (i.e. Systolic 140-159 mmHg or Diastolic 90-99 mmHg). For measurements occurring in or after 2017, we applied the 2017 ACC/AHA criteria for BP in the hypertensive range (i.e. Systolic 130-139 mmHg or Diastolic 80-89 mmHg).

Covariate and Outcome Variable Definitions

Primary Outcome. Our primary outcome of interest was achievement of documented BP control within 15-months of the baseline visit (a binary outcome defined for each individual in the sample). To be conservative, BP control was defined at the encounter level as BP measurement at an ambulatory care visit with systolic BP (SBP) < 140 mmHg and diastolic BP (DBP) < 90 mmHg, in alignment with national quality standard definitions (NQF 0018). If more than one BP measurement was taken, the lowest systolic and lowest diastolic measurements were used for assessment. We chose a 15-month timepoint to assess the outcome, instead of a one-year (12 month) timepoint, to account for real-world influences on annual wellness exam timing given that this is clinical data from a real-world EHR. For example, some insurances providers require a full calendar year between annual physical exams to authorize coverage. If multiple follow-up measures/encounters were available prior to the 15-month timepoint, we used the most recent measure closest to the 15-month timepoint within the window. We excluded any visits occurring after 15-months. Patients who did not have a measurement within the 15-month follow-up window were classified as uncontrolled.

Patient Baseline Characteristics. Baseline characteristics were defined as patient-level sociodemographic and clinical characteristic at the time of the index encounter and were considered as confounders which potentially influence both receipt of a care process metric and blood pressure control. For all patients we extracted demographic information from the EHR, including patients' age at encounter, sex (categorical male, female, other), self-reported race/ethnicity, and primary insurance. Age was classified as ages 18 to 30 and in ten-year age categories thereafter, with 80+ as the oldest category. Race and ethnicity were defined by Hispanic identity as ethnicity, followed by racial group. If a patient did not self-identify as Hispanic, we classified them based on their race. Individuals who identified with multiple race categories were classified as "other racial identity". Documentation of interpreter needed (Yes/No) at the baseline encounter was used as an indicator of non-English speaking. Insurance status was identified by the active

primary payer documented in the EHR at baseline, classified as commercial, Medicaid, Medicare (Part A/B or Part C), other insurance, or self-pay/not reported.

Housing status was assessed using documentation on patient registration and patient address associated with the encounter. As part of standard health system practices and standard work, homelessness status is assessed at every inpatient and emergency department (ED) encounter with standardized systemwide protocols. (Appendix 2) Both self-reported smoking status and alcohol use at baseline were extracted.

We geocoded patients' residential addresses reported as of the baseline encounter to map them to a census tract and thereby obtain a Healthy Places Index (HPI)[7] for each patient. We compared baseline characteristics of the patients with missing HPI to the overall cohort (Appendix 6). Given that the characteristics did not differ meaningfully by missingness, we assumed that these data are missing at random, and imputed HPI score for individuals without a residential address listed at the time of index, using the mean value by race/ethnicity. The Healthy Places Index was developed by the Public Health Alliance of Southern California, a non-profit public health foundation and combines weighted data across 25 different measurements at the census tract level to give a detailed and holistic metric of a community's health. HPI score is from 0-100, with higher scores indicating more community-based resources. HPI 2.0 was used for encounters from 2011-2015, and HPI 3.0 was used for 2015-2019. [8]

We extracted comorbidities using ICD-9/ICD-10 diagnoses as of the baseline encounter, based on most recent data available in the 12 months prior to the baseline encounter (See Appendix 3). These included type 2 diabetes, depression, congestive heart failure, cancer, chronic obstructive pulmonary disease, asthma, liver disease, renal disease, end stage renal disease and migraine. Body mass index was also extracted and categorized (i.e. BMI< 25 kg/m^3; 25 < 27 kg/m^3; 27 < 30 kg/m^3; 30 < 40 kg/m^3; >= 40 kg/m^3).

Care Process Metrics (Primary Exposure). At the index visit, we measured four care process metrics (Table 1). The care process metrics examined in this analysis are based on recommendations in currently available guidance, [9] [10,11] and include measures at the index visit – 1) confirmatory repeated BP measurement, 2) time to first follow-up (post-index) 3) whether the BP measure recorded ended in a zero,

which sometimes indicates inappropriate rounding and 4) evidence of BP medication initiation at the time of the index encounter by addition of medication class (i.e. antihypertensive, beta blockers, calcium channel blockers, diuretics, see Appendix 3). Three of the metrics are binary (yes/no) variables. The time to first follow-up is a categorical variable that includes the following categories: within 4 weeks, between 4-8 weeks, between 9-12 weeks, > 12 weeks. Additional details for all care process metrics in this analysis can be found in Table 1.[9]

Other Clinic Characteristics. We used patient-level data to construct variables to describe annual clinic-specific sociodemographic composition and patient mix. The numerator is the number of patients who received care at a given clinic who meet a given criteria, the denominator is the total number of patients seen at that clinic/department within a given year who met our eligibility criteria for inclusion in the analytic cohort. Clinic/department factors also include size of the clinic (i.e. number of adult patients with HTN), and distribution of sociodemographic characteristics and comorbidities of HTN patients.

Statistical Analysis

Patient sociodemographic and clinical characteristics, healthcare utilization, and care process metrics were summarized using descriptive statistics, overall and stratified by racial/ethnic group. We also summarized the proportion of patients with controlled BP at baseline and 15-month follow-up overall and stratified by racial/ethnic group.

We estimated the associations between care process metrics (primary predictor variables) at the time of diagnosis of HTN with the binary indicator of BP control observed at 15-months (Primary outcome) using logistic regression, with robust standard errors accounting for clustering of responses within clinics. We initially fitted separate models for the overall cohort, including an interaction term for race/ethnicity and each care process metric. These included the primary predictors, without adjustment (Model 1) and with adjustment (Model 2) for patient-level factors influencing BP control (i.e. sociodemographic, clinical and healthcare utilization characteristics), as well as clinical site characteristics. We repeated these analyses for each racial/ethnic group with at least 500 patients in the denominator and if there was statistically

significant evidence of interaction among any race/ethnic group and the care process metrics in the overall model (Model 2). Smaller racial/ethnic groups (with fewer than 500 patients in the denominator) were aggregated with the "non-Hispanic Other" group in fitted models. (Disaggregated data are presented in the descriptive analysis, as described above.) We also include a racial/ethnic category for individuals who identify as more than one race (i.e. non-Hispanic Multi-Race). Data cleaning and statistical analyses were performed using Stata version 16.0 (College Station, Texas).

2.4 RESULTS

Cohort Characteristics

Full details of the cohort formation can be found in Appendix 4. After applying criteria for active patient status, we identified a total of 370,050 primary care patients with evidence of incident HTN during the study period (i.e. by official diagnosis OR by clinical measures), 2012 to 2019 (Figure 1). We then applied additional exclusion criteria as described above to derive the analytic cohort, identifying 40,469 adult patients with incident documented diagnosis of HTN at the time of their first visit (57.1% NHW, 4.1% NHB, 15.8% NHA, 12.5% Hispanic and 10.4% Other race/ethnicity; Figure 1). A majority were female (56.2%) and this was consistent across all racial/ethnic subgroups. The mean age of patients was 54.4 years (SD 14.6) with 64.2% <= 60 years (Table 2). NHW patients were significantly older than patients from other racial/ethnic subgroups (Mean [SD]; 57.2 years [14.5]). Mean age of patients in the other subgroups was 51.1 years [13.4] for NHA and 50 years for NHB [13.2] and Hispanic [14.3] patients. Approximately one-quarter (24.4%) of patients had Medicare FFS/HMO insurance coverage and 3.1% with Medicaid/Medi-Cal overall, with NHB patients having the highest proportion (8%) of Medicaid/Medi-Cal coverage.

The cohort includes individuals with incident diagnosis and a BP of >= 140 mmHg systolic and/or >= 90 mmHg diastolic (i.e. Stage 2) at the index encounter. At baseline, the mean systolic BP was 150.5 mmHg [12.1] and mean diastolic BP was 88.7 mmHg [10.2]. Baseline systolic and diastolic BP was similar across all racial/ethnic groups.

In terms of care process metrics overall, approximately half of newly diagnosed patients returned to the clinic either within 4 weeks (24.1%), between 4-8 weeks (22.8%) or between 9-12 weeks (8.5%) after their index visit. This was generally consistent across racial/ethnic subgroups. The mean number of total visits to primary care between index and 15 months was approximately 4 visits (4.23 [3] for the overall cohort) and was similar across racial/ethnic groups. Approximately 11.7% (n = 4,731) of patients did not have a follow-up visit post index (i.e. lost to follow-up). These patients tended to be younger, commercially insured, and with fewer co-morbidities (Appendix 6). Approximately a quarter of patients had a repeated, confirmatory BP measured at the index visit.

We examined evidence of BP medication initiation at index. Among those whose BP was uncontrolled at a given encounter, 20% had evidence of medication class changes. Slightly fewer NHB and NHA patients had medication initiation compared to other groups.

Logistic Regression Results

Our primary outcome of interest was achievement of documented BP control, defined is a systolic BP < 140 mmHg and diastolic BP of < 90 mmHg, within 15-months of incident diagnosis of HTN (a binary outcome defined for each individual patient in the cohort). In the stratified models, adjusted only for the care process metrics (i.e. primary predictors; Model 1), several care process metrics were influential on an individual patient's BP control at 15-months across racial/ethnic groups. In the overall model, interaction terms were included to assess for possible interactions between racial/ethnicity and each care process metric. There were some statistically significant interaction terms for weeks to follow-up and medication intensification indicating an interaction between race/ethnicity and these care process metrics (Table 3). Given this, as well as for qualitative purposes, we estimated each model for the overall cohort as well as separately by racial/ethnic group, and we present findings for Models 1 and 2 stratified by race/ethnicity (Table 4).

Across racial/ethnic groups, the range for percentage in control at 15-months was 53.3%-58.4% (Figure2). Hispanic patients (58.4%) had the highest percent of the subpopulation achieving BP control at

15-months post incident diagnosis. Approximately 53.5% of NHB had a measured controlled BP within 15-months. The groups with the lowest proportion of the population with BP control was the non-Hispanic Other race/ethnicity group and those indicating non-Hispanic and more than 1 racial identity (53.3% and 53.4% respectively).

In the models adjusting only for primary predictors (Table 4, Model 1), patients who self-identified as NHA or Hispanic were more likely to achieve BP control at 15-months post diagnosis (1.13 [1.07-1.22] and 1.09 [1.02-1.17] respectively) compared to NHW patients. Having a confirmatory BP measured at index was statistically significantly associated with higher odds of BP control overall (1.17 [1.01-1.13]) but was not significant across racial/ethnic groups. Across all racial/ethnic groups, having a follow-up visit within 4 weeks of diagnosis of HTN, compared to greater than 12 weeks, was statistically significantly associated with greater odds of BP control at 15-months, with odds ratios of 2.19 [2.05-2.34] (NHW), 2.71 [2.05-2.34] (NHB), 2.55[2.26-2.87] (NHA) and 2.27 [1.94-2.65] (Hispanic). Patients with a follow-up between 4 and 8 weeks also had better odds of control at 15 months compared to patients whose first follow-up occurred more than 12 weeks after diagnosis, with statistically significant ORs ranging from 2.22 (Hispanic) to 2.88 (NHB). Further, first follow-up within 4-8 weeks was associated with higher odds of control for all racial/ethnic groups compared to return between 9-12 weeks, with the exception of NHB patients (2.88 [2.18-3.81] for 4-8 weeks vs 2.92 [1.92-4.45] for 9-12 weeks for NHB patients). For BP medication initiation, any addition of a medication class compared to no initiation was statistically significantly associated with increased odds of BP control for NHW (1.1 [1.04-1.17]) and NHA patients (1.22 [1.1-1.36]). It was not associated with BP control for NHB and Hispanic patients.

For the fully adjusted subgroup models (Model 2), the association for confirmatory BP was no longer statistically significant for increased odds of BP control. Return visit within 12 weeks post diagnosis remained significantly associated with increased odds of BP control across all racial/ethnic groups. Medication initiation remained statistically significantly associated with higher odds of BP control at 15-months for NHW and NHA patients, and not significant for NHB and Hispanic patients.

2.5 DISCUSSION

We use clinical outcomes data from a large healthcare system in Northern California to examine the comparative influence of several BP care management practices among newly diagnosed patients with HTN on odds of achieving BP control at 15-months post diagnosis. Our hypothesis was that implementation of evidence-based care management practices will increase the odds of a patient achieving timely BP control, especially for patient racial/ethnic subgroups with persisting disparities in BP control. BP control was comparable across the four racial/ethnic patient subgroups at 15-months, ranging from 53.3% of NHB patients (lowest) to 58.4% of Hispanic patients (highest). Of the four care management practices assessed, having a clinical encounter within 12 weeks of incident diagnosis (i.e. within 4 weeks, 4-8 weeks and 9-12 weeks) was the only metric that was statistically significantly associated with higher odds of BP control, across all racial/ethnic groups for both the unadjusted and fully adjusted models. Returning to the clinic within this time frame more than doubles the odds of control at 15 months post diagnosis among all subgroups, and nearly triples the odds for NHB, a group that has historically experienced persisting disparities in HTN control. These findings, along with the influence of additional visits to primary care, underscore the high importance of patient engagement for ensuring timely BP control among those with newly diagnosed HTN.

Our findings, in part, agree with other recent studies examining the influence of clinical management practices on BP control. Visit frequency, specifically returning to the clinic within 4 weeks of an elevated BP measure, has been found to be an important factor in achieving BP control.[12] In analyses of NHANES data from 2015-2018, not having a health care visit in the past year was associated with higher likelihood of having uncontrolled BP (i.e. SBP >= 140 and/or DBP >= 90 mmHg) among individuals with hypertension.[13,14] Another recent analysis aimed at assessing the association of several care processes with racial/ethnic disparities in BP control among those with diagnosed hypertension found that Black patients, compared to patients from all racial/ethnic groups, were less likely to have a visit within 4 weeks of a clinic-measured uncontrolled BP, and that this discrepancy accounted for 14% of the observed disparity in BP control.[15] Our analysis, in agreement with these studies, shows increased likelihood of BP control at 15-months associated with returning to the clinic for a visit, especially within 12 weeks of diagnosis. This is

an especially compelling finding given that control rates at 15-months were suboptimal (i.e. < 70%)[3] across all racial/ethnic subgroups and many patients (45%) did not have a follow-up within 12 weeks post-index. Among patients, 11.7% having had no follow-up at all in the 15-month period. Visit frequency and primary-care access are central to facilitating effective patient care. The Surgeon's General's call to action emphasizes the need to optimize patient care for hypertension as a foundational approach to improving hypertension control[3,16-19], which involves advancing the use of standardized treatment approaches and guideline-recommended care as a crucial strategy towards optimization.[2,13]

Therapeutic inertia, which has been defined as clinicians' failure to initiate or intensify antihypertensive therapy when appropriate and necessary for achieving BP control, has been identified as a persisting challenge.[3,16-19] Some evidence from simulation studies suggests that treatment intensification, may be more influential than system-level processes or patient-level behaviors (i.e. adherence) in controlling hypertension.[15,20] A simulation study using data from the Centers for Disease Control and Prevention's Million Hearts initiative found that, via a validated simulation model, increasing treatment intensification rates to 62% of office visits with an uncontrolled BP resulted in ≥80% BP control.[12] Our findings suggest that medication initiation was statistically significantly associated with greater odds of timely BP control, specifically for NHW patients and NHA patients based on the fully adjusted, stratified models. We found in our cohort that overall, treatment initiation for those with uncontrolled BP at the time of diagnosis occurred for approximately one-quarter of eligible visits across racial/ethnic groups, and for only one-fifth of NHB patients. In our analysis, we found that in the fully adjusted model, medication initiation was not associated with increased odds of BP control for Black patients and further may be associated with lower odds of timely control. Our findings are surprising given evidence of the importance of medication management for NHB individuals and the contribution of treatment inertia to observed disparities within this patient group.[15] One recent study showed that Black patients had lower treatment intensification scores (mean[SD],−0.33[0.26] vs −0.29[0.25], P<.001) compared to their NHW counterparts, which accounted for 21% of the observed disparity in BP control. In our analysis we were not able to assess adherence, which has also been identified as a crucial contributor to blood pressure control

and with prior evidence identifying lower adherence among Black patients even among commercially insured individuals.[21] Prior studies have identified more barriers to adherence for Black patients which include lower levels of shared decision making between patients and providers[22] which can contribute to mismatched expectations of benefit, side effects, and efficacy. In our cohort of newly diagnosed patients with evidence of primary care engagement, a higher proportion of NHB patients had Medicaid compared to all other racial/ethnic groups and HPI scores were lower indicating lower community resources. While we did not find these to be associated with lower likelihood of timely BP control in this analysis, a growing body of evidence identifies societal inequities and the social drivers of health as barriers to adherence, timely follow-up and primary care access.[2]

In this analysis we see comparable control at 15 months across racial/ethnic groups, but also higher rates of first follow-up visits within 12 weeks for NHB in our sample and lower rates of medication initiation. This finding is not consistent with numerous reports of disparate outcomes for NHB individuals, which persist after adjustment for socioeconomic factors.[13,23] Our cohort intentionally includes active patients who had evidence of prior visits to primary care, which may be indicative of having an established medical home and reliable access to primary care services. Mounting evidence suggests that remote monitoring programs which support self-monitored BP in the home environment with transmission of readings to the care team have is a promising approach to improving BP control[23], offering a possible way to mitigate barriers to access when paired with expanding access to validated telemonitoring devices and high-speed internet and cloud services in rural and low-socioeconomic-status.[23,24]

An important observation is that while BP control was similar across racial/ethnic groups, all subgroups had <= 60% of patients achieve control with NHB still the lowest. While our findings did not suggest disparities in treatment initiation, concerns have been raised by others regarding differential treatment where discrimination may increase treatment inertia.[25] Findings from a meta-analysis of 44 studies demonstrated that perceived racial discrimination, including institutional racism, was associated with hypertension status and higher BP for individuals self-identifying as Black.[23,26] Efforts to address and

eliminate racism at multiple levels, are needed because racism is a recognized driver of hypertension disparities.[23,27]

Recognition for clinicians and health systems that excel in hypertension control was another identified strategy that can be used to optimize patient care for HTN. Several national programs have been established in recent years to encourage transparent benchmarking and comparisons across institutions in order to improve outcomes across the healthcare sector. The Million Hearts initiative began in 2012 and is a nation-wide effort led by the Centers for Disease Control and Prevention (CDC) in partnership with the Centers for Medicare and Medicaid Services (CMS), with a focus on improving BP control.[28] Among the 1,709 organizations participating in the AHA / American Medical Association's (AMA's) Target BP recognition program, representing 8.6 million patients with hypertension across 47 states, less than half (48%) achieved BP control rates of at least 70% amongst their patient populations in 2023.[29,30]

2.6 LIMITATIONS

In this analysis, we focused on an established primary care patient population of patients who are newly diagnosed with hypertension and have evidence of engagement with the primary care team. We do not include those that have less engagement, meaning less than 1 visit to primary care in the 2-year pre-period prior to the study observation period. Further, we focused on a patient population that is diagnosed and therefore recognized by the primary care team as having hypertension. Future work may include an intentional examination of barriers to access and diagnosis among those who have less engagement with primary care, given the limited evidence in the peer-reviewed literature addressing this.

The health system in which this study was conducted is an open health system. It is possible that some patients had been diagnosed elsewhere, outside the system, or prior to the study period and thus were identified as having incident hypertension but could have had a pre-existing diagnosis that was not captured. We implemented the washout period excluding those with prior evidence of hypertension (i.e. prior

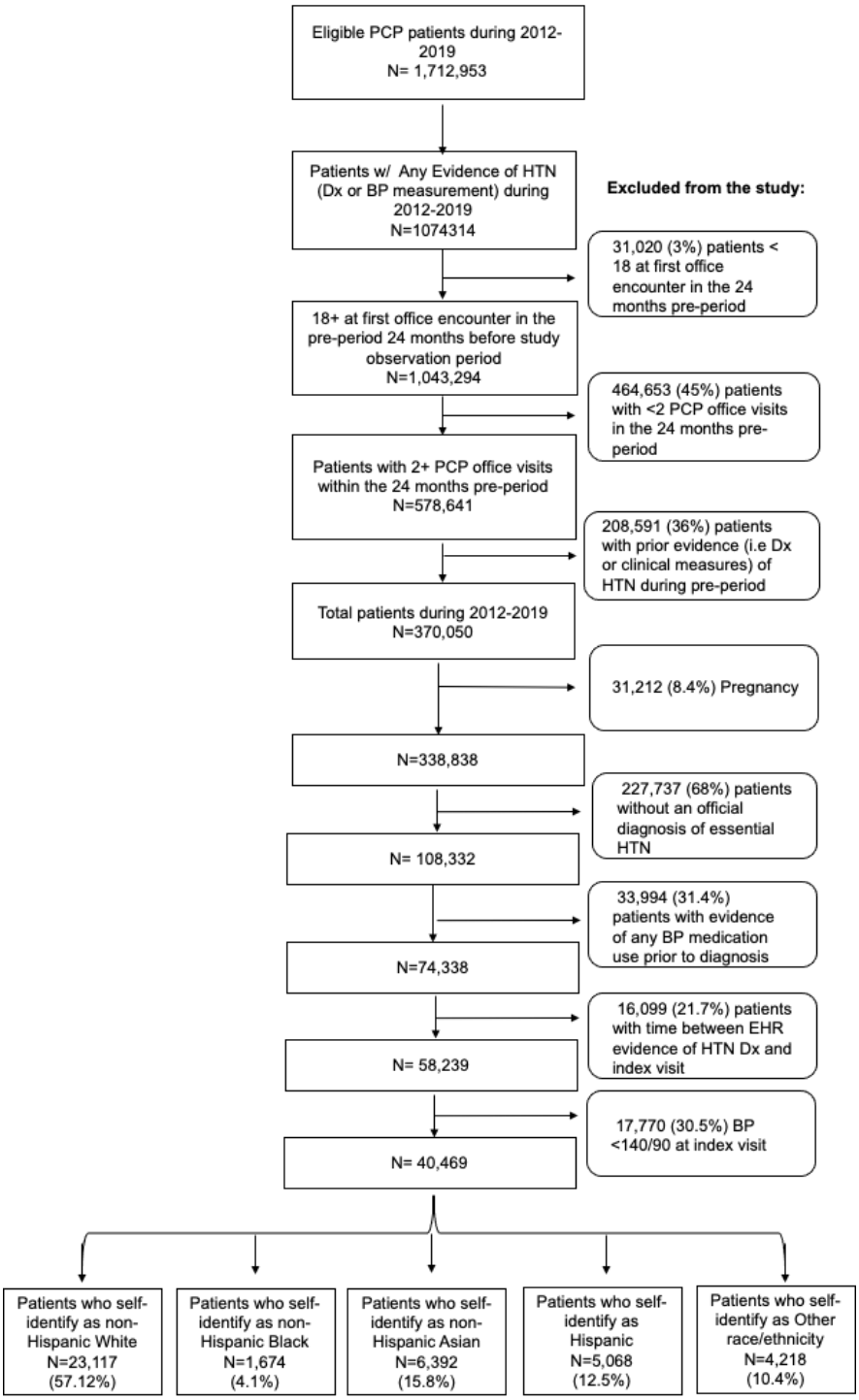
diagnosis, BP medications and measures) and ensured established primary care in the pre-period to attempt to address this.

For our medication initiation metric, we were unable to account for changes in medication dose and only accounted for the addition of classes to active medication orders in the prior 12 months. This may limit our ability to understand nuances in treatment influence and could be an area of opportunity for future work.

2.7 CONCLUSION

For those with incident HTN, returning to see a primary care provider within 12 weeks of the visit in which a patient is diagnosed is a crucial care management practices for achieving timely BP control. Care teams should focus considerable effort on ensuring timely follow-up with newly diagnosed individuals.

2.8 FIGURES AND TABLES



PCP= primary care provider; HTN = hypertension; Dx = diagnosis; BP = blood pressure; EHR= electronic health record

Figure 2.1. Cohort Inclusion/Exclusion Flow Diagram
This figure shows the inclusion and exclusion criteria for those included in the analytic cohort.

Table 2.1. Care Process Metrics and their Definitions

Care Process Metric	**Definition**
1. Confirmatory repeated BP measurement	Binary indicator for at least one additional BP measure entered after an initial uncontrolled BP measure during the index encounter
2. Time to first follow-up	Categorical indicator for time to next visit after the post-index visit, where patients could return within 4 weeks, between 4-8 weeks, 9-12 weeks and > 12 weeks
3. Terminal Digit Zero	Binary indicator if any Systolic BP measure ends in zero during the index encounter
4. Medication Initiation	Binary indicator for addition of any new class of antihypertensive medication at the time of the index encounter based on a 12-month look-back

This table describes each process metric variable and its definition.

Table 2.2. Baseline Characteristics

	Overall	Non-Hispanic White	Non-Hispanic Black	Non-Hispanic Asian	Hispanic
N	40,469	23,117	1,674	6,392	5,068
Race/ethnicity, N(%)					
Non-Hispanic White	23,117 (57.1)	--	--	--	--
Non-Hispanic Black	1,674 (4.1)	--	--	--	--
Non-Hispanic Asian	6,392 (15.8)	--	--	--	--
American Indian/Alaka Native	110 (0.3)	--	--	--	--
Native Hawaiian/Pacific Islander	222 (0.5)	--	--	--	--
Other	3,289 (8.1)	--	--	--	--
Mulit-Race	597 (1.5)	--	--	--	--
Hispanic	5,068 (12.5)	--	--	--	--
Age, Mean (SD)	54.4 (14.6)	57.2 (14.5)	50.1 (13.2)	51.1 (13.4)	50 (14.3)
Age Categories, N(%)					
Less than 30 yrs	1,599(4)	727 (3.2)	96 (5.8)	177 (2.8)	339 (6.7)
31-40 yrs	4776 (11.8)	1972 (8.5)	271 (16.2)	988 (15.5)	890 (17.6)
41-50 yrs	9253 (22.9)	4189(18.1)	449 (26.8)	2158 (33.8)	1399 (27.6)
51-60 yrs	10347(25.6)	6048 (26.2)	480 (28.7)	1532 (24)	1167 (23)
61-70 yrs	8100 (20)	5542 (24)	243 (14.5)	867 (13.6)	767 (15.1)
71-80 yrs	4414 (10.9)	3196 (13.8)	106 (6.3)	436 (6.8)	376 (7.4)
Greater than 81 yrs	1970 (4.9)	1438 (6.2)	29 (1.7)	233 (3.7)	129 (2.6)
Male, N(%)	17,742 (43.8)	10,206 (44.1)	694 (41.5)	2,644 (41.4)	2,219 (43.8)
Interpreter Needed , N(%)	1,141 (2.8)	78 (0.3)	5 (0.3)	312 (4.9)	629 (12.4)
Insurance Type, N(%)					
Commercial PPO/FFS	21,017 (51.9)	10,975 (47.5)	827 (49.4)	4,085 (63.9)	2,742 (54.1)
Commercial HMO	6,583 (16.3)	3,385 (14.6)	327 (19.5)	1,133 (17.7)	1,000 (19.7)
Medicaid/Medi-Cal	1,263 (3.1)	565 (2.4)	133 (7.9)	138 (2.2)	265 (5.2)
Medicare FFS/HMO	9,868 (24.4)	7,036 (30.4)	321 (19.2)	939 (14.7)	829 (16.4)
Self/Undocumented	1,679 (4.1)	1,122 (4.9)	65 (3.9)	91 (1.4)	220 (4.3)
Other	59 (0.1)	34 (0.1)	1 (0.1)	6 (0.1)	12 (0.2)
Smoking History, N(%)					
(1) current	2,986 (7.4)	1,847 (8.0)	216 (12.9)	253 (4.0)	341 (6.7)
(2) past	9,037 (22.3)	5,983 (25.9)	329 (19.7)	860 (13.5)	973 (19.2)
(3) never	22,177 (54.8)	11,422 (49.4)	874 (52.2)	4,532 (70.9)	2,993 (59.1)
(4) unknown/other	6,269 (15.5)	3,865 (16.7)	255 (15.2)	747 (11.7)	761 (15.0)
EtOH History, N(%)					

	Overall	Non-Hispanic White	Non-Hispanic Black	Non-Hispanic Asian	Hispanic
(1) current	19,643 (48.5)	12,444 (53.8)	738 (44.1)	2,267 (35.5)	2,290 (45.2)
(3) no/never	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
(4) unknown/other	11,788 (29.1)	5,249 (22.7)	525 (31.4)	2,974 (46.5)	1,682 (33.2)
Homeless, N(%)	57 (0.1)	40 (0.2)	4 (0.2)	0 (0.0)	10 (0.2)
Healthy Places Index*, Mean (SD)	0.35 (0.5)	0.36 (0.5)	0.15 (0.5)	0.53 (0.48)	0.16 (0.5)
Body Mass Index, Mean (SD)	29.7 (6.6)	29.7 (6.5)	32.3 (7.2)	26.8(4.9)	31.9 (6.7)
BMI Category, N(%)					
BMI 25 < 27 kg/m^3	8,771 (22.8)	4,935 (22.6)	187 (11.9)	2,285 (37.1)	559 (11.5)
BMI < 25 kg/m^3	360 (0.9)	210 (1.0)	8 (0.5)	92 (1.5)	17 (0.4)
BMI 27 < 30 kg/m^3	13,773 (35.8)	7,819 (35.8)	494 (31.3)	2,526 (41.0)	1,558 (32.2)
BMI 30 < 40 kg/m^3	8,867 (23.1)	5,086 (23.3)	431 (27.3)	909 (14.8)	1,437 (29.7)
BMI > 40 kg/m^3	6,666 (17.3)	3,810 (17.4)	458 (29.0)	342 (5.6)	1,275 (26.3)
T2DB, N(%)	5,360 (13.2)	2,383 (10.3)	272 (16.2)	1,083 (16.9)	1,002 (19.8)
Depression, N(%)	5,880 (14.5)	3,997 (17.3)	207 (12.4)	419 (6.6)	718 (14.2)
CHF, N(%)	835 (2.1)	604 (2.6)	40 (2.4)	62 (1.0)	64 (1.3)
CVD, N(%)	3,411 (8.4)	2,440 (10.6)	108 (6.5)	309 (4.8)	305 (6.0)
Cancer, N(%)	3,557 (8.8)	2,581 (11.2)	105 (6.3)	349 (5.5)	288 (5.7)
COPD, N(%)	2,563 (6.3)	1,815 (7.9)	112 (6.7)	196 (3.1)	229 (4.5)
Asthma, N(%)	5,258 (13.0)	3,072 (13.3)	274 (16.4)	659 (10.3)	709 (14.0)
Liver, N(%)	3,284 (8.1)	1,656 (7.2)	93 (5.6)	637 (10.0)	563 (11.1)
Renal, N(%)	1,985 (4.9)	1,367 (5.9)	129 (7.7)	151 (2.4)	192 (3.8)
ESRD, N(%)	99 (0.2)	50 (0.2)	12 (0.7)	8 (0.1)	22 (0.4)
Migraine, N(%)	3,458 (8.5)	2,093 (9.1)	137 (8.2)	408 (6.4)	509 (10.0)
Systolic BP, Mean (SD)	150.5 (12.1)	151.2 (12.2)	149.8 (12)	149 (11.8)	149.6 (12)
Diastolic BP, Mean (SD)	88.7 (10.2)	88.1 (10.4)	90.3 (10.2)	89.7 (9.7)	89.2 (10)
Repeat BP Measured, N(%)	9,726 (24.0)	5,442 (23.5)	469 (28.0)	1,580 (24.7)	1,111 (21.9)
SBP Last Digit Rounded to Zero, N(%)	11,059(27.3)	6,543 (28.3)	422 (25.2)	1,679 (26.3)	1,435 (28.3)
Time to First Follow-up, N(%)					
Less than 1-month post-index	9,734 (24.1)	5,467(23.7)	443 (26.5)	1,455 (22.8)	1,345 (26.5)
Between 1-2 months post-index	9,208 (22.8)	5,408 (23.4)	371 (22.2)	1,341 (20.1)	1,203 (23.7)
Between 2-3 months post-index	3,439 (8.5)	2,008 (8.7)	151 (9)	524 (8.2)	441 (8.7)
Greater than 3 months post-index	18,088 (44.7)	10,234 (44.3)	709 (42.4)	3,072 (48.1)	2,079 (41)
Medication Initiation, N(%)	9,929 (24.5)	5,643 (24.4)	362 (21.6)	1,465 (22.9)	1,389 (27.4)

***** Healthy Places Index (HPI) Score is based on those with an address in the EHR

CHF = Congestive heart failure; COPD = Chronic obstructive pulmonary disease; CAD = coronary artery disease; T2DM = type 2 diabetes

Table 2.3. Interactions for Patient-Level Care Process Metrics and Race/ethnic Subgroup

	P- Values for Interaction Terms				
Care Process Metric	**NHB**	**NHA**	**Hispanic**	**Multi-Race**	**Other**
1. Confirmatory repeated BP measurement	0.228	0.322	0.775	0.995	0.548
2. Terminal Digit Zero	0.190	0.321	0.317	0.767	0.402
3. Time to first follow-up					
9-12 weeks post index	0.099	0.547	0.691	0.553	0.462
4-8 weeks post index	0.140	0.443	0.458	0.36	0.079
< 4 weeks post index	0.998	0.029	0.213	0.597	0.976
4. Medication Intensification	0.008	0.259	0.214	0.893	0.271

Reference Group = Non-Hispanic White (NHW); NHB = Non-Hispanic Black; NHA = Non-Hispanic Asian

This table shows the p-values for each of the interaction terms for race/ethnicity and care process metrics included in Model 2.

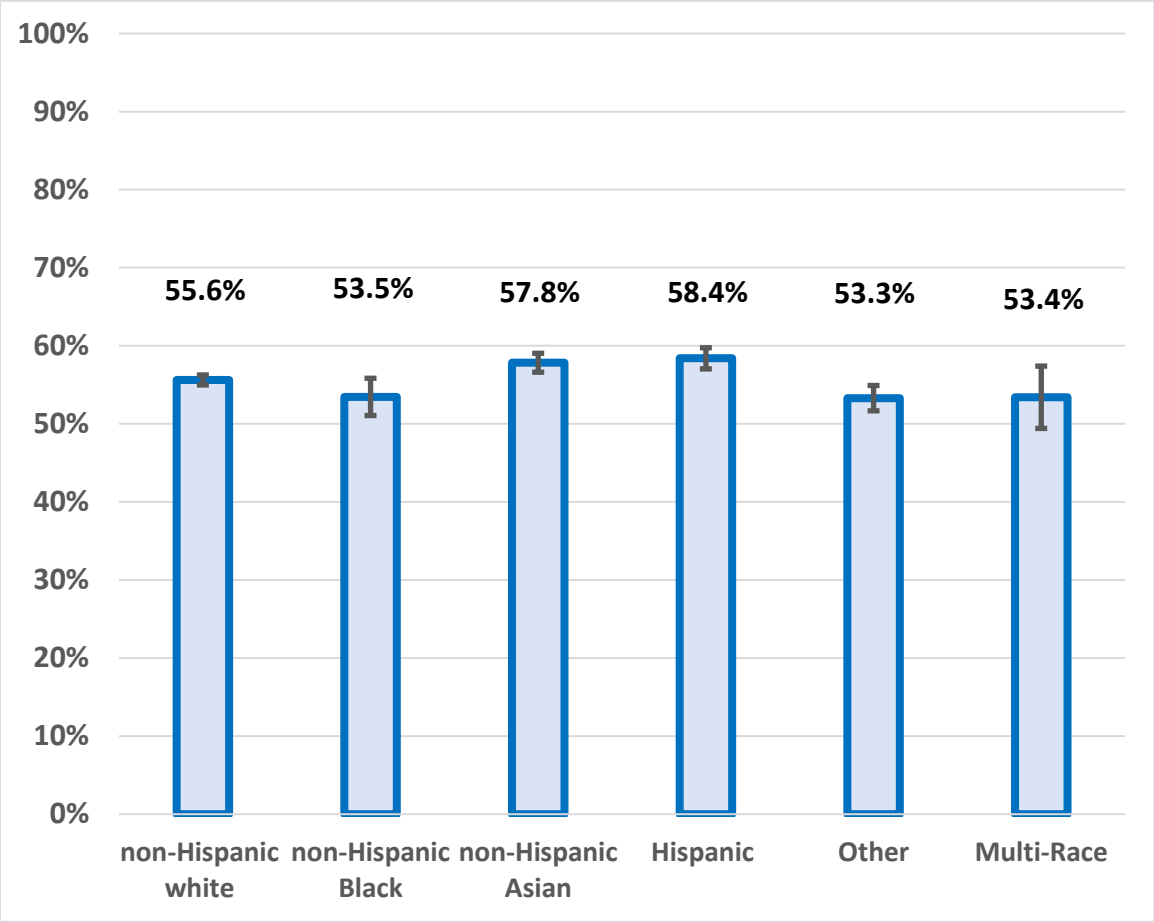


Figure 2.2. Percent of Patients with SBP < 140 mmHg and DBP < 90 mmHg at 15-months post diagnosis
This figure shows the percent of patients who have achieved blood pressure control at 15-months post incident diagnosis.

Table 2.4. Logistic Regression Results*

MODEL 1

	Total Cohort			Non-Hispanic White			Non-Hispanic Black			Non-Hispanic Asian			Hispanic		
	OR	**95%CI**		**OR**	**95%CI**		**OR**	**95%CI**		**OR**	**95%CI**		**OR**	**95%CI**	
CARE PROCESS METRICS															
Confirmatory BP	1.07	1.01	1.13	1.07	0.99	1.15	1.18	0.95	1.46	0.99	0.88	1.10	1.07	0.89	1.29
Terminal Digit Zero	0.94	0.90	0.99	0.95	0.89	1.01	1.10	0.89	1.38	0.99	0.89	1.11	0.87	0.76	1.00
Weeks to post-index follow-up Visit (Ref: > 12 weeks*)															
9 - 12 weeks	2.12	1.96	2.30	2.13	1.94	2.34	2.92	1.92	4.45	1.99	1.61	2.48	1.98	1.61	2.44
4-8 weeks	2.38	2.22	2.55	2.34	2.18	2.51	2.88	2.18	3.81	2.44	2.13	2.79	2.22	1.88	2.62
< 4 weeks	2.27	2.14	2.40	2.19	2.05	2.34	2.21	1.71	2.88	2.55	2.26	2.87	2.27	1.94	2.65
Medication Initiation	1.10	1.06	1.15	1.10	1.04	1.17	0.85	0.69	1.06	1.22	1.10	1.36	1.01	0.92	1.12

OR = odds ratio; CI= Confidence Interval; BP = blood pressure

This table shows the logistic regression results from Model 1 with odds ratios and 95% confidence intervals for each care process metric by racial/ethnic patient subgroup

MODEL 2

	Total Cohort			Non-Hispanic White			Non-Hispanic Black			Non-Hispanic Asian			Hispanic		
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Non-Hispanic Black	0.92	0.82	1.03	-	-	-	-	-	-	-	-	-	-	-	-
Non-Hispanic Asian	1.15	1.08	1.23	-	-	-	-	-	-	-	-	-	-	-	-
Other	0.96	0.89	1.03	-	-	-	-	-	-	-	-	-	-	-	-
Multi-Race	0.96	0.80	1.15	-	-	-	-	-	-	-	-	-	-	-	-
Hispanic	1.08	1.00	1.16	-	-	-	-	-	-	-	-	-	-	-	-
CARE PROCESS METRICS															
Confirmatory BP	1.03	0.97	1.10	1.04	0.96	1.11	1.08	0.86	1.36	0.95	0.85	1.07	1.08	0.88	1.31
Terminal Digit Zero	0.95	0.91	1.00	0.95	0.89	1.02	1.15	0.89	1.48	1.03	0.91	1.15	0.87	0.76	1.01
Weeks to post-index follow-up Visit (Ref: > 12 weeks)															
9 - 12 weeks	2.08	1.92	2.26	2.07	1.88	2.29	3.21	2.00	5.15	1.95	1.57	2.42	1.98	1.60	2.46
4-8 weeks	2.33	2.17	2.51	2.28	2.12	2.45	2.91	2.19	3.87	2.45	2.12	2.83	2.15	1.80	2.55
< 4 weeks	2.24	2.11	2.38	2.18	2.03	2.34	2.15	1.61	2.88	2.54	2.27	2.85	2.18	1.85	2.57
Medication Initiation	1.10	1.05	1.15	1.10	1.03	1.18	0.80	0.64	1.00	1.20	1.06	1.35	1.01	0.90	1.13
CLINIC LEVEL FACTORS															
Racial/ethnic Distribution															
% NHB Patients	1.01	0.96	1.06	1.00	0.94	1.07	1.02	0.93	1.12	1.04	0.92	1.17	1.03	0.91	1.15
% NHA Patients	0.98	0.95	1.01	0.98	0.94	1.02	1.05	0.91	1.20	0.98	0.92	1.05	0.98	0.90	1.06
%AIAN Patients	1.14	0.87	1.48	0.92	0.60	1.42	7.25	1.43	36.71	0.86	0.29	2.59	0.95	0.43	2.08
% PINH Patients	1.32	1.01	1.72	1.56	1.03	2.36	1.97	0.85	4.60	1.70	0.92	3.14	1.01	0.58	1.75
% Other	1.02	0.96	1.08	0.99	0.91	1.08	0.95	0.72	1.25	1.17	1.05	1.31	1.04	0.90	1.20
% Multi-Race	0.95	0.85	1.06	0.90	0.77	1.06	1.17	0.75	1.84	1.18	0.84	1.67	0.91	0.68	1.23

	Total Cohort			Non-Hispanic White			Non-Hispanic Black			Non-Hispanic Asian			Hispanic		
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
% Hispanic	1.05	1.01	1.09	1.07	1.02	1.13	0.98	0.85	1.12	1.10	0.98	1.24	1.02	0.95	1.09
Sex Distribution															
% Female	1.00	0.98	1.02	0.99	0.97	1.02	1.10	1.00	1.22	0.98	0.93	1.04	0.98	0.92	1.03
Clinical site Age Distribution															
% Age <20y	1.00	0.92	1.08	0.98	0.88	1.09	1.06	0.78	1.43	0.87	0.71	1.07	1.11	0.89	1.39
% Age 21-40 y	0.97	0.92	1.02	0.98	0.93	1.04	0.94	0.78	1.14	0.93	0.83	1.05	0.98	0.86	1.11
% Age 41-60 y	1.00	0.95	1.05	1.02	0.95	1.09	0.82	0.68	0.99	0.99	0.90	1.10	1.07	0.95	1.21
% Age 61-80 y	0.96	0.92	1.01	0.97	0.92	1.03	0.82	0.68	1.00	0.99	0.86	1.13	1.01	0.88	1.17
% Age ≥80 y	1.04	0.98	1.09	1.03	0.96	1.10	0.94	0.75	1.17	1.06	0.91	1.25	1.13	0.99	1.29
Patient Co-morbidities Distribution															
%T2DM	0.94	0.89	0.99	0.95	0.89	1.01	0.97	0.82	1.14	0.85	0.75	0.97	0.98	0.87	1.10
% Depression	0.99	0.95	1.03	1.00	0.95	1.05	1.00	0.84	1.20	0.96	0.84	1.09	0.97	0.86	1.09
%CHF	0.87	0.77	0.98	0.91	0.80	1.04	0.58	0.35	0.96	0.52	0.37	0.74	0.91	0.68	1.21
%CVD	0.94	0.88	1.00	0.97	0.90	1.05	0.87	0.70	1.09	1.06	0.90	1.26	0.86	0.75	0.99
%Cancer	0.95	0.90	1.01	0.96	0.90	1.04	1.02	0.81	1.27	0.90	0.77	1.06	0.98	0.84	1.15
%COPD	1.02	0.96	1.09	1.01	0.94	1.09	1.03	0.82	1.30	1.20	1.01	1.44	1.03	0.87	1.22
%Asthma	1.02	0.96	1.07	1.01	0.95	1.08	0.99	0.81	1.21	0.92	0.79	1.08	1.06	0.94	1.18
%Liver Disease	1.04	0.98	1.10	1.03	0.96	1.11	0.86	0.66	1.12	1.09	0.94	1.27	1.03	0.90	1.17
%Renal Disease	1.04	0.97	1.12	1.01	0.93	1.10	1.15	0.85	1.57	1.25	1.01	1.54	1.12	0.92	1.35
%ESRD	1.17	0.86	1.60	1.18	0.76	1.82	1.19	0.53	2.68	1.48	0.49	4.45	0.95	0.49	1.83
%Migraine	0.95	0.90	1.00	0.92	0.86	0.99	1.18	0.93	1.49	0.89	0.77	1.02	0.96	0.83	1.11
PATIENT LEVEL FACTORS															
Sex (ref: female)															
Male	0.89	0.84	0.94	0.91	0.85	0.97	0.84	0.68	1.03	0.88	0.77	1.00	0.88	0.78	0.99

	Total Cohort			Non-Hispanic White			Non-Hispanic Black			Non-Hispanic Asian			Hispanic		
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Age Category (ref: <30 years old)															
31-40 yrs	0.94	0.83	1.07	0.94	0.79	1.12	0.81	0.48	1.35	0.91	0.61	1.37	1.03	0.79	1.34
41-50 yrs	0.99	0.87	1.13	1.03	0.87	1.22	0.81	0.46	1.44	0.87	0.62	1.24	1.19	0.92	1.53
51-60 yrs	1.04	0.93	1.17	1.02	0.87	1.20	0.74	0.48	1.15	1.10	0.75	1.61	1.22	0.95	1.55
61-70 yrs	0.99	0.87	1.13	0.99	0.85	1.16	0.89	0.50	1.60	0.95	0.64	1.41	1.28	0.94	1.73
71-80 yrs	0.96	0.81	1.14	1.00	0.82	1.22	1.39	0.66	2.96	0.89	0.51	1.56	0.85	0.54	1.34
Greater than 80 yrs	0.82	0.70	0.97	0.83	0.67	1.03	0.57	0.22	1.48	0.88	0.55	1.41	0.95	0.54	1.65
Insurance Type (ref: Commercial)															
Commercial HMO	1.06	0.99	1.14	1.05	0.97	1.14	1.11	0.83	1.49	1.11	0.97	1.26	1.01	0.85	1.21
Medicaid/Medi-Cal	0.91	0.80	1.02	0.87	0.72	1.05	0.82	0.50	1.33	1.05	0.75	1.47	0.97	0.75	1.27
Medicare FFS/HMO	0.98	0.91	1.06	0.99	0.91	1.08	0.76	0.53	1.11	0.99	0.77	1.28	1.11	0.89	1.39
Self/Undocumented	0.93	0.83	1.04	0.93	0.81	1.07	0.65	0.36	1.17	1.49	1.03	2.17	0.90	0.68	1.19
Other	1.08	0.61	1.91	1.06	0.54	2.06				1.46	0.20	10.67	1.21	0.32	4.52
Smoking History (ref: Currently Smoking)															
Past	1.26	1.14	1.39	1.23	1.10	1.38	1.29	0.89	1.85	1.35	0.95	1.92	1.37	1.06	1.76
Never	1.24	1.13	1.35	1.20	1.09	1.34	1.31	0.92	1.88	1.29	0.95	1.77	1.34	1.06	1.70
Unknown/Other	1.27	1.12	1.43	1.26	1.08	1.47	1.39	0.86	2.25	1.28	0.87	1.88	1.35	0.93	1.94
Alcohol Use History (Ref: Current)															
No/Never	0.97	0.93	1.03	0.97	0.91	1.05	0.86	0.67	1.12	1.01	0.90	1.13	0.97	0.86	1.10
Unknown/Other	0.85	0.78	0.92	0.81	0.74	0.89	0.70	0.47	1.04	0.90	0.71	1.15	0.86	0.70	1.05
Interpreter Needed	1.01	0.87	1.18	1.24	0.76	2.02	4.15	0.25	68.16	1.00	0.73	1.35	0.93	0.78	1.11
ED Utilization in past 12 months	1.04	0.97	1.11	1.05	0.97	1.13	0.90	0.70	1.16	1.70	1.22	2.39	0.93	0.77	1.12

	Total Cohort			Non-Hispanic White			Non-Hispanic Black			Non-Hispanic Asian			Hispanic		
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Inpatient Utilization in past 12 months	1.21	0.99	1.47	1.41	1.01	1.98	0.88	0.45	1.72	1.62	0.80	3.29	0.95	0.61	1.47
HPI Index	1.07	1.02	1.12	1.08	1.01	1.16	1.02	0.82	1.25	1.05	0.92	1.19	1.09	0.95	1.25
BMI Category (Ref: < 25 kg/m^3)															
< 25 kg/m^3	0.79	0.62	1.00	0.67	0.50	0.90	2.86	0.51	16.15	0.92	0.56	1.51	0.92	0.34	2.47
27 < 30 kg/m^3	1.02	0.97	1.07	1.06	0.99	1.14	0.96	0.66	1.40	1.00	0.88	1.14	0.99	0.82	1.18
30 < 40 kg/m^3	0.98	0.92	1.05	1.04	0.95	1.14	0.72	0.48	1.09	0.96	0.80	1.16	1.07	0.88	1.30
> 40 kg/m^3	0.91	0.84	0.98	0.94	0.85	1.02	0.83	0.58	1.18	0.91	0.72	1.15	0.89	0.72	1.10
Clinical Conditions															
T2DM	1.14	1.07	1.21	1.09	0.99	1.20	1.14	0.81	1.61	1.18	1.01	1.37	1.15	1.00	1.32
Depression	1.17	1.11	1.25	1.15	1.07	1.24	1.52	1.15	2.01	1.15	0.94	1.40	1.29	1.07	1.56
CHF	0.85	0.73	0.99	0.89	0.75	1.07	1.08	0.57	2.05	0.74	0.47	1.18	0.63	0.37	1.09
CVD	1.08	0.98	1.18	1.07	0.96	1.20	0.72	0.47	1.09	0.82	0.62	1.09	1.27	0.99	1.63
Cancer	1.13	1.03	1.24	1.12	1.01	1.24	1.39	0.94	2.05	1.04	0.81	1.33	0.86	0.67	1.10
COPD	1.12	1.02	1.23	1.12	1.00	1.26	1.29	0.84	1.96	1.04	0.78	1.38	1.06	0.79	1.42
Asthma	1.09	1.03	1.16	1.07	0.98	1.16	0.94	0.71	1.25	1.18	1.00	1.40	1.03	0.87	1.23
Liver Disease	1.06	0.99	1.14	1.04	0.93	1.16	1.00	0.65	1.54	1.09	0.94	1.26	1.13	0.93	1.37
Renal Disease	1.11	1.00	1.23	1.08	0.95	1.22	0.83	0.56	1.21	1.24	0.87	1.76	1.20	0.82	1.75
ESRD	0.71	0.45	1.10	0.69	0.39	1.24	0.61	0.12	3.18	0.48	0.09	2.56	0.76	0.24	2.43
Migraine	1.14	1.05	1.23	1.14	1.03	1.26	0.79	0.53	1.16	1.24	0.99	1.54	1.06	0.84	1.32

OR = odds ratio; CI = Confidence Interval; BP = blood pressure; HMO = Health Maintenance Organization; FFS = fee for service; HPI= Health Places Index; BMI = Body Mass Index; T2DM = type 2 diabetes; CHF = Congestive heart failure; CVD = cardiovascular disease; COPD = chronic obstructive pulmonary disease; ESRD = end stage renal disease

This table shows the logistic regression results from Model 2 with odds ratios and 95% confidence intervals for each covariate by racial/ethnic patient subgroup

2.9 APPENDICES

Appendix 1

JNC7 vs 2017 ACC/AHA Hypertension Definitions

Systolic and Diastolic BP (mm Hg)	JNC7	2017 ACC/AHA
<120 and<80	Normal BP	Normal BP
120-129 and<80	Prehypertension	Elevated BP
130-139 or 80-89	Prehypertension	Stage 1 hypertension
140-159 or 90-99	Stage 1 hypertension	Stage 2 hypertension
≥160 or ≥100	Stage 2 hypertension	Stage 2 hypertension

Appendix 2

Self-identified homelessness status was determined by the presence of any of the following criteria:

1) patients' address is documented as "homeless"

2) zip code indicates homelessness

3) patient encounter has a check box indicating if homeless

4) evidence of a Homeless Discharge Flowsheet (i.e. written plan for homeless patient mandated by Senate Bill 1152)

5) discharge diagnosis documented as "Problems related to housing and economic circumstances" (i.e. ICD-10 Z59*) or

6) patient type=Homeless in-patient demographic table.

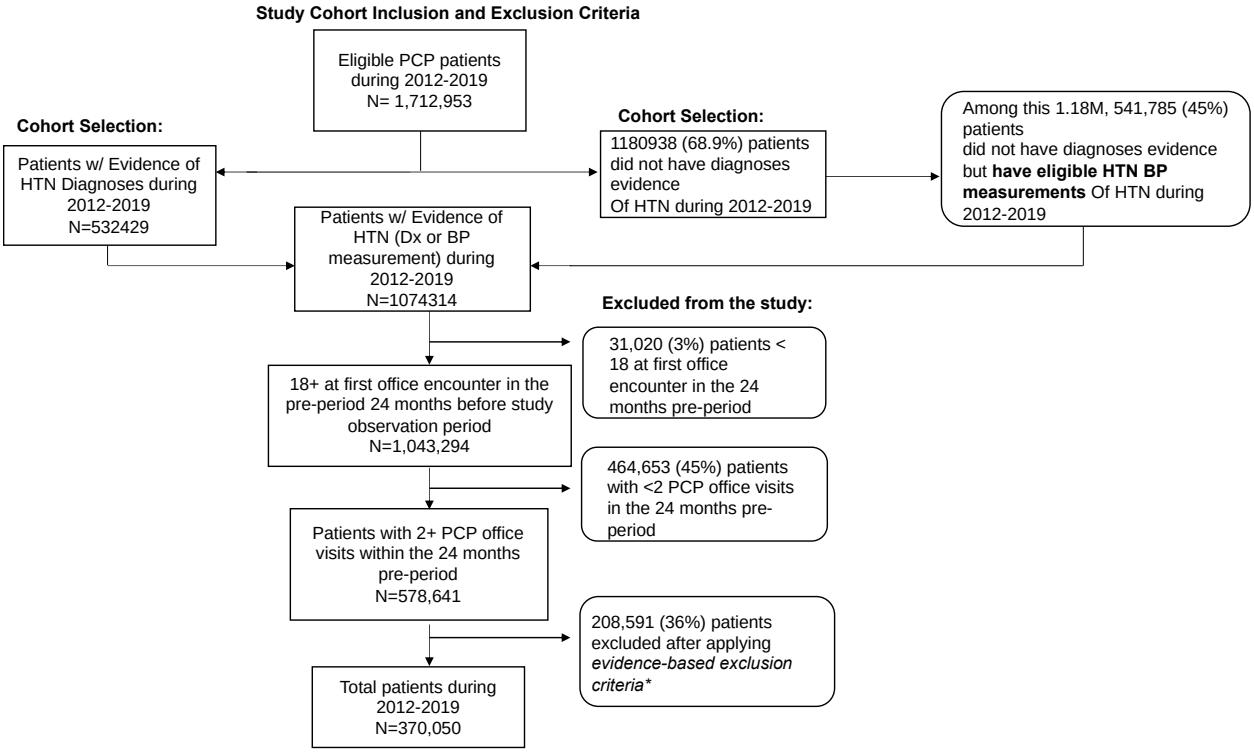
Appendix 3

Condition	ICD-9CM	ICD-10	Description
Serious Mental Illness	See additional Table	See Additional Table	See Additional Table
Myocardial infarction	410-410.9 412	I21.x, I22.x, I25.2	Acute MI Prior MI
Congestive heart failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 425.4–425.9, 428.x	I09.9, I11.0, I13.0, I13.2, I25.5, I42.0, I42.5–I42.9, I43.x, I50.x, P29.0	Heart Failure
Peripheral vascular disease	093.0, 437.3, 440.x, 441.x, 443.1–443.9, 47.1, 557.1, 557.9, V43.4	I70.x, I71.x, I73.1, I73.8, I73.9, I77.1, I79.0, I79.2, K55.1, K55.8, K55.9, Z95.8, Z95.9	Peripheral vasc disease, including claudication Aortic aneurysm Gangrene Blood vessel replace by prosthesis Resection and replace of lower limb arteries
Cerebrovascular disease	362.34, 430.x–438.x	G45.x, G46.x, H34.0, I60.x–I69.x	Cerebrovascular disease
Dementia	290.x, 294.1, 331.2	F00.x–F03.x, F05.1, G30.x, G31.1	Senile and presenile dementias
Chronic pulmonary disease	416.8, 416.9, 490.x–505.x, 506.4, 508.1, 508.8	I27.8, I27.9, J40.x– J47.x, J60.x–J67.x, J68.4, J70.1, J70.3	Chronic obstructive pulmonary disease Pneumoconioses Chronic resp disease due to fumes/vapors
Rheumatologic disease	446.5, 710.0–710.4, 714.0– 714.2, 714.8, 725.x	M05.x, M06.x, M31.5, M32.x– M34.x, M35.1, M35.3, M36.0	Systemic lupus erythematosus Systemic sclerosis Polymyositis Adult rheumatoid arthritis
Peptic Ulcer disease	531.x–534.x	K25.x–K28.x	Gastric, duodenal and gastrojejunal ulcers
Mild liver disease	070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 070.6, 070.9, 570.x, 571.x, 573.3, 573.4, 573.8, 573.9, V42.7	B18.x, K70.0– K70.3, K70.9, K71.3–K71.5, K71.7, K73.x, K74.x, K76.0, K76.2– K76.4, K76.8, K76.9, Z94.4	Alcoholic cirrhosis Cirrhosis without mention of alcohol Biliary cirrhosis Chronic hepatitis
Moderate/severe liver disease	456.0–456.2, 572.2– 572.8	I85.0, I85.9, I86.4, I98.2, K70.4, K71.1, K72.1, K72.9, K76.5, K76.6, K76.7	Hepatic coma, portal hypertension, other sequelae of chronic liver disease Esophageal varices
Diabetes without chronic complications	250.0–250.3, 250.8, 250.9	E10.0, E10.1, E10.6, E10.8, E10.9, E11.0, E11.1, E11.6, E11.8, E11.9, E12.0, E12.1, E12.6, E12.8, E12.9, E13.0, E13.1, E13.6, E13.8, E13.9, E14.0, E14.1, E14.6, E14.8, E14.9	Diabetes with or without acute metabolic dist. Diabetes with peripheral circulatory disorders

Condition	ICD-9CM	ICD-10	Description
Diabetes with chronic complications	250.4–250.7	E10.2–E10.5, E10.7, E11.2–E11.5, E11.7, E12.2–E12.5, E12.7, E13.2–E13.5, E13.7, E14.2–E14.5, E14.7	Diabetes with renal, ophthalmic, or neurological manifestations
Hemiplegia or paraplegia	334.1, 342.x, 343.x, 344.0–344.6, 344.9	G04.1, G11.4, G80.1, G80.2, G81.x, G82.x, G83.0–G83.4, G83.9	Paraplegia Hemiplegia
Renal disease	403.01, 403.11, 403.91, 404.02, 404.03, 404.12, 404.13, 404.92, 404.93, 582.x, 583.0–583.7, 585.x, 586.x, 588.0, V42.0, V45.1, V56.x	I12.0, I13.1, N03.2–N03.7, N05.2–N05.7, N18.x, N19.x, N25.0, Z49.0–Z49.2, Z94.0, Z99.2	Chronic glomerulonephritis Nephritis and nephropathy Chronic renal failure Renal failure, unspecified Disorders resulting from impaired renal func.
Any malignancy, including lymphoma and leukemia, except malignant neoplasm of skin	140.x–172.x, 174.x–195.8, 200.x–208.x, 238.6	C00.x–C26.x, C30.x–C34.x, C37.x–C41.x, C43.x, C45.x–C58.x, C60.x–C76.x, C81.x–C85.x, C88.x, C90.x–C97.x	Malignant neoplasms Leukemia and lymphoma
Metastatic solid tumor	196.x–199.x	C77.x–C80.x	Secondary malignant neoplasm of lymph nodes and other organs
AIDS/HIV	042.x–044.x	B20.x–B22.x, B24.x	HIV infection with related specific conditions

Appendix 4

Cohort Formation Flow Chart



We firstly identify eligible patients who had HTN Diagnosis ICD during 2012-2019, identify their first Dx date, we then exclude patients who had HTN Diagnosis (ICD code; encounter Dx, or Problem list) during 2010-2011 (i.e. pre-period) from the above cohort. These patients have an incident diagnosis of HTN in the EHR.

For patients who did not have HTN ICD codes as described above, we apply criteria of capturing eligible BP measurements, identify their date of first evidence of hypertension based on clinical measurements (but no ICD code). We then exclude patients who had evidence of HTN via clinical measurements during 2010-2011 (i.e. pre-period) from the above cohort of step 3. These patients have incident HTN based on clinical measurements, but no formal diagnosis.

Appendix 5

Clinical site characteristics based on patients with hypertension at a given clinic

	All Clinical Sites (n = 281)	
	Mean	**SD**
Eligible population size	34.5	48.3
Clinical Site Sex Distribution		
Male (%)	34.8	25.6
Female (%)	65.2	25.6
Clinical site Race/Ethnicity distribution		
Non-Hispanic White (%)	59.5	27.3
Non-Hispanic Black (%)	4.9	11.3
Non-Hispanic Asian (%)	12.9	19.2
American Indian/Alaska Native (%)	0.3	1.3
Pacific Islander/ Hawaiian Native (%)	0.4	2.0
Hispanic (%)	13.9	16.9
Multi Race (%)	2.0	6.0
Other/Unknown Race (%)	6.0	9.7
Clinical site Age distribution		
Age < 20 y (%)	4.3	11.7
Age 21 -40y (%)	11.5	13.8
Age 41-60 y (%)	21.5	20.6
Age 61 -80 y (%)	23.1	18.6
Age >= 81 y (%)	20.4	16.6
Clinical Site Composition of Patient Co-morbidities		
% with T2DM	10.3	11.7
% with Depression	15.7	15.0
% with CHF	1.8	7.0
% with CVD	8.0	10.5
% with Cancer	9.1	12.3
% with COPD	5.9	10.8
% with Asthma	14.5	15.5
% with Liver Disease	7.6	10.2
% with Renal Disease	4.7	8.0
% with ESRD	0.3	2.2
% with Migraine	9.9	14.4

*At most recent measurement year

T2DM = type 2 diabetes; CHF = Congestive heart failure; CVD= cardiovascular disease; COPD = Chronic obstructive pulmonary disease; ESRD = end stage renal disease

Appendix 6

Baseline Characteristics of patients without healthy places index (HPI) score and those Lost to follow-up (LTFU; no follow-up visit beyond Index) compared to the overall cohort

	Overall	No HPI	LTFU
N	40,469	3,541	4,731
Race/ethnicity, N(%)			
Non-Hispanic White	23,117 (57.1)	1,969 (55.6)	2,601 (55.0)
Non-Hispanic Black	1,674 (4.1)	141 (4.0)	209 (4.4)
Non-Hispanic Asian	6,392 (15.8)	590 (16.7)	788 (16.7)
American Indian/Alaska Native	110 (0.3)	10 (0.3)	12 (0.3)
Native Hawaiian/Pacific Islander	222 (0.5)	12 (0.3)	28 (0.6)
Other	3,289 (8.1)	338 (9.5)	503 (10.6)
Multi-Race	597 (1.5)	59 (1.7)	71 (1.5)
Hispanic	5,068 (12.5)	422 (11.9)	519 (11.0)
Age, Mean (SD)	54.4 (14.6)		
Age Categories, N(%)			
Less than 30 yrs	1,599(4)	308 (8.7)	728 (15.4)
31-40 yrs	4776 (11.8)	808 (22.8)	1,192 (25.2)
41-50 yrs	9253 (22.9)	966 (27.3)	1,240 (26.2)
51-60 yrs	10347(25.6)	748 (21.1)	803 (17.0)
61-70 yrs	8100 (20)	418 (11.8)	329 (7.0)
71-80 yrs	4414 (10.9)	165 (4.7)	130 (2.7)
Greater than 81 yrs	1970 (4.9)	0 (0.0)	0 (0.0)
Male, N(%)	17,742 (43.8)	1,536 (43.4)	2,594 (54.8)
Interpreter Needed, N(%)	1,141 (2.8)	90 (2.6)	109 (2.3)
Insurance Type, N(%)			
Commercial PPO/FFS	21,017 (51.9)	1,769 (50.0)	2,814 (59.5)
Commercial HMO	6,583 (16.3)	630 (17.8)	761 (16.1)
Medicaid/Medi-Cal	1,263 (3.1)	102 (2.9)	142 (3.0)
Medicare FFS/HMO	9,868 (24.4)	907 (25.6)	709 (15.0)
Self/Undocumented	1,679 (4.1)	132 (3.7)	298 (6.3)
Other	59 (0.1)	1 (0.0)	7 (0.1)
Smoking History, N(%)			
(1) current	2,986 (7.4)	261 (7.4)	395 (8.3)
(2) past	9,037 (22.3)	766 (21.6)	946 (20.0)
(3) never	22,177 (54.8)	1,976 (55.8)	2,693 (56.9)
(4) unknown/other	6,269 (15.5)	538 (15.2)	697 (14.7)
	Overall	**No HPI**	**LTFU**

Alcohol Use History, N(%)			
(1) current	19,643 (48.5)	1,788 (50.5)	2,450 (51.8)
(3) no/never	0 (0.0)	0 (0.0)	0 (0.0)
(4) unknown/other	11,788 (29.1)	1,029 (29.1)	1,236 (26.1)
Homeless, N(%)	57 (0.1)	7 (0.2)	5 (0.1)
BMI Category, N(%)			
25 < 27 kg/m^3	8,771 (22.8)	813 (24.1)	973 (21.7)
< 25 kg/m^3	360 (0.9)	27 (0.8)	33 (0.7)
27 < 30 kg/m^3	13,773 (35.8)	1,223 (36.3)	1,649 (36.8)
30 < 40 kg/m^3	8,867 (23.1)	752 (22.3)	1,069 (23.9)
> 40 kg/m^3	6,666 (17.3)	556 (16.5)	755 (16.9)
T2DB, N(%)	5,360 (13.2)	436 (12.3)	431 (9.1)
Depression, N(%)	5,880 (14.5)	481 (13.6)	476 (10.1)
CHF, N(%)	835 (2.1)	57 (1.6)	67 (1.4)
CVD, N(%)	3,411 (8.4)	261 (7.4)	204 (4.3)
Cancer, N(%)	3,557 (8.8)	264 (7.5)	309 (6.5)
COPD, N(%)	2,563 (6.3)	245 (6.9)	191 (4.0)
Asthma, N(%)	5,258 (13.0)	442 (12.5)	480 (10.1)
Liver, N(%)	3,284 (8.1)	270 (7.6)	305 (6.4)
Renal, N(%)	1,985 (4.9)	149 (4.2)	120 (2.5)
ESRD, N(%)	99 (0.2)	10 (0.3)	11 (0.2)
Migraine, N(%)	3,458 (8.5)	286 (8.1)	298 (6.3)
Repeat BP Measured, N(%)	9,726 (24.0)	1,124 (31.7)	1,190 (25.2)
SBP Last Digit Rounded to Zero, N(%)	11,059(27.3)	867 (24.5)	1,241 (26.2)
Time to First Post- Index Follow-up, N(%)			
Less than 1 month post-index	9,734 (24.1)	288 (8.1)	0
Between 1-2 months post-index	9,208 (22.8)	778 (22.0)	0
Between 2-3 months post-index	3,439 (8.5)	779 (22.0)	0
Greater than 3 months post-index	18,088 (44.7)	0 (0.0)	0
Medication Initiation, N(%)	9,929 (24.5)	759 (21.4)	

HPI= Health Places Index; LTFU = Lost to follow-up; HMO = Health Maintenance Organization; FFS = fee for service; BMI = Body Mass Index; T2DM = type 2 diabetes; CHF = Congestive heart failure; CVD = cardiovascular disease; COPD = chronic obstructive pulmonary disease; ESRD = end stage renal disease

Appendix 7

Logistic Regression of baseline sociodemographic and clinical patient characteristics on an outcome of no HPI score

	Total Cohort		
	OR	**95%CI**	
Non-Hispanic Black	1.04	0.85	1.26
Non-Hispanic Asian	1.13	0.99	1.30
Other	1.17	1.02	1.33
Multi-Race	1.32	1.03	1.69
Hispanic	1.05	0.93	1.19
Sex (ref: female)			
Male	0.99	0.91	1.08
Age Category (ref: <30 years old)			
31-40 yrs	0.83	0.66	1.05
41-50 yrs	1.15	0.92	1.44
51-60 yrs	1.30	1.04	1.62
61-70 yrs	1.32	1.05	1.66
71-80 yrs	1.43	1.11	1.85
Greater than 80 yrs	1.25	0.92	1.70
Insurance Type (ref: Commercial)			
Commercial HMO	1.14	1.03	1.26
Medicaid/Medi-Cal	1.04	0.78	1.40
Medicare FFS/HMO	1.04	0.91	1.20
Self/Undocumented	0.86	0.69	1.07
Other	0.20	0.03	1.39
Interpreter Needed	0.87	0.69	1.09
BMI Category (Ref: < 25 kg/m^3)			
< 25 kg/m^3	0.77	0.54	1.09
27 < 30 kg/m^3	0.97	0.90	1.05
30 < 40 kg/m^3	0.96	0.87	1.07
> 40 kg/m^3	0.99	0.88	1.13
Clinical Conditions			
T2DM	0.89	0.80	1.00
Depression	0.95	0.86	1.05
CHF	0.76	0.55	1.04
CVD	0.85	0.72	1.00
Cancer	0.77	0.66	0.89
COPD	1.17	0.99	1.38
Asthma	0.95	0.84	1.07
Liver Disease	0.95	0.83	1.10
Renal Disease	0.82	0.67	1.01
ESRD	1.69	0.81	3.52
Migraine	0.97	0.86	1.10
	0.08	0.07	0.10

OR = odds ratio; CI = Confidence Interval; BP = blood pressure; HMO = Health Maintenance Organization; FFS = fee for service; HPI= Health Places Index; BMI = Body Mass Index; T2DM = type 2 diabetes; CHF = Congestive heart failure; CVD = cardiovascular disease; COPD = chronic obstructive pulmonary disease; ESRD = end stage renal disease

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CHAPTER 3

Clinical Engagement Trajectories and Patient Factors Associated with Optimal Blood Pressure Management Patterns among Patients with Incident Diagnosis of Hypertension

3.1 ABSTRACT

Introduction: The established paradigm of "awareness (i.e. diagnosis), treatment and control" as a central strategy to achieve blood pressure control is well accepted as the optimal approach to hypertension (HTN) management, but few studies have explored how real-world patterns of healthcare engagement, treatment and blood pressure control within the first two years of diagnosis of HTN may differ for different sociodemographic patient groups.

Methods: We analyzed electronic health record (EHR) from a large integrated healthcare system in Northern California to characterize trajectories of clinical engagement, blood pressure treatment and control after incident hypertension diagnosis. The cohort was comprised of 22,727 women and 17,742 men who received primary care between 2012-2019, and who had incident hypertension. For each month for 24 months after incident HTN diagnosis, patients were assigned to one of 3 mutually exclusive categories according to HTN treatment with medications, blood pressure control, and visit status (up to date or not). We applied sequence and cluster analysis to identify common patient engagement trajectories, stratified by sex, then further categorized trajectories into the broader groups of clusters representative of "optimal care management", "suboptimal care management" and "unknown care management". Using multinomial logistic regression, we estimated associations between patients' socio-demographic characteristics and BP care management. We hypothesized that engagement trajectories most closely resembling the hypothesized paradigm for sequential diagnosis, treatment and control are more common among the most societally advantaged individuals (i.e. non-Hispanic white, commercially insured) at 24-months post first evidence.

Results: Approximately one fifth of female and one- third of male patients never engaged after their initial diagnosis at the index visit, and by 24 months, only about 50% of patients were up to date with their visits. We observed 13,069 distinct care management trajectories among women that were classified into ten clusters and 9,298 distinct trajectories among men that were classified into 10 clusters. Qualitatively, the clusters did not differ by sex: five of the 10 clusters were classified as optimal BP care management (OCM), representing 57% of women and 48% of men. For both women and men, by 24 months only ~ 50% of

patients were up to date with their visits, which is representative of clinical engagement, and 20-30% never engaged after their initial diagnosis at the index visit.

Conclusion: Self-identification with a historically marginalized racial/ethnic group was not associated with OCM membership while older age and more clinical co-morbidities were associated with OCM compared to suboptimal trajectories. Future studies are needed to identify predictors of clinical engagement trajectories resulting in lack of clinical engagement post-diagnosis.

3.2 INTRODUCTION

Blood pressure control remains a challenge among many in the U.S. despite advances in treatments and pharmaceutical interventions. Among the 1,709 organizations participating in the American Heart Association (AHA) / American Medical Association's (AMA's) Target BP recognition program, representing 8.6 million patients with hypertension(HTN) across 47 states, less than half (48%) achieved blood pressure control rates of at least 70% amongst their patient populations in 2023.[1,2] Clinical care management practices play a crucial role in helping individuals diagnosed with HTN to achieve and maintain blood pressure control. These practices and processes can be defined as strategies and interventions employed by healthcare professionals to manage and maintain healthy blood pressure levels in patients.

The established paradigm of "awareness (i.e. diagnosis), treatment and control" as a central strategy to achieve blood pressure control is well accepted[3,4] and having a usual source of care, optimizing adherence, and minimizing therapeutic inertia are associated with higher rates of BP control.[5] Despite this, it is unclear how closely different patient subgroups follow this trajectory over time. Two barriers to optimal outcomes are suboptimal treatment of HTN and lack of follow-up for patients[3], both of which may result in missed opportunities for intervention and, as a result, suboptimal management of blood pressure. Disparities exist with a disproportionate number of patients from historically marginalized groups being undertreated[6,7], experiencing structural and societal inequities that result in lower engagement with the care team[7] and ultimately experiencing persistent disparities in BP control.[6-8] Furthermore, there have been well-documented significant sex-based differences in onset of HTN, antihypertensive drug effectiveness and use and BP control, such that women are more likely to be treated for[9] and achieve BP control than men.[9-12] Sex-based differences in the manifestation of cardiovascular diseases and in risk for CVD may indicate the need for different approaches to management and treatment of HTN for men and women, where men have higher prevalence of CVD.[9-11] Given this, it is important to better understand different patterns of clinical engagement and treatment of HTN between men and women, in order to optimize outcomes for both groups.

Few studies have explored how real-world patterns of healthcare engagement, treatment and blood pressure control within the first two years of diagnosis of HTN (i.e. incident HTN) may be associated with different patient sociodemographic characteristics and groups. In this study, we use sequence and cluster analysis to examine clinical-engagement trajectories over the first two years after incident diagnosis of HTN among a large cohort of patients of a large, integrated healthcare system in Northern California. Sequence and cluster analysis allow for grouping thousands of individual-level engagement trajectories that patients may follow over time, into a smaller, analytically tractable of smaller trajectory clusters, while maintaining substantive differences between trajectories of engagement, treatment and control. This novel application of sequence analysis to examine healthcare management trajectories for chronic diseases using real-world, electronic health record data is innovative and hold much promise.[13] We further evaluate sociodemographic characteristics of each of the identified engagement trajectories. We hypothesize that engagement trajectories most closely resembling the hypothesized, and optimal, paradigm for sequential diagnosis, treatment and control are more common among individuals with the most social advantages (i.e. non-Hispanic white, commercially insured).

3.2 METHODS

Setting

This retrospective study was conducted at Sutter Health (SH), a large not-for-profit integrated health system in northern California. SH provides comprehensive medical services in 22 counties across 130 ambulatory clinics and 24 acute-care hospitals, with approximately 11 million outpatient visits, 850,000 emergency department (ED) visits, and 200,000 hospital discharges, annually. SH provides services in geographies with some of the greatest diversity in the country, in both urban and rural settings. The Epic EHR (Epic Systems Corporation; Verona, Wisconsin) is fully integrated across all sites throughout SH. SH has collected patient self-reported race, ethnicity, ancestry, and language (REAL) data since 2010. As of 2023, SH patients self-identified as 41.4 percent non-Hispanic white, 17.5 percent Hispanic, 16.5 percent non-Hispanic Asian, 4.8 percent non-Hispanic Black, and 20.1 percent non-Hispanic Other (American Indian/Alaskan

Native, mixed race, declined-to-state, and unknown). We use the designation "Hispanic", instead of "LatinX", for consistency with SH self-reported data collection procedures which align with the 1997 U.S. census categories.[14] (ref) Data were extracted from the Sutter EHR for the study period between January 1, 2012 to December 31, 2019. This study was approved by Sutter's Institutional Review Board and was conducted according to Health Insurance Portability and Accountability Act standards.

Sample

Data were extracted from the SH EHR for adult patients (age 18+ years old as of the first encounter) with at least one SH in-person visit to primary care (i.e. family medicine, internal medicine, OB/GYN) within the observation period (January 1, 2012 to December 31, 2019) and 2 visits to primary care within the two-year period prior to the observation period. We defined the index encounter as the first primary-care encounter with an International Classification of Diseases, Ninth and Tenth Revision of Essential hypertension (ICD 9: 401.0, 401.1 and 401.9; 796.2 or ICD 10 [I10, Essential hypertension]) diagnosis code documented in the EHR (see Figure 1). For the analytic cohort in the present analysis, we exclude individuals 1) with evidence of pregnancy at any point during the observation period and 2) who had BP < 140 and/or 90 mmHg at the index visit. We exclude those who were pregnant during the study period because the pathophysiology of hypertension in the perinatal and postpartum period is distinct.

To study individuals with incident diagnosed and documented HTN, we further excluded individuals who had evidence of HTN during the two-year period prior to the observation period on two methods of identification of pre-existing hypertension. First, we excluded individuals who had an ICD code for HTN as described above. Second, we excluded those with clinical evidence of HTN but no diagnosis, defined as at least two clinic measured BP values, at least 30 days apart, in the Stage 1 or higher hypertensive range in accordance with the timing of the measurement (see Appendix 1). To define exclusions for measurements occurring in the EHR prior to 2017, we applied the JNC7 criteria (i.e. Systolic 140-159 mmHg or Diastolic 90-99 mmHg). For measurements occurring in or after 2017, we applied the 2017

ACC/AHA criteria for BP in the hypertensive range (i.e. Systolic 130-139 mmHg or Diastolic 80-89 mmHg).

Our final analytic sample included 40,469 individuals (22,727 female patients [56.2%] and 17,742 male patients [43.8%]). Given our existing evidence regarding sex-based differences in HTN and CVD prevalence and risk, all analyses described below were stratified by sex assigned at birth (i.e. female; male).

Sequence and Cluster Analysis

There is a high level of variability in the sequence of healthcare engagement, primary-care utilization, treatment of HTN and blood-pressure control over time. We used sequence analysis to create analytically tractable and clinically meaningful subsets of similar trajectories, while retaining substantive differences between clusters. We first created individual healthcare engagement trajectories, we then used sequence analysis to quantify differences between trajectories, and finally we used cluster analysis to group similar trajectories.

1. Creation of individual healthcare engagement trajectories

Each month post-index visit for each patient in the dataset was classified as one of 7 mutually exclusive and exhaustive categories (or "states") (Table 1) based on the combination of the following variables: 1) was up-to-date on their expected primary care visits (Yes/No, see below) 2) had an order for a BP medication (Yes/No) and 3) had a clinic-measured blood pressure reading under 140 mmHg (systolic) and under 90 mmHg (diastolic) as a proxy for blood pressure control (Yes/No/Unknown). Definitions were informed by national treatment guidelines, which recommend a return visit within one-month of a visit with uncontrolled BP for those with diagnosed HTN[15], and at least annual exams for those with controlled hypertension. Definitions and assumptions for each factor and its options are found in Table 1 and Appendix 1. If more than one visit occurred within a given month, we used the information from the last visit chronologically.

Visit (yes/no): For a given month (up to 24), if no visit was documented, the patient's state could still be "up-to-date" if their last visit was controlled and <12 months ago, or if their last visit was uncontrolled and <1 month ago. Otherwise, it was marked as "not up to date".

BP meds (yes/no): An individual was determined to be on BP treatment based on available evidence of active orders for any BP medication based on medication class (i.e. antihypertensive, beta blockers, calcium channel blockers, diuretics, see Appendix 2) at the time of a visit for a given month, or for the 6 subsequent months if no other visit was documented in that time.

BP control (yes/no/unknown): We defined blood-pressure control status based on available evidence of systolic BP >= 140 mmHg and/or diastolic BP >= 90 mmHg at the time of a visit for a given month that a visit occurred. For months without a documented visit, the individual was considered to be uncontrolled if the preceding visit was in the uncontrolled range and was considered in control if within 12 months of a preceding visit with BP control. If greater than 12 months from a visit with controlled BP, the individual's BP control status was considered to be "unknown".

The combination of these three variables and their possible values (Table 1) can result in 12 total possible combinations. However, 5 states are not possible given our definitions and thus did not appear in our data. If a visit is "up to date" then BP control status is known. It was only possible to have an unknown BP control status if the visit was not up to date AND the preceding visit occurred more than 12 months from the timepoint, which would also disallow a person to be considered on medication (Table 1, states 8 and 9). It would not be possible for a patient be considered in control and on treatment, but not up to date on visits because this would either correspond to uncontrolled or unknown BP control status (Table 1, state 10). We did not observe this in our data. Further, we did not observe anyone whose visit was not "up to date" and on medication whose control status was unknown (Table 1, state 11). Finally, it was not possible to have a visit that was not "up to date", with no evidence of medication but and be considered controlled (Table 1, state 12). As a result, only the seven possible states appear in our analysis.

For visualization, states were color coded where green indicates the most desirable treatment state (i.e. visit is up to date, blood pressure is controlled), the progression to pale yellow and orange indicate less

desirable states where engagement and active management is occurring but BP is not in control, and finally red and purple indicate no contact with the care team (i.e. visit not up to date) and BP is either known to be out of control or control status is unknown.

We generated index plots of the overall cohort, as well as for each sex-based subgroup. Sequence index plots are a primary means of visualization in sequence analysis[16,17] The sequence index plot graphs horizontal stacked bars across the x-axis, which represents the sequence of states, for each participant, by month, over the 24 months of follow-up. Each horizontal bar represents one individual patient and their sequence based on the seven states as described in Table 1. We also generated sex-stratified state frequency plots, also known as state distribution plots, which show the aggregate the frequency of each state at each timepoint across the population.

2. Sequence Analysis: Quantitative Evaluation of How Individual Trajectories Differed

We applied sequence analysis to calculate distances between every pair of engagement trajectories observed.[17,18] The distance between two trajectories is calculated as the total "cost" to transform one engagement trajectory into another via a combination of substitutions (i.e., changing 1 state to another state; e.g., treated to untreated), insertions or deletions (i.e., inserting or deleting a state to make 2 sequences equivalent). We set substitution costs between states by using the mean probability distance to calculate cost transition frequencies in our data, such that more common transitions were assigned lower costs than less frequent transitions. Insertions and deletions were set equal to 1, corresponding to ½ the maximum substitution cost. We used the "optimal matching" (OM) algorithm which calculates the cost between trajectories by estimating the distance between two sequences via the three transformations described above (i.e. substitution, insertion, deletion). The principle of OM is to assign a value to the number of operations necessary to render two sequences strictly similar[19] and OM considers the full complexity of sequences. It uses an iterative minimization procedure to find the distance between every pair of sequences in a sample. Costs are calculated between each pair of sequences each time point and then summed across timepoints, resulting in a total cost, or "distance" between two trajectories. This exercise is repeated between every

observed pair of sequences in the dataset, resulting in a square, symmetric distance matrix. This distance matrix is the result of the sequence analysis.

3. Cluster Analysis: Grouping Similar Trajectories

We used hierarchical, agglomerative clustering with Ward linkage to choose the final number of healthcare engagement trajectories. Agglomerative clustering initially treats all unique trajectories as distinct clusters, then sequentially groups similar trajectories, based on the distance matrix until only one cluster remains.[20] The Wards linkage maximizes similarities within clusters (i.e., maximize within group homogeneity by minimizing the mean distance between all pairs within a cluster and maximize across group heterogeneity by maximizing the mean differences between all pairs between clusters) and maximizes mean differences between clusters. We used TraMineR package and procedures in R.[21]

There are often several cluster solutions that will work with a given dataset. To choose the optimal number of healthcare engagement trajectories clusters, we used a combination of cluster quality measures, interpretability, and cluster size.[22] We evaluated four metrics to assess cluster quality (Table 2): 1) the average silhouette width weighted (ASWw; higher numbers reflect better cluster solutions) 2) Hubert's Gamma (HG; higher numbers reflect better cluster solutions) 3) Point Biserial Correlation (PBC; higher numbers reflect better cluster solutions) and 4) Hubert's C (HC; lower numbers reflect better cluster solutions) . We selected cluster solutions that optimized the most of these metrics while considering interpretability of the final number of clusters. Once clusters were identified, we generated a chronogram, modal plot (which shows the most common state at each timepoint for the cluster, or the model) and an index plot for each cluster to visualize the heterogeneity within the cluster. We also generated sequence modal plots for each cluster by sex-group (see below), where the most common state at each timepoint determines the color of that part of the horizontal bar and serves as a higher-level summary of a given cluster. We further include chronograms of each cluster for each sex-based subgroup, an alternative cluster visualization approach, to provide additional details of the clusters. The index plots show individual-level engagement trajectories represented in the EHR data over a 24-month period. The chronograms show the frequency of state for a given month and are specific to individuals within a given cluster, thus reflecting

the proportion of the analytics sample that is part of a given cluster. Modal plots represent the most common state at each timepoint (i.e. month post index) and serve as a high-level summary of the cluster.

After generating the clusters, we qualitatively grouped them based on whether the trajectory was indicative of 1) optimal care management (OCM; i.e. resulting in long-term and timely BP control and following the "diagnose – treat- control" paradigm by 24 months of follow-up, 2) Suboptimal care management (SCM) with uncontrolled BP at 24 months and 3) Unknown care management (UCM) where BP control is unknown at 24 months, for each sex subgroup. The 2003 Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7)[23] and 2014 Eighth Report (JNC 8)[24] guidelines defined hypertension stage 1 as BP of >= 140/90 mmHg and emphasized lifestyle modification as the first line of treatment for adults diagnosed with HTN. According to current treatment guidelines from the American Heart Association and the American College of Cardiologists[25], all individuals included in this study cohort (i.e. adults diagnosed with stage 2 HTN) should have a combination of nonpharmacological and antihypertensive drug therapy (with 2 agents of different classes) initiated at the time of diagnosis, as well as a follow-up visit within 1 month of the initial diagnosis. Given the timeframe of the observation period and the changes in guidelines as described above, achieving BP control with sustained appropriate engagement without medication (i.e. lifestyle alone) was considered the optimal pattern.

Covariates

We examined patient sociodemographic characteristics for associations with optimal HTN control. Patient sociodemographic characteristics were determined at the index encounter. For all patients we extracted demographic information from the EHR, including patients' age at encounter, sex (binary male, female), self-reported race/ethnicity and primary insurance. Age was categorized as follows: < 30 years old, 31-40 years old, 41-50 years old, 51-60 years old, 61-70 years old, 71-80 years old, > 80 years old. Race and ethnicity were defined by Hispanic identity as ethnicity, followed by racial group. If a patient did not self-identify as Hispanic, we classified them based on their race. Individuals who identified with multiple

race categories were classified as "other racial identity"; the categories were: non- Hispanic white, non-Hispanic Black, non-Hispanic Asian, non-Hispanic American Indian/ Alaska Native (AI/AN), non-Hispanic Native Hawaiian/Pacific Islander (NHPI), Multi-race, Hispanic, Other Race. Documentation of interpreter needed (Yes/No) at the baseline encounter was used as an indicator of non-English speaking. Insurance status was identified by the active primary payer documented in the EHR at baseline, classified as follows: Commercial PPO/FFS, Commercial HMO, Medicaid/Medi-Cal, Medicare FFS/HMO, Self-pay/Nor Reported, or other insurance.

Smoking status was included and categorized as follows: current, past, never and unknown. We extracted comorbidities using ICD-9/ICD-10 diagnoses as of the baseline encounter, based on most recent data available in the 12 months prior to the baseline encounter (See Appendix 2). These included type 2 diabetes, depression, congestive heart failure, cancer, chronic obstructive pulmonary disease, asthma, liver disease, renal disease, end stage renal disease and migraine. Body mass index was also extracted and categorized (i.e. BMI< 25 kg/m^2; 25 < 27 kg/m^2; 27 < 30 kg/m^2; 30 < 40 kg/m^2; > 40 kg/m^2).

Statistical Analysis

Patient sociodemographic and clinical characteristics were summarized using descriptive statistics, overall and stratified by sex group. We estimated the associations between patient sociodemographic and clinical characteristics (exposure variables) at the time of diagnosis of HTN with clusters indicative of suboptimal care management (SCM) or unknown care management (UCM) compared to optimal care management (OCM; reference group) fitting a multinomial regression model[26] with a 3-level categorical outcome (i.e. OCM, SCM, UCM). We fit models for men and women separately.

We further conducted sensitivity analyses. We fit a logistic regression model with a binary outcome of optimal care management (yes/no), to examine differences in combining clusters within the SCM and UCM groups.

Dataset preparation, descriptive statistics, figures and multinomial regression analyses were performed using Stata statistical software version 16 (StataCorp. 2019. Stata Statistical Software: Release

16. StataCorp LLC, College Station, TX); Cluster analysis was performed using R Studio. All data cleaning and analysis code were reviewed by a second programmer (LP) who was not involved in the initial programming, as is recommended best practice.

3.4 RESULTS

Cohort Characteristics

Among female patients, the majority self-identified as non-Hispanic white (NHW; 56.8%; Table 3), followed by non-Hispanic Asian (NHA; 16.6%) and Hispanic (12.5%). The race/ethnic distribution was similar among male patients. The mean age of female patients was 55.6 years (SD 14.7) with 58% <= 50 years (Table 3). Male patients were younger, with mean age 52.8 years old (14.3) and a higher proportion <= 50 years (63.1%).

By definition, all patients were considered to have blood pressure in the uncontrolled range, per the NQF definition at baseline, with a systolic BP of >= 140 mmHg or diastolic BP of >= 90 mmHg at baseline. Mean baseline systolic BP was higher for women (Mean [SD]; 151.3 [12.5]) compared to men (149.4 [11.5]). Mean baseline diastolic BP was slightly lower for women (88.3 [10.4]) compared to men (89.4 [10]). The distribution of BP measures at the index visit are shown in Figure 2. Approximately one-quarter of both women and men had BP medication initiated at of the index visit.

Sequence and Cluster Analysis Results

We found 13,069 distinct trajectories among the female subsample and 9,298 distinct trajectories among the male subsample (Figure 3). The index plots show the individual patient sequences across the 24 months, color coded for each state for each month post-index (Figure 3). All patients begin with state 4 (gold) which indicates that they are not on medication and BP is uncontrolled at this first visit. In the lower left quadrant, we can generally see purple in all plots which indicates that the patient is not up to date on visits, there is no evidence of medication treatment and BP is uncontrolled. As patients return for follow-up, we see gold and then variation of engagement and treatment trajectories over time. In the upper left

quadrant, we see those who returned as recommended to receive clinical management with some patients continuing with lifestyle management alone (dark green) and others showing evidence of anti-hypertensive medication (bright green) both with successful BP control. For female and male subgroups, one difference is the increased proportion of male patients that have a delay in time to follow-up for the first visit post diagnosis (Figure 3, Panel A vs B).

In addition, state frequency plots (Figure 4) provide a relative frequency and distribution of states across individual patients within a given month over the 24-month period, in order of most optimal to most suboptimal management state (i.e. 1-7, Table 1). The frequency distribution of states was different for women and men, where the majority of women did not have up to date visits until month 4 verses month 9 for men. In addition, approximately 25% of patients overall had evidence of medication initiation at baseline (Table 3), and those on medication generally displaying good BP control (i.e. light green compared to beige). By 24 months post diagnosis, approximately 50% of patients were up to date with their visits. For both groups, engagement peaked at month 14, where most patients had visits up to date, regardless of control or treatment status.

After applying sequence cluster analysis, we assessed cluster quality (Figure 5), and elected to limit number of clusters to 10 or less to ensure interpretability and sufficient sample size within a cluster, while trying to optimizing measures of cluster quality. [22] For cluster selection, we attempt to maximize the average weighted distance of an observation from the other members of its group and from the closest group (i.e. ASWw), the capacity of a cluster of the data to reproduce the distance matrix (i.e. HG and PBC), while minimizing the HC metric which compares the partition obtained with the best partition that could have been obtained with this number of clusters and the distance matrix.[20] We include details for the quality metrics by cluster in Appendix 3. Given this constraint, 10 BP healthcare engagement clusters were selected for men and women.

Clusters differed slightly between women and men, but overall were qualitatively similar. When comparing index plots, chronograms and modal plots for the ten clusters by sex group (Figure 6), we grouped the 10 clusters into three mutually exclusive categories: 1) clusters representing a clinical

engagement trajectory that is representative of the paradigm "diagnosis/treatment/control" where the patient has evidence of BP control at 24 months post diagnosis (i.e. Optimal BP Care Management [OCM]) 2) clinical engagement trajectory that results in uncontrolled BP at 24 months post diagnosis (i.e. Suboptimal BP Care Management [SCM]) and 3) a clinical engagement trajectory where BP control status at 24 months is unknown (Unknown BP Care Management [UCM]). Though suboptimal based on our assessment, for comparison, sequence chronograms and modal plots for 8-cluster solutions did not reveal substantive differences in terms of qualitative interpretation of findings, with the exception of the obscuring of UCM trajectories for women (Appendix 4).

Optimal BP Care Management

Clusters included in the OCM group (Figure 6) consisted of groups that resulted in evidence of BP control whether by lifestyle management (i.e. no meds) or pharmacological treatment, with sustained clinical engagement through 24 months (i.e. visit up to date). This group represents the BP management paradigm for sequential "diagnosis – treatment – BP control" where patients are diagnosed at index and continue to engage with the care team either receiving BP control medications or undergoing lifestyle modification in order to achieve sustained BP control at 24 months post-index visit.

Five of the ten female clusters were classified as OCM (Figure 6, Panel A), representing the trajectories of 57% of the sample. For men, there were also five clusters that were classified as OCM (48% of male patients). For both women and men, OCM clusters included 1) timely BP control, high engagement and no pharmacological treatment (24.2% of women, 16.3% of men) 2) delayed but subsequently high engagement, consistent BP control and no pharmacological treatment (16.4% of women, 13.2% of men) and 3) timely BP control, high engagement with pharmacological treatment (16.4% of women, 10% of men). In addition, men 5.6% of men had delayed but subsequently high engagement with pharmacological treatment and 2.4% of men exhibited a trajectory of timely BP control, high engagement with initially lifestyle alone followed by pharmacological treatment.

Suboptimal BP Care Management

A cluster was considered to be indicative of SCM when the trajectory resulted in visit "not up to date", no evidence of treatment and BP considered uncontrolled (i.e. purple). This group included 36% of women and 38.7% of men. Of note, for both female and male patients, one of the suboptimal treatment clusters included a period of high engagement and good control without medication (12.6% of females, 7.2% of males). Unique to the male patients, one cluster in the SCM consisted of evidence of continued medication treatment but no engagement (visit not up to date) and no BP control. Approximately one-fifth of women (17.1%) and 27% of men exhibited virtually no follow-up visit after the initial index visit.

Unknown BP Care Management

Clusters included in the UCM group consisted of clusters where the ultimate outcome of management, in terms of BP control, is unknown or unclear. For both men and women, two clusters of the ten consisted of clusters identified as UCM. For 7.7% of men and 3% of women, the pattern indicates timely BP control and medication initiation with high engagement, with a potential transition to lifestyle intervention only and eventual loss of engagement with an unknown BP control status. Additionally, 4.2% of women and 6% of men were treated with medication. This may indicate that the patient was last known to have BP in control but is not engaging with the care team for long-term management and support.

Multinomial Regression

We sought to examine how patient sociodemographic and clinical characteristics at baseline may be associated with optimal BP management (i.e. diagnosis – treatment -control paradigm). The results of the sex-stratified multinomial regression with the categorical outcome for SCM or UCM (vs OCM) are presented in Figure 7.

Suboptimal BP Care Management vs Optimal BP Care Management

Among women and men, there were several factors associated with lower odds of suboptimal BP care management (SCM) compared to optimal BP care management (OCM). Female patients who self-identify as non-Hispanic Asian (OR [95%CI] 0.9 [0.82,0.98]) had lower odds of SCM compared to their non-Hispanic white counterparts. For men only, older age was also associated with lower odds of SCM (OR range 0.63 [0.53, 0.75] for ages 61-70 years old to 0.7 [0.6,0.83] for 41-50 years old). Compared to those that currently smoke, for both women and men, patients who quit smoking (0.78 [0.68-0.9] women and 0.77 [0.68-0.88] men) and who never smoked (0.8 [0.71, 0.91] women and 0.81 [0.72, 0.92] men) have lower odds of SCM compared to OCM. Finally, for both women and men, several co-morbidities were associated with significantly lower odds of SCM including T2DM (0.85 [0.77,0.93] for women and 0.82 [0.75,0.91] for men), depression (0.84 [0.77, 0.91] for women and 0.74 [0.66, 0.83] for men), CVD (0.86 [0.77,0.97] for women and 0.85 [0.75,0.97] for men), asthma (0.88 [0.81, 0.95] for women and 0.79 [0.71, 0.88] for men) and migraine (0.87 [0.79,0.95] for women and 0.76 [0.64,0.9] for men). Additionally, COPD was associated with lower odds for women only (0.82 [0.72, 0.93]), while liver disease (0.83 [0.74, 0.93]), renal disease (0.83 [0.71,0.98]) were associated with lower odds of SCM for men only.

There were several factors associated with higher odds of suboptimal BP care management (SCM) compared to optimal BP care management (OCM). Patients who self-identify as "Other" race/ethnicity had nearly 20% higher odds of being in a suboptimal cluster (1.17 [1.04, 1.31] for women and 1.19 [1.06,1.34] for men) and further, the odds are nearly 30% higher for women who self-identify as multi-race (1.3 [1.04, 1.62]). In terms of insurance, for women having Medicaid/Medi-Cal (1.17 [1, 1.38]) was associated with higher odds of SCM. For men, having self/undocumented insurance (1.3 [1.1, 1.5]) was associated with higher odds of SCM, compared to OCM. Finally, for men only, end stage renal disease (ESRD) was significantly associated with more than double the odds of having belonging to a suboptimal care management cluster (2.02 [1.05, 3.87]).

Unknown BP Care Management vs Optimal BP Care Management

Among women and men, there were several factors associated with lower odds of unknown BP care management (UCM) compared to optimal BP care management (OCM), meaning a patient is more likely to belong to a cluster representative of optimal care management compare the those that result in an unknown control status. For both women and men, there was some associations with lower odds of UCM and older age. For women, odds were lower for all age groups compared to their < 30-year-old counterparts, and odds ratio ranged from 0.57 [0.42, 0.76] for ages 61-70 years old to 0.66 [0.5, 0.87] for 41-50 and 51-60 years old. For men, only those aged 51-60 years old (0.73 [0.58, 0.92]) and 61-70 years old (0.65 [0.51, 0.83]) had lower odds of UCM, compared to their younger counterparts. For women, several co-morbidities were significantly associated with lower odds of UCM, including T2DM (0.77[0.64,0.92]), Asthma (0.85 [0.72, 0.99]) and liver disease (0.72 [0.57,0.9]). Only asthma (0.83 [0.71, 0.96]) was associated with lower odds of UCM for men.

There were less factors associated with higher odds of unknown BP care management (UCM) compared to optimal BP care management (OCM). For women, having Medicaid/Medi-Cal insurance (1.32 [1.01, 1.72]) as well as obesity (1.2 [1.02,1.41] for BMI 30-40 kg/m^2 and 1.2 [1.01, 1.42] for BMI >40 kg/m^2) was associated with increased odds of belonging to a UCM cluster. No covariates were statistically significantly associated with higher odds of unknown BP care management UCM for men.

3.5 DISCUSSION

We used sequence and cluster analysis to examine differences in patient sociodemographic and clinical characteristics associated with optimal BP care management trajectories by sex. We did this using real-world electronic health record data from a large, integrated healthcare system in Northern California. We sought to examine how patient sociodemographic and clinical characteristics at baseline may be associated with the established "diagnosis – treatment -control paradigm"[3] which, for the purposes of this analysis, was identified as optimal BP care management, compared to the other BP management trajectories. Our hypothesis was that engagement trajectories most closely resembling the hypothesized paradigm for

sequential diagnosis, treatment and control are more common among individuals with the most social advantages at 24-months post first evidence. Our findings did not fully support our hypothesis in that sociodemographic factors associated with identified and persisting disparities in hypertension were not associated with suboptimal clinical engagement. While we did not see associations between historically marginalized race/ethnic subgroups, there was some evidence that insurance status may play a role in increased likelihood of suboptimal care management. Further, not smoking, older age and having clinical comorbidities for both sexes seemed to be more influential in terms of increasing odds of optimal vs suboptimal care management.

Factors associated with cluster membership representative of suboptimal care management, compared to an optimal trajectory, included women who have Medicaid/Medi-Cal and men who have self-pay/undocumented insurance. There is an abundance of evidence documenting factors that are typically associated with racial/ethnic disparities in hypertension diagnosis, treatment and control. Specifically, individuals who self-identify as Black, Hispanic and American Indian/Alaska Native, independent of other risk factors, experience disparities in HTN control and higher occurrence of treatment inertia.[6,7,27-29] Individuals with low socioeconomic status are less likely to have controlled blood pressure than their counterparts.[6,8,30,31] Our findings are consistent with the identification of socioeconomic disparities as influential in suboptimal care and outcomes. Based on the multinomial regression results, we did not observe the race/ethnic associations we expect, but patients who self-identify as "Other" race/ethnicity had nearly 20% higher odds of being in a suboptimal cluster for both sexes and the odds are nearly 30% higher for women who self-identify as multi-race. Further, women who self-identify as NHA were more likely to belong to the OCM group.

It has been well recognized that after accurate diagnosis, lifestyle modification and pharmacological treatment should be initiated and sustained for optimal long-term BP control and CVD risk reduction.[4] We found a high amount of heterogeneity in the clinical engagement trajectories that patients experience in the 24 months following an incident diagnosis of HTN. Nearly 40% of women and men experienced suboptimal care management, representing a major opportunity for improvement and intervention. Given

the risk of developing CVD[32,33] and at lower BP levels[11,32,34] is higher for women compared to men, it may be especially important for women to achieve and maintain optimal BP control and long-term clinical engagement. For both women and men, engagement peaked at month 14, and then began to decline. By 24 months only ~ 50% of patients were up to date with their visits, which is representative of clinical engagement, and between 20-30% never engaged after diagnosis at the index visit. Visit frequency, specifically returning to the clinic within 4 weeks of an elevated BP measure, has been found to be an important factor in achieving BP control.[35] In analyses of NHANES data from 2015-2018, not having a health care visit in the past year was associated with higher likelihood of having uncontrolled BP (i.e. SBP/DBP >= 140/90 mmHg) among individuals with hypertension.[8,36] Based on index plots and state frequency distribution, men waited longer than women to begin to engage after the diagnosis. We assume BP was not controlled during this time, but it is possible that this delay could be related to lifestyle interventions underway where lifestyle is recommended for 3-6 months after diagnosis as a primary mode of intervention for all guidelines.

Many people, and more men than women, are initially controlled and engaged, but do not follow-up within a year making it challenging to ascertain if they were able to stay in control. Within this group, some patients managed to achieve BP control with lifestyle along and others were prescribed BP medication. Medication initiation was approximately 25% for both sexes, with patients receiving a BP medication order at the time of diagnosis. Despite this, the state indicative of pharmacological treatment and engagement but with uncontrolled BP (i.e. State 3), which would likely indicate a period of titration and would follow initiation, was very infrequently observed in our data. Clinician therapeutic inertia, defined as suboptimal prescription of antihypertensive therapy, has been identified as a major barrier to achieving BP control for those with HTN[4], especially for older aged individuals.[37] National hypertension treatment guidelines changed three times during the observation period, with the prevailing treatment guidance during the observation period placing emphasis on lifestyle intervention prior to medication (between 2012 to 2017). Given that this is real-world clinical data, a younger cohort (mean age in the mid 50s) and relatively low occurrence of T2DM (15% of women, 12% of men) and CVD (9% of women, 8% of men) in the study

population, it is not surprising that medication initiation rates are relatively low. Nearly half of the women (41%) and a third of men (30%) were classified in a cluster indicative of achieving sustain BP control and clinical engagement without BP medication, with another 4% of women and 6% of men whose last recorded BP was in control with lifestyle alone but no are no longer up to date on visits (i.e. the UCM group). This may, in part, be due to some regression to the mean. Of note, mean baseline diastolic blood pressure was below 90 mmHg for both sex groups.

This study is an important contribution to the literature, in part, because it is a relatively novel application of sequence analysis to real-world clinical data. A recent systematic review examining the application of sequence analysis to real-world data found that of the 19 studies applying sequence analysis to identify clinical pathways, 60% were published after 2021 and more than half were conducted outside of the U.S.. Sequence analysis, as a methodology, is relatively young with numerous advances over the past decade[16,18,38] including the recent publication of a textbooks focused on the methodology.[39,40] The studies identified included a variety of clinical conditions, but none of the studies included in the review examined clinical pathways related to hypertension treatment and control.

3.6 LIMITATIONS

In this analysis, we focused on an established primary care patient population of patients who are newly diagnosed with hypertension and have evidence of engagement with the primary care team. We do not include those that have less engagement, meaning less than 1 visit to primary care in the 2-year pre-period prior to the study observation period. Further, the health system in which this study was conducted is an open health system. It is possible that some patients had received treatment elsewhere, outside the system, or prior to the study period and thus were identified as having incident hypertension but could have had a pre-existing diagnosis that was not captured. We implemented exclusion criteria to prevent this, excluding those with prior evidence of hypertension (i.e. prior diagnosis, BP medications and measures) in the pre-period and ensured established primary care in the pre-period to attempt to attempt to address this.

When developing the states for treatment and BP control, we made several assumptions. For our assessment of treatment with BP medication, we relied on the placement of an active order within the EHR and made assumptions regarding the length of time that automatic refills would be available. This is a customizable feature within the EHR and can differ with a given clinical department or physician group within the health system. Further, we assumed that if a last measured BP was uncontrolled and no other visit occurs, the patient remains out of control. This is a conservative approach and could mean that some of those that did not return to the clinic post-index may not have suboptimal control outcomes. Regardless of this, as stated above, low engagement with the care team increases likelihood of suboptimal control and is not in line with treatment guidelines. These assumptions could affect identified trajectories.

The change in treatment guidelines also made interpretation challenging. A future study may focus on clinical engagement trajectories after 2017 to explore the appropriate use of medication initiation for newly diagnosed patients with uncontrolled BP given that this is considered the optimal treatment pattern. Regardless – for those that did not have medication but achieved sustained control, this may still be representative of the most optimal trajectory.

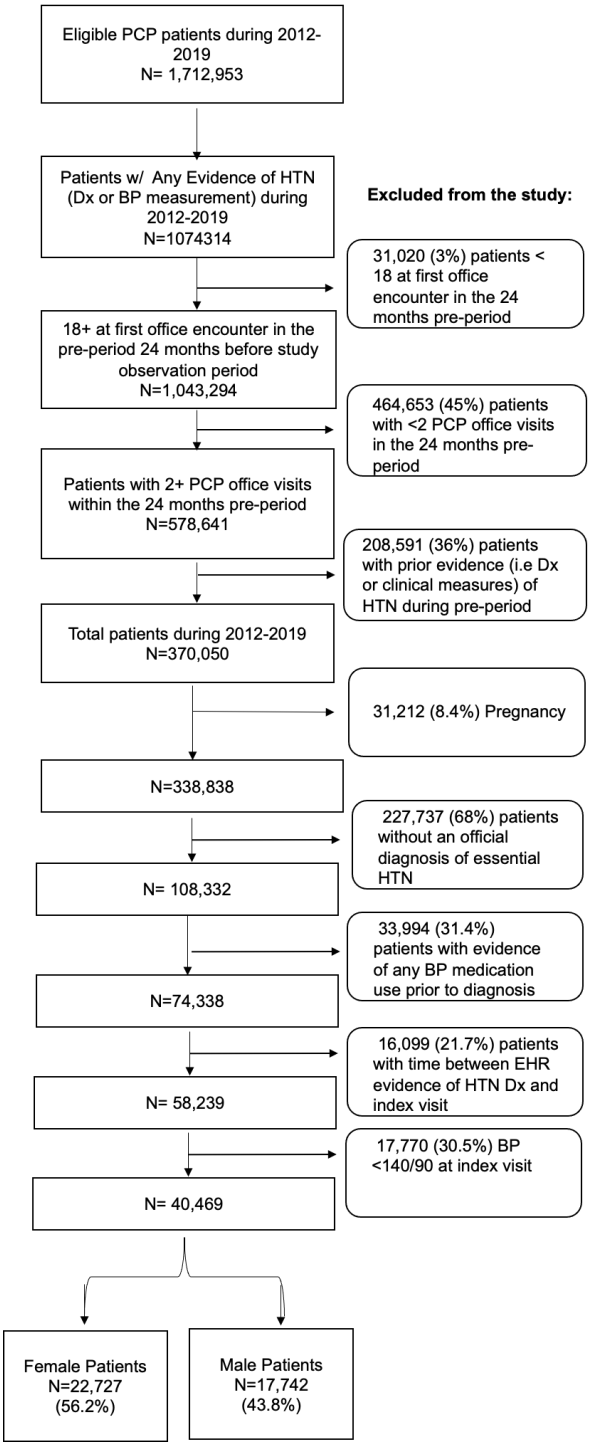
We used monthly intervals and chose to use the last visit in a given month if multiple visits were present. This may not have been ideal for understanding nuances in treatment patterns or clinical engagement. Finally, our selection of 10 clusters was based on a combination of consideration of the cluster quality metrics and interpretability. Given this, there was some subjectivity in the number of clusters selected, which could influence our findings and interpretation.

3.7 CONCLUSIONS

This study represents a novel and initial application of sequence and cluster analysis to examine real-world clinical engagement and treatment trajectories for hypertension management and control. In this stratified analysis, we found some differences by sex but we did not find that individuals from historically marginalized groups and well documented disparities in hypertension treatment and control were more

likely to belong to a suboptimal treatment trajectory. We did find that age and co-morbid conditions play an important role in membership in suboptimal treatment trajectories. We also observed that there is a substantial proportion of patients (both sexes) who do not engage with the care team after diagnosis. This may be an important insight and presents an opportunity for intervention if predictive models can be developed to identify these individual at the time of diagnosis.

3.8 FIGURES AND TABLES



PCP= primary care provider; HTN = hypertension; Dx = diagnosis; BP = blood pressure; EHR= electronic health record

Figure 3.1. Cohort Inclusion/Exclusion Flow Diagram
This figure shows the inclusion and exclusion criteria for those included in the analytic cohort.

Table 3.1. Outcome Variable Definitions and Assumptions

STATE	Visit Up-to-Date	Treated	BP Control	Definitions
1	1	0	1	Visit is up to date, no meds, and in control
2	1	1	1	Visit is up to date, yes meds, and in control
3	1	1	0	Visit is up to date, yes meds, but not in control
4	1	0	0	Visit is up to date, no meds, and not in control
5	0	1	0	Visit is NOT up to date, yes meds, but not in control
6	0	0	2	Visit is NOT up to date, no meds, and unknown if in control
7	0	0	0	Visit is NOT up to date, no meds, and not in control
8	1	1	2	Visit is up to date, meds, and unknown if in control
9	1	0	2	Visit is up to date, no meds, and unknown if in control
10	0	1	1	Visit is NOT up to date, yes meds, and in control
11	0	1	2	Visit is NOT up to date, yes meds, and unknown if in control
12	0	0	1	Visit is NOT up to date, no meds, and in control

Above are the 12 states based on all combinations of the three variables, where states 1-7 are observed in the data and states 8-12 are not observed. States 1-7 are color coded to represent most optimal to least optimal states, with gray representing unobserved states. Below are the coding rules for used to define engagement states.

Visit Up-To-Date (Yes/No):
No (0) = if no visit AND NOT in control at last encounter
No (0) = if there is no visit AND in control at last encounter] BUT more than 12 months since last visit
Yes (1) = if there is a visit in that month
Yes (1) = No visit AND in control at last encounter AND less than 12 months since last visit

Treated (Yes/No):
Yes(1) = if evidence of any BP meds at an encounter
Yes(1) = if last visit had evidence of treatment and it is no more than 6 months
No (0)= if no evidence of BP med at an encounter
No (0)= more than 6 months since a visit where there was evidence of an active BP med order

BP Control (Yes/No/Unknown):
No (0) = if last visit is not in control and no other info available
Yes (1)= if last visit is in control AND not more than 12 months since visit/encounter
Unknown (2)= if last visit is in control AND more than 12 months since last visit without additional info

Table 3.2. Measures of Cluster Quality

Name	Range	Min/Max	Interpretation
Average Silhouette Width Weighted (ASWw)	[-1;1]	Max	Coherence of assignments. High coherence indicates high between-group distances and strong within-group homogeneity, for floating point weights.
Hubert's Gamma (HG)	[-1;1]	Max	Measure of the capacity of the clustering to reproduce the distances (order of magnitude).
Point Biserial Correlation (PBC)	[-1;1]	Max	Measure of the capacity of the clustering to reproduce the distances.
Hubert's C (HC)	[0;1]	Min	Gap between the partition obtained and the best partition theoretically possible with this number of groups and these distances.

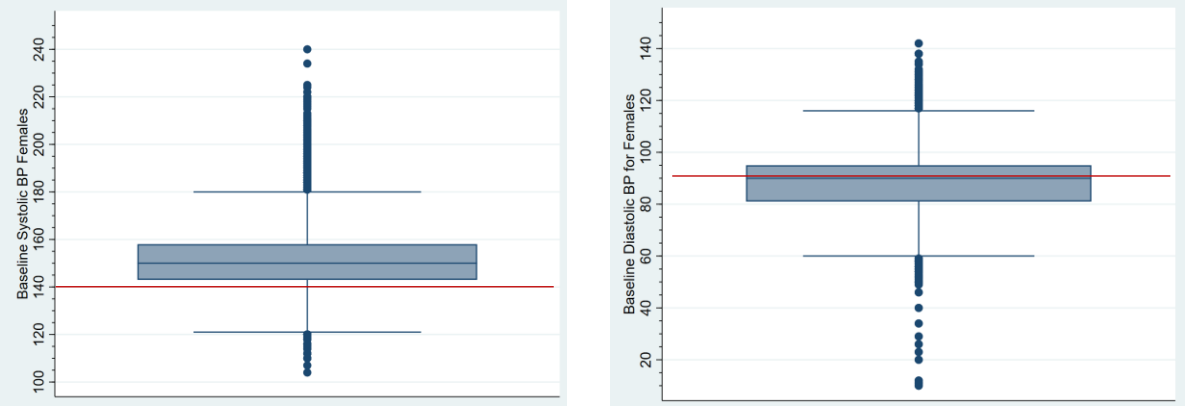
The Average Silhouette Width Weighted (ASWw) is based on the coherence of the assignment of an observation to a given group, comparing the average weighted distance of an observation from the other members of its group and from the closest group. If this is strong, it means that the groups are clearly separated or that the homogeneity of the groups is high. Hubert's Gamma (HG) and Point Biserial Correlation (PBC) follow the same logic, measuring the capacity of a cluster of the data to reproduce the distance matrix. The PBC metric measures the capacity of a cluster to reproduce the exact value of the distances. The HG is based on the concordances where a cluster is valid if the distances between the clusters are greater than those within the clusters. The Hubert's C index (HC) compares the partition obtained with the best partition that could have been obtained with this number of clusters and the distance matrix.
Reference: https://cran.r-project.org/web/packages/WeightedCluster/vignettes/WeightedCluster.pdf

Table 3.3. Baseline Characteristics by Sex

		Females	Males
	N	22,727	17,742
Race/ethnicity, N(%)	Non-hispanic White	12,911 (56.8)	10,206 (57.5)
	Non-hispanic Black	980 (4.3)	694 (3.9)
	Non-Hispanic Asian	3,748 (16.5)	2,644 (14.9)
	American Indian/Alaka Native	61 (0.3)	49 (0.3)
	Native Hawaiian/Pacific Islander	120 (0.5)	102 (0.6)
	Other	1,687 (7.4)	1,602 (9.0)
	Mulit-Race	371 (1.6)	226 (1.3)
	Hispanic	2,849 (12.5)	2,219 (12.5)
Age Categories, N(%)	Less than 30 yrs	2,392 (10.5)	2,384 (13.4)
	31-40 yrs	5,090 (22.4)	4,163 (23.5)
	41-50 yrs	5,693 (25.1)	4,654 (26.2)
	51-60 yrs	4,749 (20.9)	3,351 (18.9)
	61-70 yrs	2,740 (12.1)	1,674 (9.4)
	71-80 yrs	1,337 (5.9)	633 (3.6)
	Greater than 81 yrs	0 (0.0)	0 (0.0)
Insurance Type, N(%)	Commercial PPO/FFS	11,223 (49.4)	9,794 (55.2)
	Commercial HMO	3,540 (15.6)	3,043 (17.2)
	Medicaid/Medi-Cal	785 (3.5)	478 (2.7)
	Medicare FFS/HMO	6,263 (27.6)	3,605 (20.3)
	Self/Undocumented	889 (3.9)	790 (4.5)
	Other	27 (0.1)	32 (0.2)
Smoking History, N(%)	(1) current	1,339 (5.9)	1,647 (9.3)
	(2) past	4,420 (19.4)	4,617 (26.0)
	(3) never	13,428 (59.1)	8,749 (49.3)
	(4) unknown/other	3,540 (15.6)	2,729 (15.4)
BMI Category, N(%)	< 25 kg/m^2	321 (1.5)	39 (0.2)
	25 < 27 kg/m^2	6,082 (28.5)	2,689 (15.7)
	27 < 30 kg/m^2	6,745 (31.6)	7,028 (41.1)
	30 < 40 kg/m^2	4,298 (20.1)	4,569 (26.8)
	> 40 kg/m^2	3,912 (18.3)	2,754 (16.1)
	T2DM, N(%)	2,645 (11.6)	2,715 (15.3)
	Depression, N(%)	4,055 (17.8)	1,825 (10.3)
	CHF, N(%)	432 (1.9)	403 (2.3)
	CVD, N(%)	1,787 (7.9)	1,624 (9.2)
	Cancer, N(%)	2,059 (9.1)	1,498 (8.4)
	COPD, N(%)	1,432 (6.3)	1,131 (6.4)
	Asthma, N(%)	3,330 (14.7)	1,928 (10.9)
	Liver, N(%)	1,672 (7.4)	1,612 (9.1)
	Renal, N(%)	1,028 (4.5)	957 (5.4)
	ESRD, N(%)	45 (0.2)	54 (0.3)
	Migraine, N(%)	2,716 (12.0)	742 (4.2)
	Systolic BP (mmHg), Mean (SD)	151.3 (12.5)	149.4(11.5)
	Diastolic BP(mmHg),Mean (SD)	88.3(10.4)	89.4(10)
	Medication Initiation, N (%)	5,533 (24.4)	4,396 (24.8)

BP = blood pressure; SCM = Suboptimal BP care management; OCM = Optimal BP care management; UCM = Unknown BP Care Management; NHW = non-Hispanic white; NHB = non-Hispanic Black; NHA = non-Hispanic Asian; AIAN= non-Hispanic American Indian/Alaskan Native; NHPI = non-Hispanic Native Hawaiian/Pacific Islander; PPO = preferred provider organization; FFS = fee for service; HMO = health maintenance organization; BMI= body mass index; T2DM = type 2 diabetes; CHF = congestive heart failure; CVD = cardiovascular disease; COPD= chronic obstructive pulmonary disease; ESRD = End stage renal disease; SD = standard deviation

Females



Males

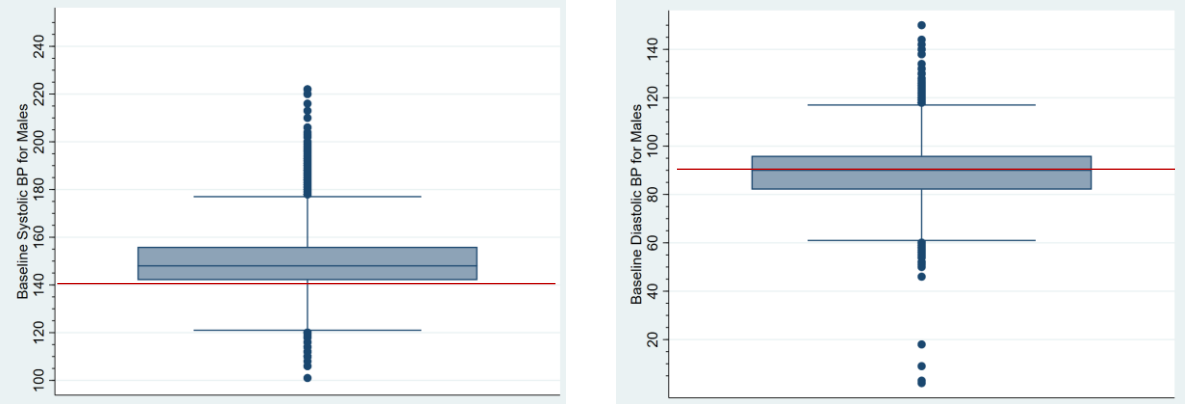
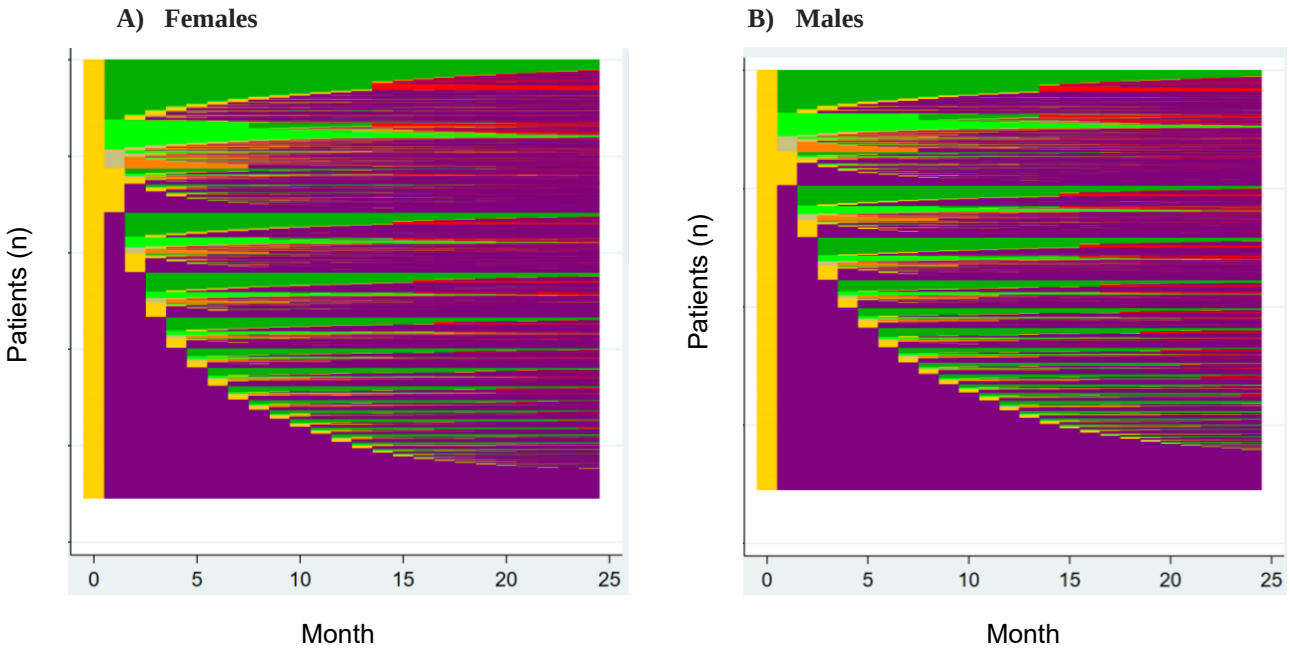


Figure 3.2. Baseline Blood Pressure Distribution
This figure shows the distribution of blood pressure measures at baseline by sex. Red line indicates threshold for blood pressure contro; There were several outlier measures for diastolic BP that were <= 40 mmHg for women (n = 10) and men (n =4). We believe these were due to data entry error and each is assoicated with a viable systolic blood pressure measure, as well as complete documentation of other clinical information.
BP = Bood Pressure



1	Visit is up to date, no meds, and in control
2	Visit is up to date, yes meds, and in control
3	Visit is up to date, yes meds, but not in control
4	Visit is up to date, no meds, and not in control
5	Visit is NOT up to date, yes meds, but not in control
6	Visit is NOT up to date, no meds, and unknown if in control
7	Visit is NOT up to date, no meds, and not in control

Figure 3.3. Index Plot for Clinical Engagement Trajectories
Individual-level engagement trajectories represented in the EHR data over a 2-year period. Each individual patient is a row on the y-axis; 24 months post incident diagnosis (i.e. index visit) is represented on the x-axis. Panel A is women only (n = 22.727) and Panel B is men only (n = 17,742). We categorized month post-index into 1 of 7 mutually exclusive states.

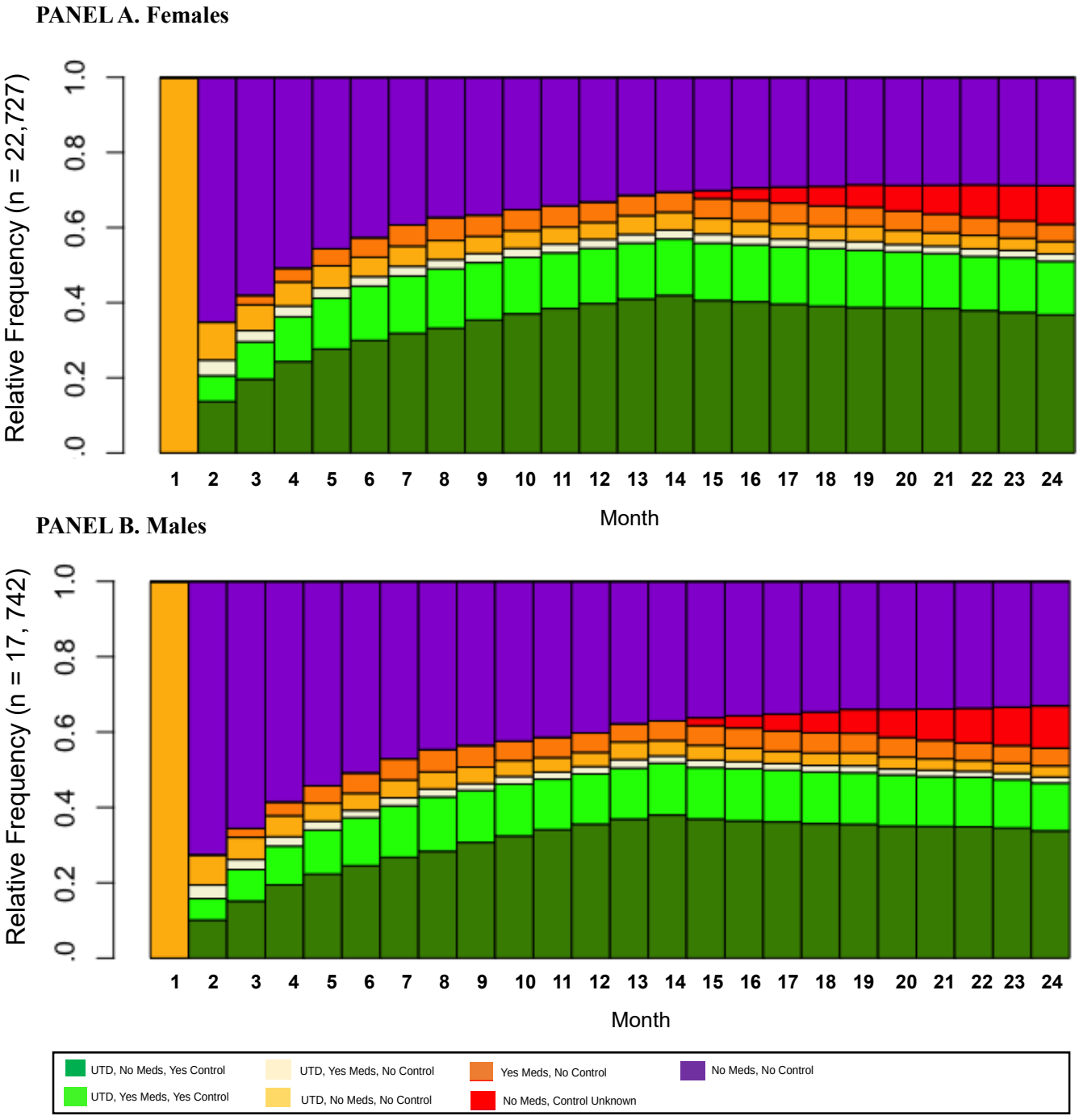


Figure 3.4. State Frequency plots for 10 Clusters by Sex Over Time
State frequency plots, also known as state distribution plots, aggregate the frequency of each state at each timepoint across the population. This figure shows the state distribution plot for women (n = 22,727, Panel A) and men (n = 17,742, Panel B). At the beginning of the sequences, only one state occurs: having an up-to-date visit with no evidence of medication and blood pressure uncontrolled. At the end of the sequences, all seven states occur.

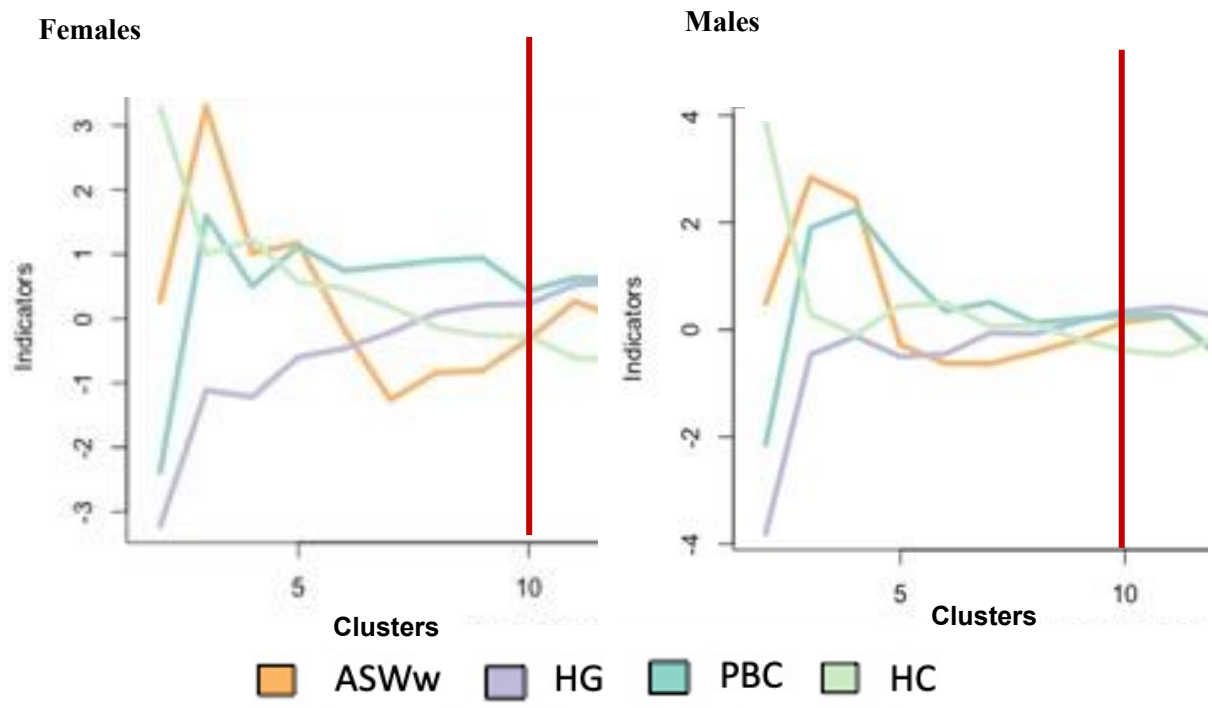
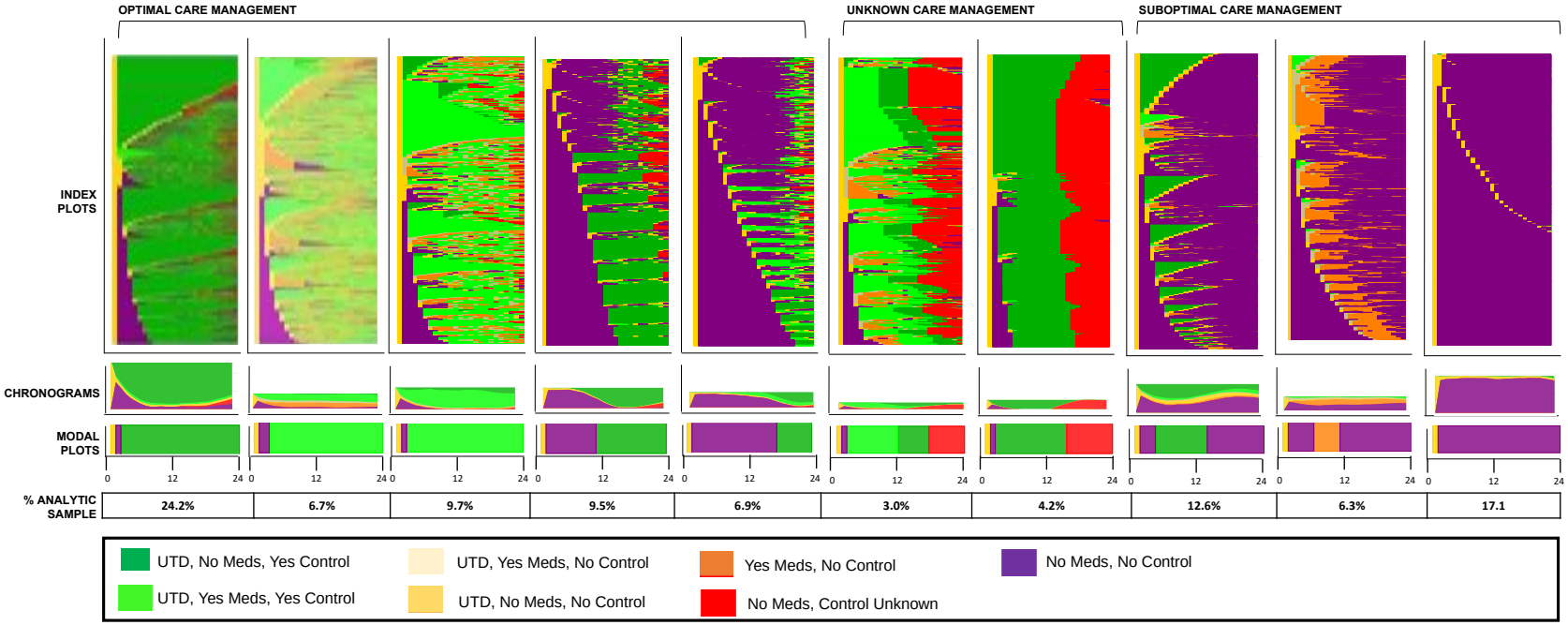


Figure 3.5. Cluster Quality Assessment
The red line indicates the selection of 10 clusters and associated metrics. The Average Silhouette Width Weighted (ASWw) is based on the coherence of the assignment of an observation to a given group, comparing the average weighted distance of an observation from the other members of its group and from the closest group. If this is strong, it means that the groups are clearly separated or that the homogeneity of the groups is high. Hubert's Gamma (HG) and Point Biserial Correlation (PBC) follow the same logic, measuring the capacity of a cluster of the data to reproduce the distance matrix. The PBC metric measures the capacity of a cluster to reproduce the exact value of the distances. The HG is based on the concordances where a cluster is valid if the distances between the clusters are greater than those within the clusters. The Hubert's C index (HC) compares the partition obtained with the best partition that could have been obtained with this number of clusters and the distance matrix.

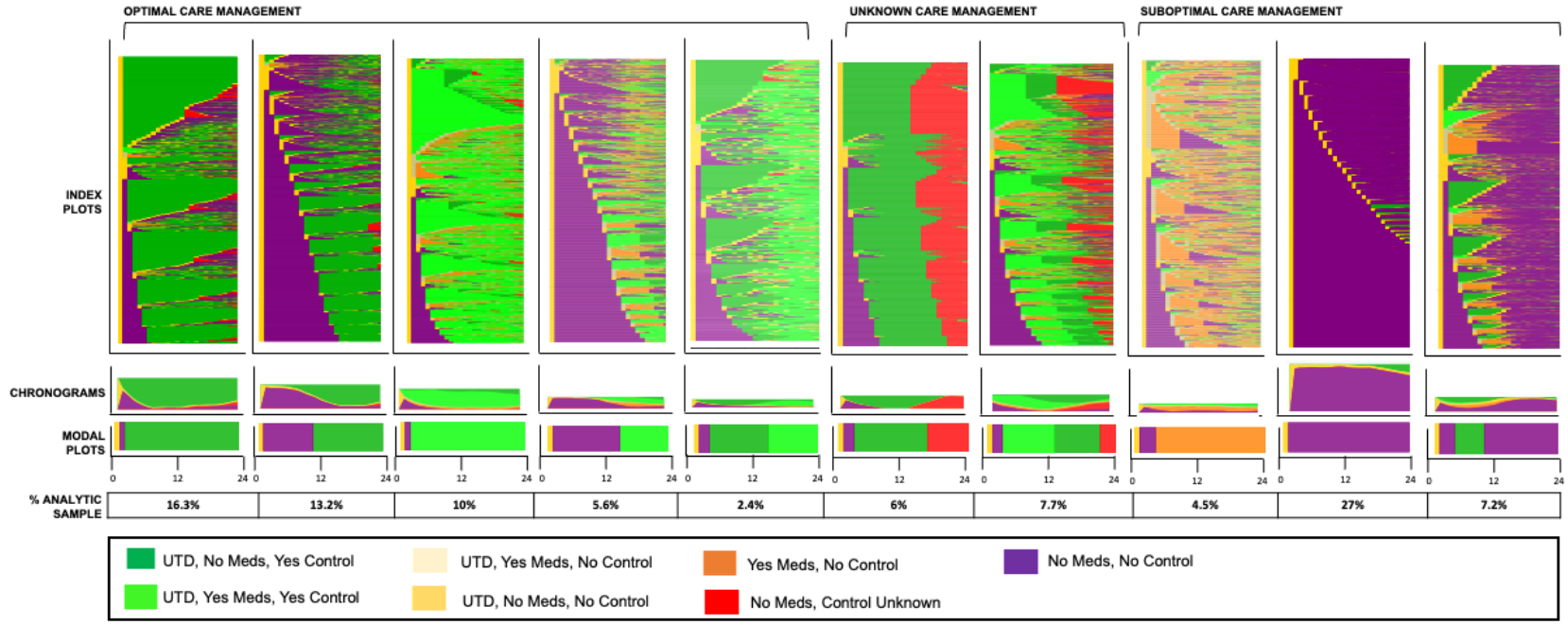
PANEL A. Females



UTD = Visit is "up to date"; Meds = Blood pressure medication; Control.= Systolic blood pressure < 140 mmHg and Diastolic blood pressure < 90 mmHg.

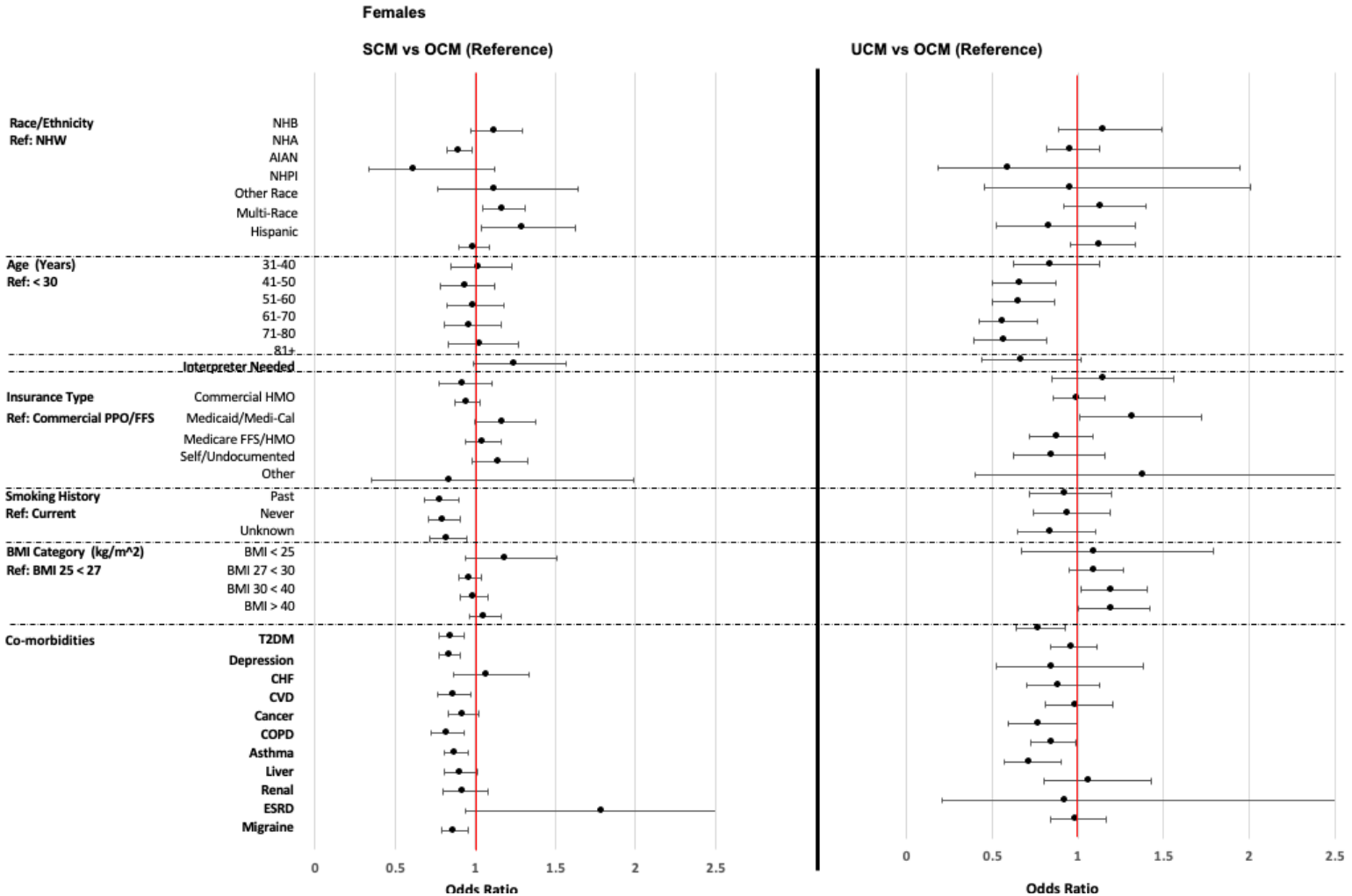
Figure 3.6. Index, Chronogram and Modal plots for Ten Clusters by Sex-group
Visual representation of the 10 engagement sequences used to characterize the clinical engagement trajectories for newly diagnosed patients with HTN in the 2 years post incident diagnosis (i.e. index visit). Panel A is women only (n = 22.727) and Panel B is men only (n = 17,742). We categorized month post-index into 1 of 7 mutually exclusive states. We converted thousands of individual-level trajectories into a meaningful and interpretable number of similar engagement sequences. We then categorized the 10 clusters into three categories representing optimal and suboptimal HTN management. The index plots show individual-level engagement trajectories represented in the EHR data over a 24- month period. The chronograms show the frequency of state for a given month and are specific to individuals within a given cluster, thus reflecting the proportion of the analytics sample that is part of a given cluster. Modal plots represent the most common state at each timepoint (i.e. month post index) and serve as a high-level summary

PANEL B. Males



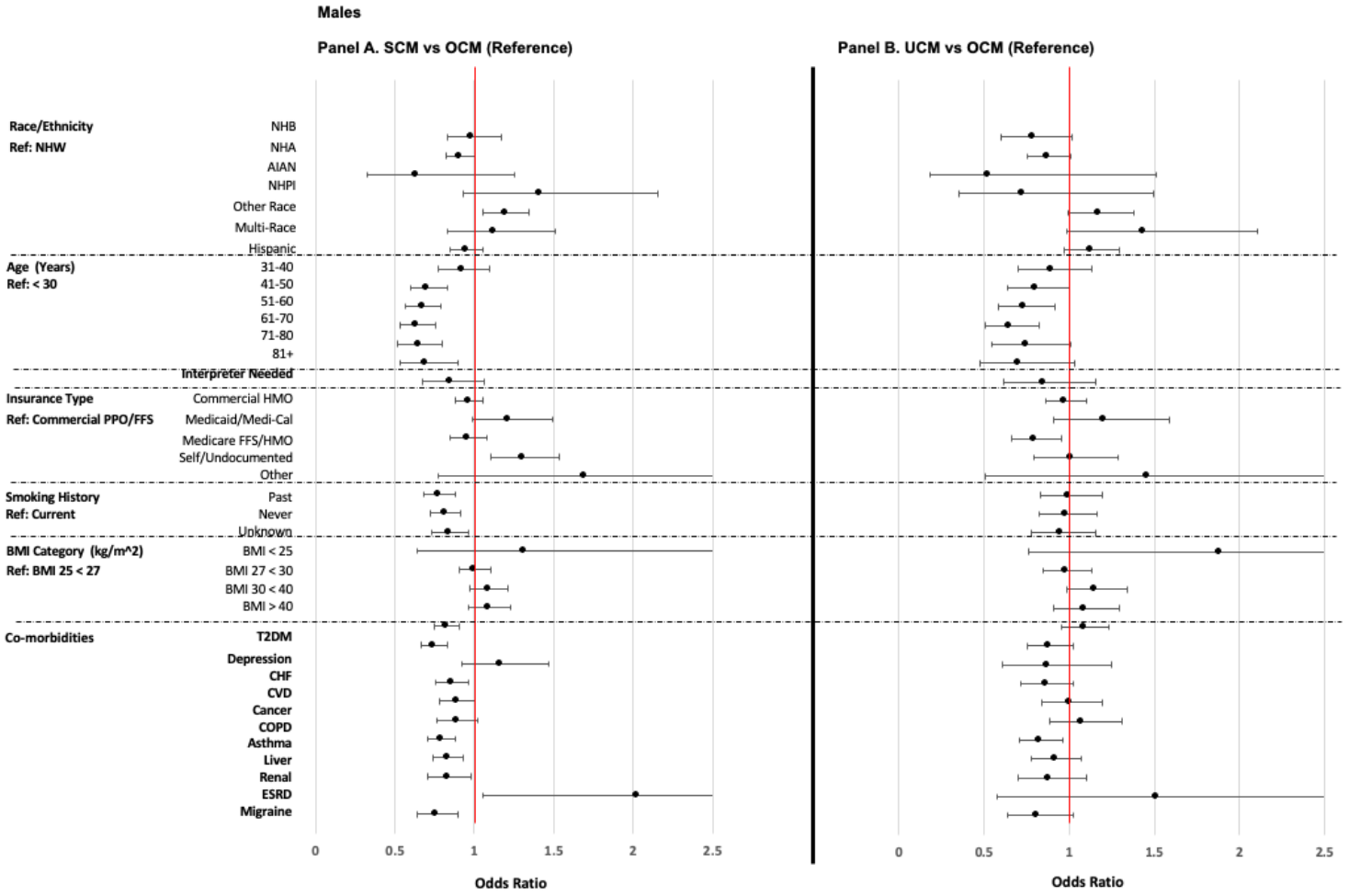
UTD = Visit is "up to date"; Meds = Blood pressure medication; Control.= Systolic blood pressure < 140 mmHg and Diastolic blood pressure < 90 mmHg.

Visual representation of the 10 engagement sequences used to characterize the clinical engagement trajectories for newly diagnosed patients with HTN in the 2 years post incident diagnosis (i.e. index visit). Panel A is women only (n = 22.727) and Panel B is men only (n = 17,742). We categorized month post-index into 1 of 7 mutually exclusive states. We converted thousands of individual-level trajectories into a meaningful and interpretable number of similar engagement sequences. We then categorized the 10 clusters into three categories representing optimal and suboptimal HTN management. The index plots show individual-level engagement trajectories represented in the EHR data over a 24- month period. The chronograms show the frequency of state for a given month and are specific to individuals within a given cluster, thus reflecting the proportion of the analytics sample that is part of a given cluster. Modal plots represent the most common state at each timepoint (i.e. month post index) and serve as a high-level summary



BP = blood pressure; SCM = Suboptimal BP care management; OCM = Optimal BP care management; UCM = Unknown BP Care Management; NHW = non-Hispanic white; NHB = non-Hispanic Black; NHA = non-Hispanic Asian; AIAN= non-Hispanic American Indian/Alaskan Native; NHPI = non-Hispanic Native Hawaiian/Pacific Islander; PPO = preferred provider organization; FFS = fee for service; HMO = health maintenance organization; BMI= body mass index; T2DM = type 2 diabetes; CHF = congestive heart failure; CVD = cardiovascular disease; COPD= chronic obstructive pulmonary disease; ESRD = End stage renal disease

Figure 3.7. Multinomial Regression Results for 3 Outcomes by Sex
These figures show the odds ratios for covariates included in the multinomial regression models for females and males



BP = blood pressure; SCM = Suboptimal BP care management; OCM = Optimal BP care management; UCM = Unknown BP Care Management; NHW = non-Hispanic white; NHB = non-Hispanic Black; NHA = non-Hispanic Asian; AIAN= non-Hispanic American Indian/Alaskan Native; NHPI = non-Hispanic Native Hawaiian/Pacific Islander; PPO = preferred provider organization; FFS = fee for service; HMO = health maintenance organization; BMI= body mass index; T2DM = type 2 diabetes; CHF = congestive heart failure; CVD = cardiovascular disease; COPD= chronic obstructive pulmonary disease; ESRD = End stage renal disease

3.9 APPENDICES

Appendix 1

Data cleaning details and assumption for the creation of individual healthcare engagement trajectories

States	Variable Definitions
Up-to-date on their expected primary care visits Yes/No)	For a given month (up to 24), if there is a visit documented then this was coded as "visit up-to-date". These definitions were informed by national treatment guidelines which recommend return visit within one-month of an uncontrolled BP for those with diagnosed HTN[25], and at least annual exams for those with controlled hypertension. For our definitions, if no visit was documented for a given month, we defined patients as "up-to-date" on their clinical visits based on two factors: 1)BP control status at the prior visit and 2) time between encounters. If BP was controlled at preceding encounter, and the current encounter occurs within 12 months of the preceding one, then the patient was considered "up-to-date with their visit". If BP was controlled but there are greater than 12 months without a follow-up visit, these were considered to be months where the visit is not "up-to-date". If BP was uncontrolled at preceding encounter, and the current encounter occurs within 1 month of the preceding one, then this is considered "up-to-date". If BP was uncontrolled and there were more than 1 month without a follow-up visit, these are considered to be months where the visit was not "up-to-date".
Order for a BP medication (Yes/No)	We defined BP treatment based on available evidence of active orders for any BP medication based on medication class (i.e. antihypertensive, beta blockers, calcium channel blockers, diuretics, see Appendix 2) at the time of a visit for a given month. We used two definitions for identifying individuals who are receiving treatment for BP management in order to account for variation in default EHR settings. When a medication order is placed with an electronic health record, it is often accompanied by an automated renewal for a given time period. This may vary across clinicians and practices. First, if no visit occurred within a given month and the assessment month is within 6 months of the last documented visit with evidence of an active medication order, an individual was considered to be treated.
Blood pressure control (Yes/No/Unknown)	We defined blood-pressure control status based on available evidence of systolic BP >= 140 mmHg and/or diastolic BP >= 90 mmHg at the time of a visit for a given month that a visit occurred. If no visit occurred in a given month, the individual was considered to not be in control if the preceding visit was in the uncontrolled range. The individual was considered in control if no visit occurred but the month is within 12 months of a preceding visit with BP control. If greater than 12 months from a visit with controlled BP, individual's BP control status was considered to be "unknown".

Appendix 2

Variable Definitions

Class	GPI 6-digit for Antidepressants; GPI 2-digit for all other medication classes
Antihypertensive ACE inhibitor, angiotensin receptor blocker, aldosterone antagonist, alpha blocker, beta blocker; centrally acting antihypertensive, renin antagonist, vasodilator, and "other"	36
Beta blockers	33
Calcium blockers	34
Diuretics (K-sparing, Loop, and Thiazide)	37

Blood Pressure Medication Classes – The following classes are considered: diuretics (K-sparing, Loop, and Thiazide), ACE inhibitor, angiotensin receptor blocker, aldosterone antagonist, alpha blocker, beta blocker, calcium channel blocker, centrally acting antihypertensive, renin antagonist, vasodilator, and "other" (treated as a single class for metric calculation).

Condition	ICD-9CM	ICD-10	Description
Serious Mental Illness	See additional Table	See Additional Table	See Additional Table
Myocardial infarction	410-410.9 412	I21.x, I22.x, I25.2	Acute MI Prior MI
Congestive heart failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 425.4–425.9, 428.x	I09.9, I11.0, I13.0, I13.2, I25.5, I42.0, I42.5–I42.9, I43.x, I50.x, P29.0	Heart Failure
Peripheral vascular disease	093.0, 437.3, 440.x, 441.x, 443.1–443.9, 47.1, 557.1, 557.9, V43.4	I70.x, I71.x, I73.1, I73.8, I73.9, I77.1, I79.0, I79.2, K55.1, K55.8, K55.9, Z95.8, Z95.9	Peripheral vasc disease, including claudication Aortic aneurysm Gangrene Blood vessel replace by prosthesis Resection and replace of lower limb arteries
Cerebrovascular disease	362.34, 430.x–438.x	G45.x, G46.x, H34.0, I60.x–I69.x	Cerebrovascular disease
Dementia	290.x, 294.1, 331.2	F00.x–F03.x, F05.1, G30.x, G31.1	Senile and presenile dementias

Condition	ICD-9CM	ICD-10	Description
Chronic pulmonary disease	416.8, 416.9, 490.x–505.x, 506.4, 508.1, 508.8	I27.8, I27.9, J40.x–J47.x, J60.x–J67.x, J68.4, J70.1, J70.3	Chronic obstructive pulmonary disease Pneumoconioses Chronic resp disease due to fumes/vapors
Rheumatologic disease	446.5, 710.0–710.4, 714.0–714.2, 714.8, 725.x	M05.x, M06.x, M31.5, M32.x–M34.x, M35.1, M35.3, M36.0	Systemic lupus erythematosus Systemic sclerosis Polymyositis Adult rheumatoid arthritis
Peptic Ulcer disease	531.x–534.x	K25.x–K28.x	Gastric, duodenal and gastrojejunal ulcers
Mild liver disease	070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 070.6, 070.9, 570.x, 571.x, 573.3, 573.4, 573.8, 573.9, V42.7	B18.x, K70.0–K70.3, K70.9, K71.3–K71.5, K71.7, K73.x, K74.x, K76.0, K76.2–K76.4, K76.8, K76.9, Z94.4	Alcoholic cirrhosis Cirrhosis without mention of alcohol Biliary cirrhosis Chronic hepatitis
Moderate/severe liver disease	456.0–456.2, 572.2–572.8	I85.0, I85.9, I86.4, I98.2, K70.4, K71.1, K72.1, K72.9, K76.5, K76.6, K76.7	Hepatic coma, portal hypertension, other sequelae of chronic liver disease Esophageal varices
Diabetes without chronic complications	250.0–250.3, 250.8, 250.9	E10.0, E10.1, E10.6, E10.8, E10.9, E11.0, E11.1, E11.6, E11.8, E11.9, E12.0, E12.1, E12.6, E12.8, E12.9, E13.0, E13.1, E13.6, E13.8, E13.9, E14.0, E14.1, E14.6, E14.8, E14.9	Diabetes with or without acute metabolic dist. Diabetes with peripheral circulatory disorders

Condition	ICD-9CM	ICD-10	Description
Diabetes with chronic complications	250.4–250.7	E10.2–E10.5, E10.7, E11.2–E11.5, E11.7, E12.2–E12.5, E12.7, E13.2–E13.5, E13.7, E14.2–E14.5, E14.7	Diabetes with renal, ophthalmic, or neurological manifestations
Hemiplegia or paraplegia	334.1, 342.x, 343.x, 344.0–344.6, 344.9	G04.1, G11.4, G80.1, G80.2, G81.x, G82.x, G83.0–G83.4, G83.9	Paraplegia Hemiplegia
Renal disease	403.01, 403.11, 403.91, 404.02, 404.03, 404.12, 404.13, 404.92, 404.93, 582.x, 583.0–583.7, 585.x, 586.x, 588.0, V42.0, V45.1, V56.x	I12.0, I13.1, N03.2–N03.7, N05.2–N05.7, N18.x, N19.x, N25.0, Z49.0–Z49.2, Z94.0, Z99.2	Chronic glomerulonephritis Nephritis and nephropathy Chronic renal failure Renal failure, unspecified Disorders resulting from impaired renal func.
Any malignancy, including lymphoma and leukemia, except malignant neoplasm of skin	140.x–172.x, 174.x–195.8, 200.x–208.x, 238.6	C00.x–C26.x, C30.x–C34.x, C37.x–C41.x, C43.x, C45.x–C58.x, C60.x–C76.x, C81.x–C85.x, C88.x, C90.x–C97.x	Malignant neoplasms Leukemia and lymphoma
Metastatic solid tumor	196.x–199.x	C77.x–C80.x	Secondary malignant neoplasm of lymph nodes and other organs
AIDS/HIV	042.x–044.x	B20.x–B22.x, B24.x	HIV infection with related specific conditions

Appendix 3

Cluster Quality Metrics Data

	Females				Males			
	PBC	**HG**	**ASWw**	**HC**	**PBC**	**HG**	**ASWw**	**HC**
Cluster 2	0.44	0.51	0.29	0.24	0.49	0.57	0.37	0.2
Cluster 3	0.61	0.72	0.36	0.14	0.71	0.84	0.44	0.08
Cluster 4	0.56	0.71	0.31	0.15	0.72	0.87	0.43	0.06
Cluster 5	0.59	0.77	0.31	0.12	0.67	0.84	0.35	0.08
Cluster 6	0.57	0.78	0.28	0.12	0.63	0.85	0.34	0.08
Cluster 7	0.58	0.81	0.26	0.11	0.63	0.88	0.34	0.07
Cluster 8	0.58	0.84	0.27	0.09	0.61	0.88	0.34	0.07
Cluster 9	0.58	0.85	0.27	0.09	0.62	0.9	0.35	0.06
Cluster 10	0.56	0.85	0.28	0.09	0.62	0.91	0.36	0.05

The yellow highlight indicates the metrics associated with 10 clusters for the main analysis (see Figure 3.5) as well as those associated with 8 clusters (see Appendix 4). The Average Silhouette Width Weighted (ASWw) is based on the coherence of the assignment of an observation to a given group, comparing the average weighted distance of an observation from the other members of its group and from the closest group. If this is strong, it means that the groups are clearly separated or that the homogeneity of the groups is high. Hubert's Gamma (HG) and Point Biserial Correlation (PBC) follow the same logic, measuring the capacity of a cluster of the data to reproduce the distance matrix. The PBC metric measures the capacity of a cluster to reproduce the exact value of the distances. The HG is based on the concordances where a cluster is valid if the distances between the clusters are greater than those within the clusters. The Hubert's C index (HC) compares the partition obtained with the best partition that could have been obtained with this number of clusters and the distance matrix.

Reference: https://cran.r-project.org/web/packages/WeightedCluster/vignettes/WeightedCluster.pdf

Appendix 4

Below are the modal plots and chronograms for 8 clusters by sex

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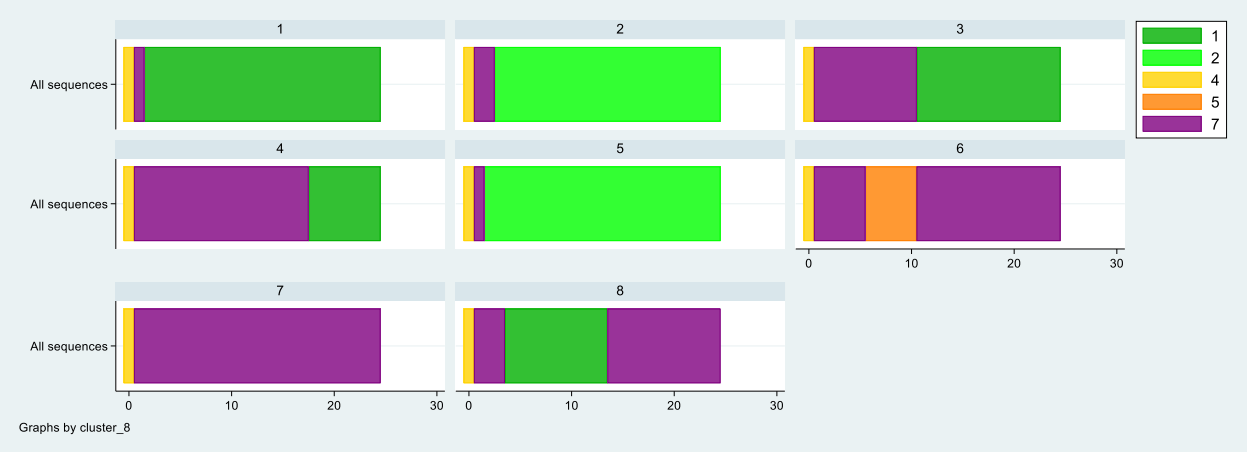
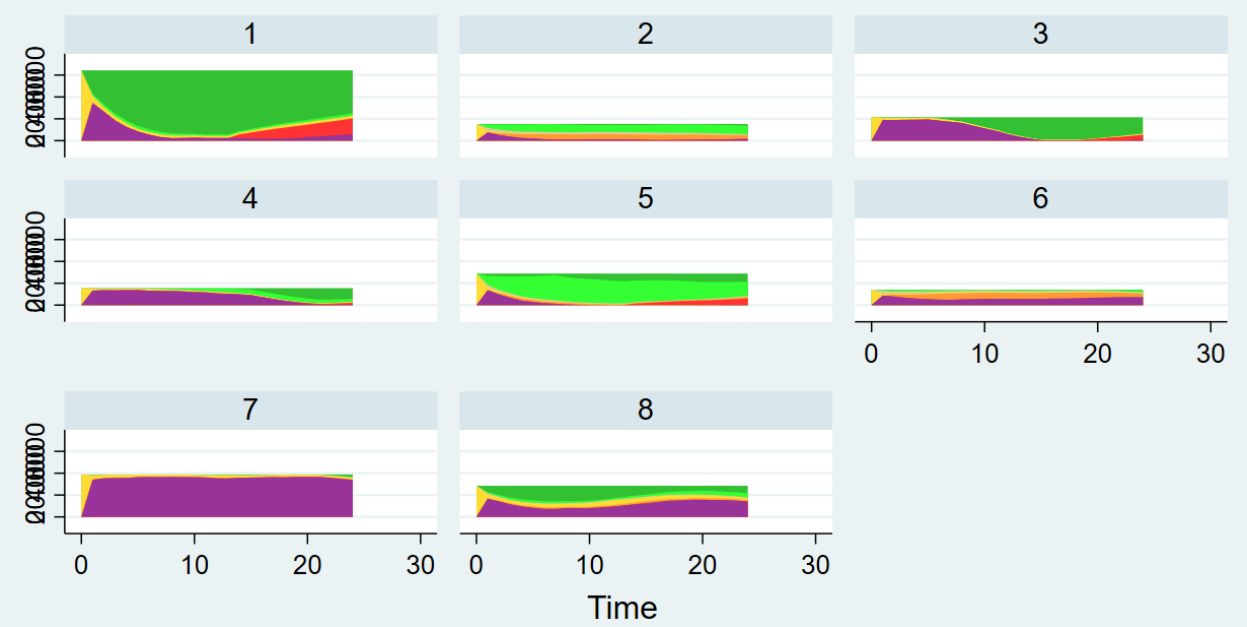
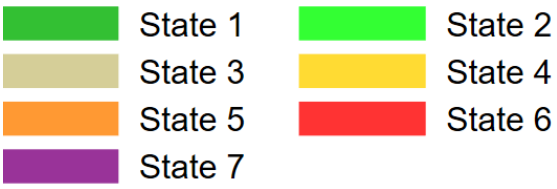
FEMALES

Modal Plots



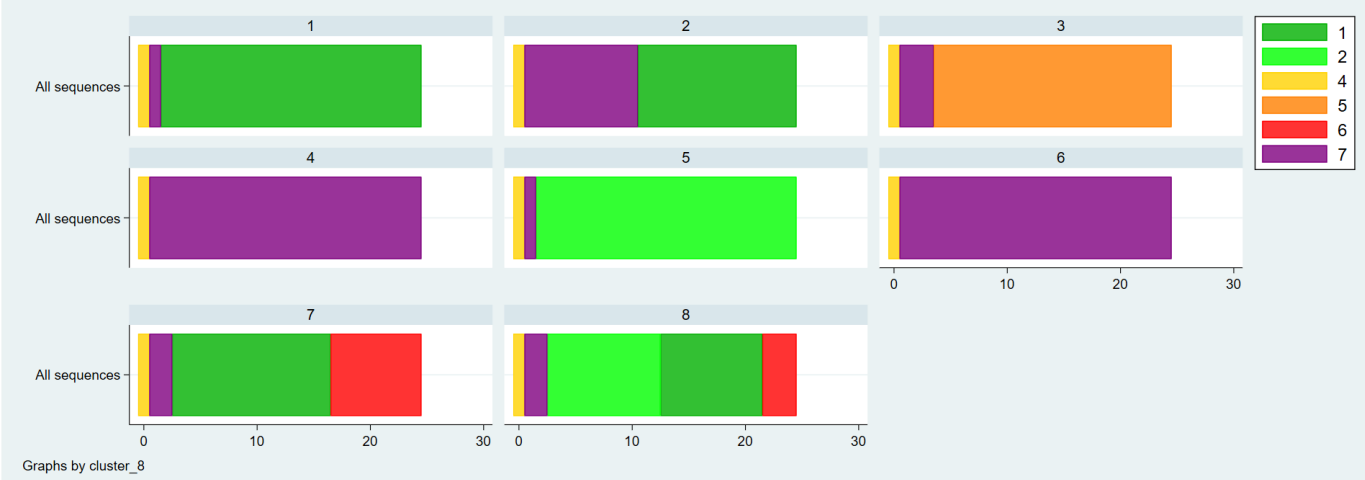
Chronograms



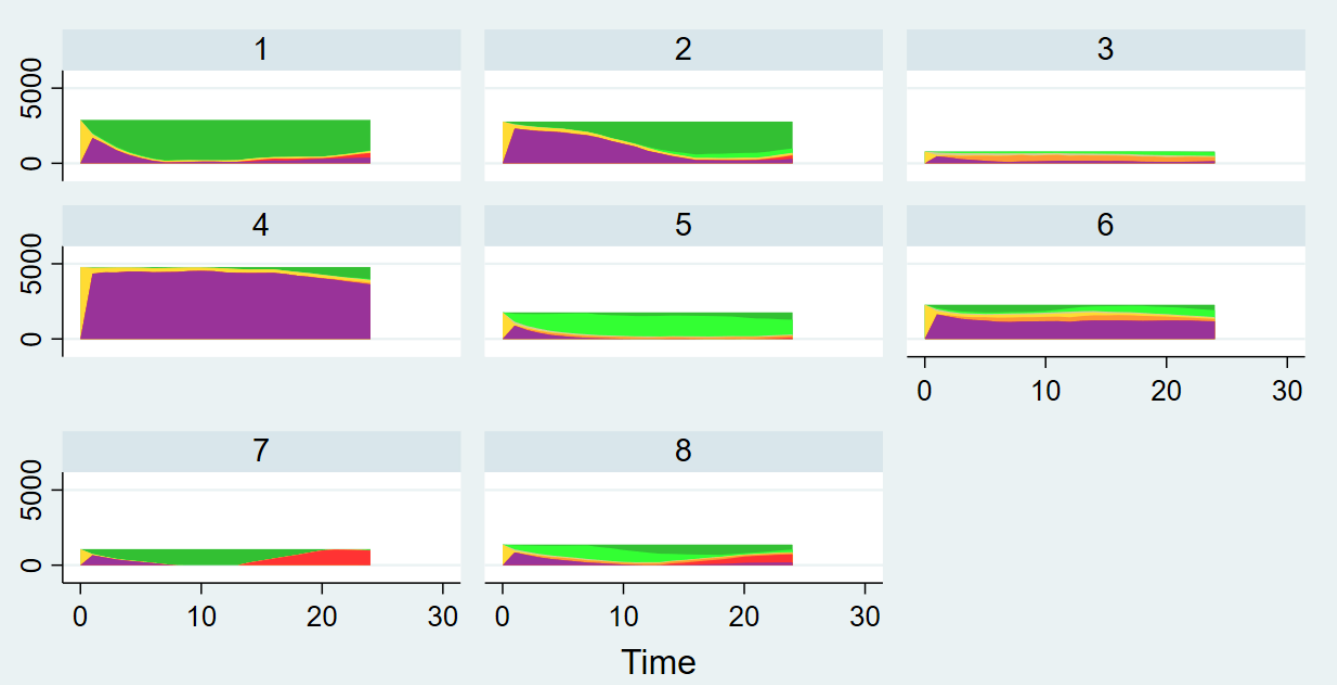


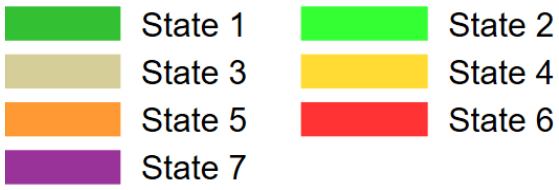
MALES

Modal Plots



Chronograms





Appendix 5

Below are the logistic regression results for a binary outcome (Optimal Yes/No) for 10 clusters groups as either optimal or not optimal

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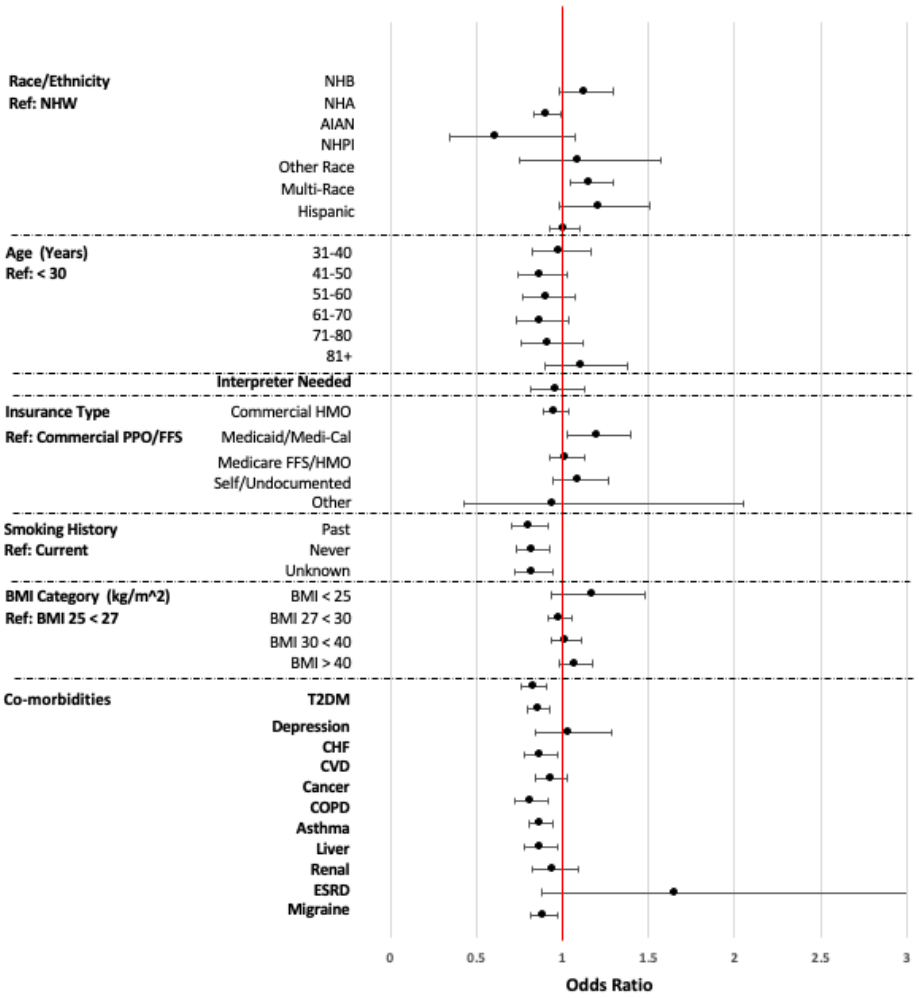
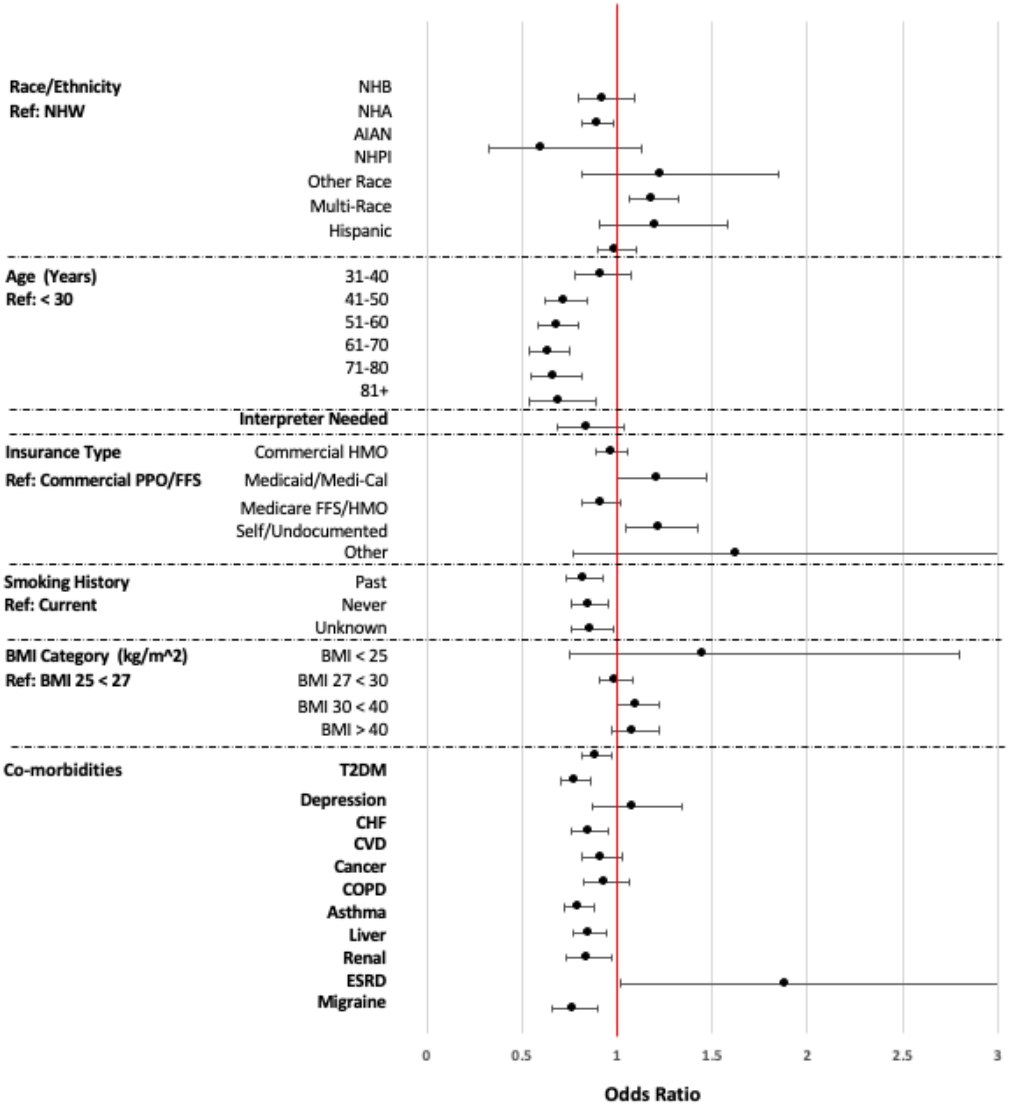
Panel A. Females



BP = blood pressure; SCM = Suboptimal BP care management; OCM = Optimal BP care management; UCM = Unknown BP Care Management; NHW = non-Hispanic white; NHB = non-Hispanic Black; NHA = non-Hispanic Asian; AIAN= non-Hispanic American Indian/Alaskan Native; NHPI = non-Hispanic Native Hawaiian/Pacific Islander; PPO = preferred provider organization; FFS = fee for service; HMO = health maintenance organization; BMI= body mass index; T2DM = type 2 diabetes; CHF = congestive heart failure; CVD = cardiovascular disease; COPD= chronic obstructive pulmonary disease; ESRD = End stage renal disease

Panel B. Males



BP = blood pressure; SCM = Suboptimal BP care management; OCM = Optimal BP care management; UCM = Unknown BP Care Management; NHW = non-Hispanic white; NHB = non-Hispanic Black; NHA = non-Hispanic Asian; AIAN= non-Hispanic American Indian/Alaskan Native; NHPI = non-Hispanic Native Hawaiian/Pacific Islander; PPO = preferred provider organization; FFS = fee for service; HMO = health maintenance organization; BMI= body mass index; T2DM = type 2 diabetes; CHF = congestive heart failure; CVD = cardiovascular disease; COPD= chronic obstructive pulmonary disease; ESRD = End stage renal disease

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CONCLUSION AND FORWARD

A substantial body of scientific literature and evidence suggests that up to 80% of a person's health is determined by social drivers of health- or the conditions in the environments where people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks. While upstream societal and social inequities undoubtedly play a major role in healthcare inequities and health disparities, healthcare affords an opportunity for mitigation of BP control disparities as it is a system that can be modified and optimized. Based on the findings of these analyses, there is an opportunity to optimize care process delivery for all patients, where implementation of appropriate and evidence-based strategies to manage BP is limited. Engagement with a care team is crucial to achieve blood pressure control and many people do not engage or do not sustain engagement. This may require innovative interventions which leverage technology to enhance access and patient engagement. Addressing social drivers of health to improve barriers to engagement must be a priority if disparities in BP control are to be eliminated.

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