Unblinded Title Page (include all contact information) and Word Count, number of figures, tables and number of text pages

Hypertension control during the COVID-19 pandemic: a cohort study among U.S. Veterans

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Acknowledgements of research support for the study: This material is based upon work supported by the Department of Veterans Affairs, Veterans Health Administration, Office of Research and Development, Health Services Research and Development, The Disrupted Care National Project, Award C19 21-287, PI: Davies.

Conflicts of Interest: CK has been an investigator on projects with research grants from Pfizer and Sanofi Pasteur for work unrelated to this manuscript. AJP is or has been principal investigator on research grants from Bayer, Boehringer-Ingelheim, Lundbeck, Reata and Vascular Dynamics to Yale University for work unrelated to this manuscript; has received honoraria for data safety monitoring activities from Ablative Solutions and KBP Biosciences; and has received consulting fees from BD, CinCor and Diamedica, all for work unrelated to this manuscript. DMW has received consulting fees for work unrelated to this manuscript from Pfizer, Merck, GSK, Affinivax, and Matrivax, and is Principal Investigator on research grants from Pfizer and Merck to Yale University for work unrelated to this manuscript. The other authors declare no conflicts.

Disclaimer: The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government

Word count: 3,464 [Limit: 3,500 words. The word count includes all text in the manuscript not including title page, abstract, references, tables, figures, figure legends, or appendices.]

Text Pages: 14

References: 25

Number of Tables and/or Figures: 3 Figures, 2 Tables.

Appendix now included

Running Title: COVID-19 & hypertension control in U.S. Veterans

Keywords: Hypertension, blood pressure, disrupted care, pandemic

Hypertension control during the COVID-19 pandemic: a cohort study among U.S. Veterans

Abstract (count: 250, limit: 250 words)

Background: Disruptions in health care were widespread during the COVID-19 pandemic.

Objective: We sought to examine if disruptions in follow-up interval contributed to hypertension control.

Design: Retrospective cohort study

Participants: We identified a cohort of individuals with hypertension in both pre-pandemic (March 2019-February 2020) and pandemic periods (March 2020-February 2022) in the Veterans Health Administration.

Main Measures: First, we calculated follow-up intervals between the last pre-pandemic and first pandemic blood pressure measurement during a primary care clinic visit, and between measurements in the pre-pandemic period. Next, we estimated the association between maintenance of (or achieving) hypertension control and period using generalized estimating equations. **We assessed associations between follow-up interval and control separately for periods.** Finally, we evaluated the interaction between period and follow-up length.

Key Results: 1,648,424 individuals met study inclusion criteria. Among individuals with controlled hypertension, likelihood of maintaining control was lower during the pandemic **versus pre-pandemic** (relative risk (RR) 0.93 (95% CI 0.93, 0.93)). **Longer follow-up intervals were associated with decreasing likelihood of maintaining controlled hypertension in both periods. Accounting for follow-up interval, likelihood of maintaining control was 2% lower during the pandemic versus pre-pandemic.** For uncontrolled hypertension, likelihood of gaining control was **modestly** higher during the pandemic **versus pre-pandemic (RR 1.01 (95%CI 1.01, 1.01)**. **Likelihood of gaining control** decreased with follow-up length during the pre-pandemic but not pandemic.

Conclusions: During the pandemic, longer follow-up between measurements contributed to lower likelihood of maintaining control. **Those with uncontrolled hypertension were modestly more likely to gain control in the pandemic.**

Word count: 3,464; limit: 3,500

Introduction

Nearly half of the adult population in the U.S. has a diagnosis of hypertension,[1,2] a strong modifiable risk factor for vascular disease.[3,4] The COVID-19 pandemic disrupted routine in-person healthcare visits,[5,6] likely disrupting routine blood pressure (BP) monitoring. For patients with hypertension taking antihypertensive medication, the American Heart Association guidelines recommend monthly office-based BP measurement until BP goals are reached, followed by three-to-six-month intervals.[7] Disruptions in monitoring BP during the pandemic potentially led to disruption in hypertension management and subsequent increases in cardiovascular disease. Indeed, a study among U.S. Veterans who had interrupted care following a previous national disaster demonstrated that disruption in monitoring was associated with increases in uncontrolled BP among those with hypertension.[8]

Some prior studies in the U.S.[9,10] demonstrated that BP increased during the pandemic without identifying specific modifiable risk factors for the increase. In their study of individuals participating in a U.S. employer-sponsored wellness program, Laffin et al[10] reported no significant change in BP between 2018 to March 2020 but significant increases for April-December 2020 compared with the prior year, where mean changes each month compared with the prior year ranged from 1.10 to 2.50 mm Hg for systolic blood pressure (SBP) and from 0.14 to 0.53 for diastolic blood pressure (DBP). In a study of individuals participating in a digital health hypertension program of at home monitoring, Shah et al 2022[9] reported the mean monthly number of BP readings increased during the pandemic from 7.3 to 9.3. Monthly adjusted mean SBP, DBP and mean arterial BP were all significantly higher in the pandemic period, and uncontrolled and severely uncontrolled hypertension increased from 15% to 19% and 4% to 5%, respectively. A

study within an integrated healthcare system in the US reported that among individuals with treated hypertension with a clinical BP measurement in the year pre-COVID-19, 72.6% had a clinical BP measurement in the first year of COVID-19, and in contrast to the other two studies[9,10] in the US reported that systolic BP and diastolic BP did not change significantly between these times.[11] A study conducted in Japan focusing on individuals with diabetes reported significant increases in office-based BP measurements following the state of the emergency announcement[12]. In contrast, a study in Brazil reported slight reductions in office-based and home-based BP measurements during the early months of the pandemic versus the prior year for patients treated for hypertension; it is not clear if this reduction was more pronounced among those who previously had controlled or uncontrolled hypertension.[13] Similarly, a study in Paris reported a decrease in home BP measurements during the lockdown period (March 17 to May 11, 2020) relative to the earlier part of 2020.[14]

While some studies have described COVID pandemic-related disruption on BP monitoring[15] and accompanying decreases in hypertension control,[16] what has not been assessed is the association between increased intervals between measurements and hypertension control, and how much pandemic-associated decrease in control could be attributed to this disruption. Our goal was to assess whether hypertension control between visits varied during the pandemic and pre-pandemic period, and whether differences in control for the two periods could be explained by differences in the length of follow-up interval between BP measurements. We examined these associations separately among individuals with controlled and uncontrolled hypertension in the Veterans Health Administration (VHA).

Methods

The study protocol was reviewed and approved by the Northern New England Research Collaborative Human Subjects Review Board of the Department of Veterans Affairs Medical Center in White River Junction, VT, and was granted an exemption for consent.

Data Source

The VHA provides comprehensive care to over nine million Veterans at more than 171 medical centers and 1,112 outpatient sites of care.[17] We analyzed electronic health record data from the VHA Corporate Data Warehouse which contains patient-level information on all patient encounters, vital signs, treatments, prescriptions, and laboratory results rendered in VHA medical facilities.

Study Design

The study period consisted of a one-year *pre-pandemic* period (March 2019 through February 2020) and a two-year *pandemic* period (March 2020 through February 2022). We identified a cohort of individuals with hypertension **that had at least one BP** measurement on date of a primary care visit in both pre-pandemic and pandemic periods. **All BP measurements in the pre-pandemic period and the first in the pandemic period were included in the analysis.** We classified patients as having controlled or uncontrolled hypertension at each measurement. **We estimated intervals between measurements during the pre-pandemic period from any measurements in the pre-pandemic period, and we defined the bridge as the interval transitioning between the last pre-pandemic and first pandemic measurements. With data from pre-pandemic intervals and the bridge interval, among individuals with controlled hypertension at the start of an interval, the association between maintenance of control of hypertension at the end of the interval and pandemic period was estimated**

(Figure 1a). Similarly, among individuals with uncontrolled hypertension at the start of an interval the association between gain of control of hypertension at the end of the interval and pandemic period was estimated (**Figure 1d**). Next, the association between length of follow-up interval and hypertension control was assessed for pandemic and pre-pandemic periods separately, and separately for those with controlled (**Figure 1b&1c**) and uncontrolled (**Figure 1e&1f**) hypertension at the start of follow-up, to determine if the association between follow-up interval and hypertension control differed by time period. **The pandemic effect was then reassessed while accounting for length of follow-up interval.**

Study Eligibility

We included individuals with hypertension, defined as at least one hypertension diagnosis in an inpatient or outpatient setting in the 2-year period preceding the study period and an outpatient treatment for hypertension in the 1-year period prior to the study period.[18] Hypertension diagnosis was identified by *International Classification of Diseases, Tenth Revision (ICD-10)* codes I10 (Essential [primary] hypertension), I11 (Hypertensive heart disease), I12 (Hypertensive chronic kidney disease), I13 (Hypertensive heart and chronic kidney disease), or I15 (Secondary hypertension). Outpatient treatment for hypertension included antihypertensive medications identified by the American Heart Association;[19] diuretics, beta-blockers, angiotensin converting enzyme inhibitors, angiotensin II receptor blockers, calcium channel blockers, alpha blockers, apha-2 receptor agonists, combined alpha and beta-blockers, and vasodilators.

Inclusion criteria required individuals to have at least one BP measurement from a primary care visit in the pre-pandemic and pandemic periods. We excluded BP readings when SBP or DBP was missing, SBP was < DBP, SBP was > 300 mm Hg or < 60 mm Hg, or DBP was >180 mm Hg or < 30 mm Hg.[20] **Pregnant individuals or those who resided in nursing homes were excluded as their hypertension management may differ from other patients. BP measurements following a COVID-19 diagnosis (i.e., positive SARS-CoV-2 antigen, PCR test, ICD-10 code U07.1) were excluded as we were interested in changes in hypertension not directly attributable to COVID-19 disease.**

Exposure, Outcome and Covariate Assessment

We classified individuals as having *controlled* hypertension at the time of measurement if they had a BP reading indicative of normal, elevated or stage 1 hypertension; *uncontrolled* hypertension was identified as stage 2 hypertension (≥140 mm Hg SBP or ≥90 mm Hg DBP).[21] If more than one BP measurement was recorded on a given day, we selected the first for analysis.

We estimated the number of days between BP measurements during the pre-pandemic period and for the bridge period for each patient and created categorical exposure variables corresponding to the number of months between readings to visualize the association between interval length and hypertension control.

We assessed demographic and clinical characteristics of individuals during the pre-pandemic period to describe the populations and adjust for confounders in the risk analysis. **We determined presence of comorbidities by ICD-10 codes at inpatient and outpatient visits during the two years preceding the start of the pandemic period; body mass index (BMI) and smoking status were determined based on the latest measurements in the pre-pandemic period.** We determined confounders *a priori* and based on known factors associated with BP control[18] **including sex**, age, race, ethnicity, smoking status, **BMI** and select comorbidities (cancer, cardiovascular disease (CVD), asthma, diabetes, chronic kidney disease (CKD), chronic obstructive pulmonary disease (COPD)).

Statistical Analyses

Demographic and clinical characteristics were described for individuals who, at their last pre-pandemic measurement, had controlled or uncontrolled hypertension, reporting frequency and proportion for categorical variables, and mean (standard deviation) for continuous variables. Missing data were reported or included within a level of a categorical variable as indicated.

Using data from both pre-pandemic and pandemic periods from individuals with controlled hypertension at the start of an interval, we estimated the **relative risk (RR)** of maintaining control of hypertension in the pandemic versus pre-pandemic period. Because individuals could have multiple BP measurement pairs, we estimated the RR with generalized estimating equations (GEEs) to adjust for this correlation (**Appendix model 1**). **We chose this method because it is well suited for scenarios when there are relatively many clusters that are small, and the choice of correlation structure is data-driven. We ran models with different correlation structures (exchangeable, autoregressive, independent) and compared the QIC from each model to select the best correlation structure. With data from the bridge intervals, we then estimated the association between length of bridge follow-up interval and maintaining hypertension control using log-binomial regression; follow-up interval length was a categorical variable, and <1 month follow-up interval length was the reference (Appendix model 2).** With data from the pre-pandemic period, we also measured the association between follow-up interval and maintenance of hypertension control for that period and used GEEs to adjust for correlation due to multiple measurements from individuals (**Appendix model 3**). Differences in the association between follow-up interval and maintaining hypertension control by period would indicate effect modification by period. We then explored whether an association between pandemic period and hypertension control could be explained by differences in follow-up interval, and whether any association between follow-up interval and hypertension control varied between the pre-pandemic and pandemic periods. For this we used GEEs with data from the pre-pandemic and pandemic periods combined where follow-up was $\leq$12 months. We modeled the effect of the pandemic period, follow-up interval as a continuous variable, the interaction of pandemic period and follow-up time, adjusting for potential confounders (**Appendix model 4**).

We repeated the analyses using data from individuals with uncontrolled hypertension at the start of each interval to assess associations between pandemic period (and follow-up interval) with gain of control of hypertension in this population (**Appendix models 5-7**). In these analyses, a RR greater than 1.0 represents a larger likelihood of a desired outcome.

All analyses were conducted using SAS, version 9.4 (Cary, NC, USA).

Results

We identified 2,118,723 individuals who met the patient study criteria including a hypertension diagnosis in the 2 years prior to the study period and a hypertension treatment in the prior year. Among them, 1,931,843 individuals had at least one BP measurement in the pre-pandemic period in a primary care setting, and were alive at the start of the pandemic (Figure 2). Of these, 1,648,424 had at least one eligible BP measurement during the pandemic and were included in the analysis. Individuals were mostly male, white, averaging 70 years old, with numerous comorbidities (**Table 1**). Among the analytic cohort, 1,029,927 (62%) and 618,497 (38%) had controlled and uncontrolled hypertension, respectively, at their last pre-pandemic measurement. Among those with controlled hypertension at their last pre-pandemic measurement, 705,242 (68%) had maintained control based on their first pandemic BP measurement. Of those with uncontrolled hypertension in the pre-pandemic, 273,593 (44%) gained control by their first BP measurement in the pandemic period.

The mean number of blood pressure readings in the pre-pandemic year was 3.1 (standard deviation 2.6). Thus, on average for the pre-pandemic period, each individual had two intervals where hypertension control was assessed at the start and end of the follow-up; for the pandemic period, each individual had one interval (the bridge interval) where hypertension control was assessed at the start of the bridge interval (last pre-pandemic measurement) and end of the bridge interval (first pandemic measurement). The mean bridge interval for those with controlled and uncontrolled hypertension at their last pre-pandemic measurement was 384 days and 372 days, respectively.

Using data from both the pre-pandemic and pandemic periods from those with controlled hypertension at the start of an interval, the likelihood of maintaining control in follow-up was lower in the pandemic than in the pre-pandemic period (adjusted RR=0.93 (95%CI 0.93, 0.93) (**Appendix model 1**). **The absolute likelihood of maintaining control in follow-up was 75% (95%CI 74-76%) in the pre-pandemic period. When focusing on the association between length of follow-up interval and hypertension control in the pandemic period, we found that relative to a follow-up less than one month, longer follow-up intervals were associated with decreasing likelihood of maintaining controlled hypertension; there were exceptions for those with follow-up at 6-7 and 12-13 months for the pandemic period. A similar association was observed for the pre-pandemic period (Figure 3A) (Appendix models 2&3). In both the pandemic and pre-pandemic period, for those with follow-up**

interval less than one month, the absolute likelihood of maintaining control at follow-up was 78%.

With both length of follow-up interval and pandemic period in the model and an interaction term, the likelihood of maintaining control of hypertension for the pandemic versus pre-pandemic period changed to 0.98; 71% of the pandemic's effect on hypertension control could be explained by length of follow-up interval. The interaction term for pandemic effect and follow-up interval was significant (p-value<0.001), but the RR for a 3-month increase in interval length differed marginally by period (**Table 2**) (**Appendix model 4**).

Using data from both pre-pandemic and pandemic periods from those with uncontrolled hypertension, the likelihood of having gained control at follow-up was **marginally** higher for the pandemic period versus pre-pandemic period (**adjusted RR=1.01 (95% CI 1.01, 1.01)**) (**Appendix model 5**). **The absolute likelihood of gaining control in follow-up was 47% (95%CI 46-48%) in the pre-pandemic period.** During the pre-pandemic period, relative to follow-up less than one month, increasing follow-up was associated with a lower likelihood of gaining control of hypertension. However, during the pandemic period there was an increase in likelihood as follow-up interval increased from less than one month to 6-7 months, and then a decreasing likelihood **(Figure 3B)** (**Appendix models 6&7**). **In both the pandemic and pre-pandemic period, for those with follow-up interval less than one month, the absolute likelihood of gaining control at follow-up was 48%.** Because the association between gaining control of hypertension and follow-up interval differed in the two periods, we did not run a combined model with data from both time periods.

Discussion

Nearly all (90%) individuals treated in the VA for hypertension with a BP measurement in the pre-pandemic period who survived the pandemic period also had a BP measurement in the primary care setting during the pandemic. The proportion of individuals taking antihypertensive medication with controlled hypertension (62% at last pre-pandemic measurement, 60% at first pandemic measurement) is similar to the 64.8% for the U.S. population in 2017-2018 estimated from National Health and Nutrition Examination Survey data.[22] Maintenance of control was 7% lower during the pandemic than the pre-pandemic period, influenced by the follow-up interval in both periods. **Change in follow-up interval accounted for part of the association between pandemic period and maintenance of control, but the pandemic maintained a modest independent effect.**

Remarkably, for individuals with uncontrolled hypertension within VHA, gaining control was **modestly** more likely during the pandemic. Further, while increasing length of follow-up interval was associated with a lower likelihood of gaining control in the pre-pandemic period, this was not true in the pandemic period in the beginning. After an uncontrolled BP in the pre-pandemic period, the probability of control during the pandemic period increased with time up to six months and then reverted to the same pattern we saw in the pre-pandemic period. It is unclear why this happened. One speculation is confounding by indication: providers may have intensely targeted those with very extreme BPs in the first 6 months of the pandemic. These individuals may have experienced improved BPs yet not crossed the threshold for control. Then, as providers worked through their most challenging patients, the pattern reverted to that seen in the pre-pandemic period. **To examine this hypothesis, a future study could examine whether patients who had uncontrolled hypertension were more likely to be seen early in the pandemic**

period if they had very extreme BPs whereas in the pre-pandemic period there was less difference in follow-length by extreme BP among those with uncontrolled hypertension.

Our study extends prior literature by showing an increased follow-up interval partially explains greater loss of BP control during the pandemic. While we did not assess how increased interval could contribute to loss of BP control, it is possible there were missed opportunities to modify treatment and maintain or achieve hypertension control with decreased monitoring. Our study adds to the literature because it assesses the pandemic effect among those with controlled and uncontrolled hypertension separately, for whom recommendations for follow-up and pandemic impact may differ.

Increased BP during the pandemic could have been due to many factors, including weight gain, alcohol consumption, emotional stress, and increased sedentary behavior.[9,10] These factors are difficult to identify in clinical records when healthcare utilization for chronic conditions decreased and documentation may be lacking. **This is a drawback of the current study as other studies have reported associations between such factors and increases in BP during the pandemic; for example, Ito et al[12] demonstrated that worsening diet and salt intake were associated with increased BP following the state of emergency announcement in a study in Japan**. BP monitoring is one potentially helpful modifiable factor for hypertension control if it provides an opportunity for clinicians to alter treatment or address related lifestyle factors**.**

Our study included BP data obtained by clinicians either in primary care settings or observed via video during a virtual visit. We excluded BP data reported during telephone visits because the accuracy of BP measurements is dependent on following standardized techniques and a trained observer[7]. Individuals may have monitored their BP at home independently, which was not assessed in this study. Home BP readings are often lower than those conducted by or observed by a clinician[7,9,23] via video during a virtual visit[24]. We restricted our analysis to vital signs data captured by trained observers to ensure accuracy of the data for analysis and because it is these readings that typically spur a change in medical management.

The strength of the current study is that it includes patients under care in the largest integrated healthcare system in the U.S., including vital signs, clinical, laboratory and medication adherence data necessary for this research. There are some limitations. First, individuals may have sought care outside the VHA during the pandemic uncaptured in the current study. We minimized this possibility by restricting the population to those diagnosed and treated in an outpatient setting at the VHA in the pre-pandemic period. **Nonetheless, there has been an increase in VA purchased care, that is care provided in the community rather than at the VA, that accelerated during the pandemic[25]; thus, there may be individuals in this study who sought care outside the VA during the pandemic which is not captured in this study.** Secondly, findings from the predominantly male VHA and concomitant study population may not generalize to the overall population. Furthermore, our study focused on individuals with prevalent hypertension prior to the pandemic and prior to any SARS-CoV-2 infection or COVID-19 diagnosis; outcomes among individuals not restricted this way may differ. **Importantly, we assumed that lack of a COVID-19 diagnosis or positive SARS-CoV-2 test indicated an individual did not have COVID-19; we may not have excluded all individuals with COVID-19 as testing has not always been easily available and asymptomatic infections may not be captured.** Our study focused on BP measurements taken by or observed by a clinician by video which are more accurate than home-based BP measurements. It is possible that patients increased home monitoring during the pandemic as seen in another study;[9] however, without physician contact management changes would be unlikely. As mentioned previously, BP elevation during the pandemic could be due to many factors including lifestyle factors not measured and adjusted for, potentially affecting how often people had BP measurements. The definition of hypertension has changed with time, and there is no international consensus definition.[2] Future studies could assess outcomes according to other definitions and examine whether uncontrolled hypertension identified at the first pandemic visit was transient or resolved subsequently.

In conclusion, our study found most individuals treated for hypertension returned to a primary care setting for BP measurement during the pandemic period. A longer interval between BP measurements was associated with a lower likelihood of maintaining hypertension control for those with controlled hypertension during both pre-pandemic and pandemic periods**, and longer intervals between measurements contributed to lower likelihood of maintaining control during the pandemic.**

Figure 1 legend: a) Using data from the pre-pandemic intervals and bridge interval where the individual had controlled hypertension at the start of the interval, the association between pandemic period and maintenance of control of hypertension at the end of the interval was estimated; b) using data from the bridge interval where the individual had controlled hypertension at the start of the interval, the association between length of follow-up interval and maintenance of control of hypertension at the end of the interval was estimated; c) using data from the pre-pandemic intervals where the individual had controlled hypertension at the start of the interval, the association between length of follow-up interval and maintenance of control of hypertension at the end of the interval was estimated; d) using data from the pre-pandemic intervals and bridge interval where the individual had uncontrolled hypertension at the start of the interval, the association between pandemic period and gain of control of hypertension at the end of the interval was estimated; e) using data from the bridge interval where the individual had uncontrolled hypertension at the start of the interval, the association between length of follow-up interval and gain of control of hypertension at the end of the interval was estimated; f) using data from the pre-pandemic intervals where the individual had uncontrolled hypertension at the start of the interval, the association between length of follow-up interval and gain of control of hypertension at the end of the interval was estimated

Figure 3 legend: The relative risk (RR) is the association between length of follow-up interval and maintaining hypertension control in 3a (and the association between length of follow-up interval and gaining hypertension control in 3b). Follow-up interval length was a categorical variable, and <1 month follow-up interval length was the reference.

References

1. Adams JM, Wright JS. A National Commitment to Improve the Care of Patients With Hypertension in the US. *JAMA*. Nov 10 2020;324(18):1825-1826. doi:10.1001/jama.2020.20356

2. Tschanz CMP, Cushman WC, Harrell CTE, Berlowitz DR, Sall JL. Synopsis of the 2020 U.S. Department of Veterans Affairs/U.S. Department of Defense Clinical Practice Guideline: The Diagnosis and Management of Hypertension in the Primary Care Setting. *Ann Intern Med*. Dec 1 2020;173(11):904-913. doi:10.7326/M20-3798

3. Bundy JD, Li C, Stuchlik P, et al. Systolic Blood Pressure Reduction and Risk of Cardiovascular Disease and Mortality: A Systematic Review and Network Meta-analysis. *JAMA Cardiol*. Jul 1 2017;2(7):775-781. doi:10.1001/jamacardio.2017.1421

4. Ettehad D, Emdin CA, Kiran A, et al. Blood pressure lowering for prevention of cardiovascular disease and death: a systematic review and meta-analysis. *Lancet*. Mar 5 2016;387(10022):957-967. doi:10.1016/S0140-6736(15)01225-8

5. DeJong C, Katz MH, Covinsky K. Deferral of Care for Serious Non-COVID-19 Conditions: A Hidden Harm of COVID-19. *JAMA Intern Med*. Feb 1 2021;181(2):274. doi:10.1001/jamainternmed.2020.4016

6. Wright A, Salazar A, Mirica M, Volk LA, Schiff GD. The Invisible Epidemic: Neglected Chronic Disease Management During COVID-19. *J Gen Intern Med*. Sep 2020;35(9):2816-2817. doi:10.1007/s11606-020-06025-4

7. Muntner P, Shimbo D, Carey RM, et al. Measurement of Blood Pressure in Humans: A Scientific Statement From the American Heart Association. *Hypertension*. May 2019;73(5):e35-e66. doi:10.1161/HYP.0000000000000087

8. Baum A, Barnett ML, Wisnivesky J, Schwartz MD. Association Between a Temporary Reduction in Access to Health Care and Long-term Changes in Hypertension Control Among Veterans After a Natural Disaster. *JAMA Netw Open*. Nov 1 2019;2(11):e1915111. doi:10.1001/jamanetworkopen.2019.15111

9. Shah NP, Clare RM, Chiswell K, Navar AM, Shah BR, Peterson ED. Trends of blood pressure control in the U.S. during the COVID-19 pandemic. *Am Heart J*. May 2022;247:15-23. doi:10.1016/j.ahj.2021.11.017

10. Laffin LJ, Kaufman HW, Chen Z, et al. Rise in Blood Pressure Observed Among US Adults During the COVID-19 Pandemic. *Circulation*. Jan 18 2022;145(3):235-237. doi:10.1161/CIRCULATIONAHA.121.057075

11. Steiner JF, Powers JD, Malone A, et al. Hypertension care during the COVID-19 pandemic in an integrated health care system. *J Clin Hypertens (Greenwich)*. 2023;25(4):315-325. doi:10.1111/jch.14641

12. Ito S, Kobayashi K, Chin K, et al. Impact of the first announced state of emergency owing to coronavirus disease 2019 on stress and blood pressure levels among patients with type 2 diabetes mellitus in Japan. *J Diabetes Investig*. Sep 2022;13(9):1607-1616. doi:10.1111/jdi.13813

13. Feitosa F, Feitosa ADM, Paiva AMG, et al. Impact of the COVID-19 pandemic on blood pressure control: a nationwide home blood pressure monitoring study. *Hypertens Res*. Feb 2022;45(2):364-368. doi:10.1038/s41440-021-00784-1

14. Girerd N, Meune C, Duarte K, Vercamer V, Lopez-Sublet M, Mourad JJ. Evidence of a Blood Pressure Reduction During the COVID-19 Pandemic and Associated Lockdown Period:

Insights from e-Health Data. *Telemed J E Health*. Feb 2022;28(2):266-270. doi:10.1089/tmj.2021.0006

15. Weber T, Amar J, de Backer T, et al. Covid-19 associated reduction in hypertension-related diagnostic and therapeutic procedures in Excellence Centers of the European Society of Hypertension. *Blood Press*. Dec 2022;31(1):71-79. doi:10.1080/08037051.2022.2060182

16. Gotanda H, Liyanage-Don N, Moran AE, et al. Changes in Blood Pressure Outcomes Among Hypertensive Individuals During the COVID-19 Pandemic: A Time Series Analysis in Three US Healthcare Organizations. *Hypertension*. Dec 2022;79(12):2733-2742. doi:10.1161/HYPERTENSIONAHA.122.19861

17. Veterans Health Administration. Secondary Veterans Health Administration. Accessed May 15, 2022, https://www.va.gov/health/aboutvha.asp#:~:text=The%20Veterans%20Health%20Administration%20(VHA,Veterans%20enrolled%20in%20the%20VA

18. Sandhu A, Ho PM, Asche S, et al. Recidivism to uncontrolled blood pressure in patients with previously controlled hypertension. *Am Heart J*. Jun 2015;169(6):791-7. doi:10.1016/j.ahj.2015.03.012

19. American Heart Association Types of Blood Pressure Medications. Accessed April 20, 2022, https://www.heart.org/en/health-topics/high-blood-pressure/changes-you-can-make-to-manage-high-blood-pressure/types-of-blood-pressure-medications

20. Fletcher RD, Amdur RL, Kolodner R, et al. Blood pressure control among US veterans: a large multiyear analysis of blood pressure data from the Veterans Administration health data repository. *Circulation*. May 22 2012;125(20):2462-8. doi:10.1161/CIRCULATIONAHA.111.029983

21. American Heart Association: Understanding Stroke Symptoms. Understanding Blood Pressure Readings. Updated May 30, 2023. Accessed June 1, 2023, https://www.heart.org/en/health-topics/high-blood-pressure/understanding-blood-pressure-readings

22. Muntner P, Hardy ST, Fine LJ, et al. Trends in Blood Pressure Control Among US Adults With Hypertension, 1999-2000 to 2017-2018. *JAMA*. Sep 22 2020;324(12):1190-1200. doi:10.1001/jama.2020.14545

23. Ben-Dov IZ. Unmasking hypertension: are both methods equal? *Am J Hypertens*. Jun 2005;18(6):779. doi:10.1016/j.amjhyper.2005.02.015

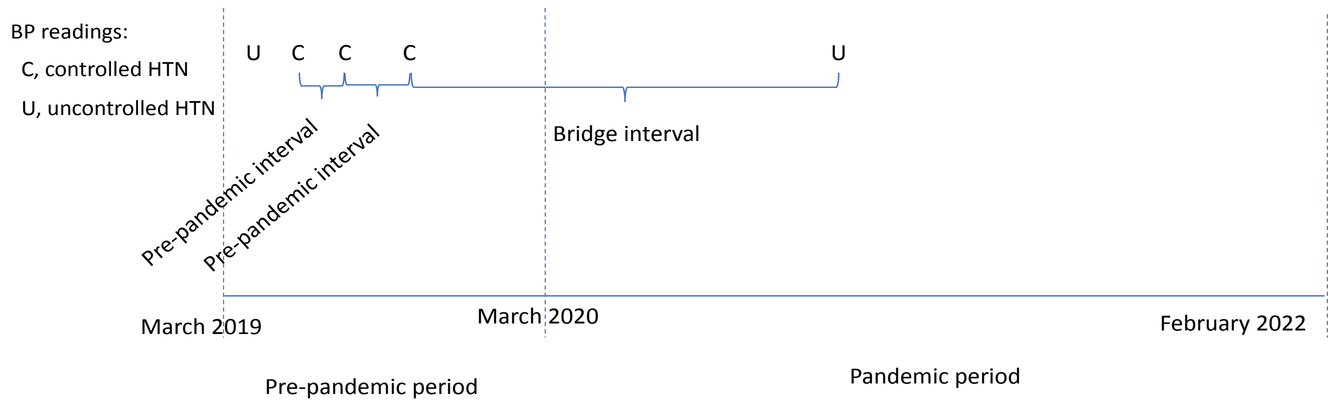
24. Barochiner J, Aparicio LS, Martinez R, Boggia J. Prognostic value of home blood pressure monitoring in patients under antihypertensive treatment. *J Hum Hypertens*. Sep 26 2022:1-8. doi:10.1038/s41371-022-00758-x

25. Rose L, Tran LD, Asch SM, Vashi A. Assessment of changes in US Veterans Health Administration care delivery methods during the COVID-19 pandemic. *JAMA Netw Open. Oct 1* 2021;4(10):e2129139. doi:10.1001/jamanetworkopen.2021.29139

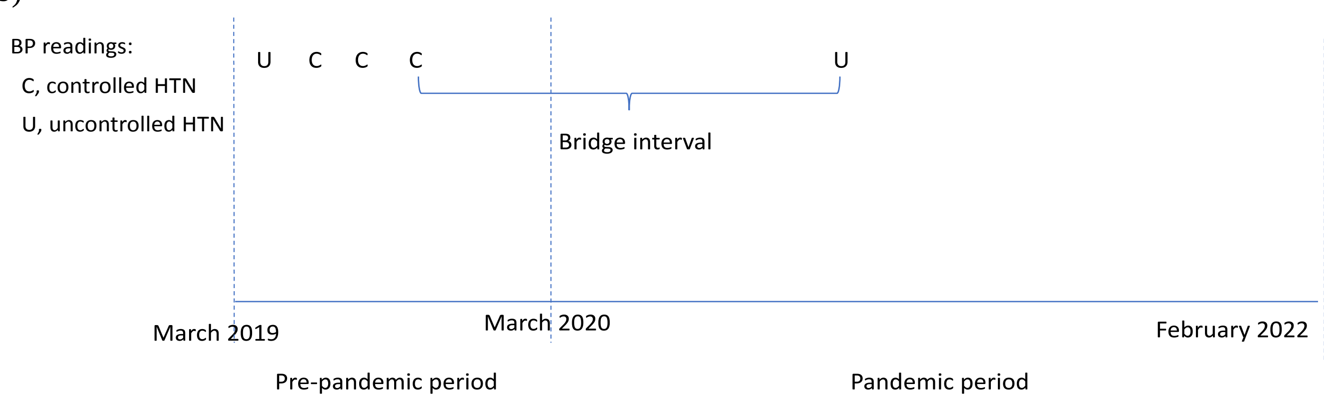
Figure 1

Figure 1. Study design

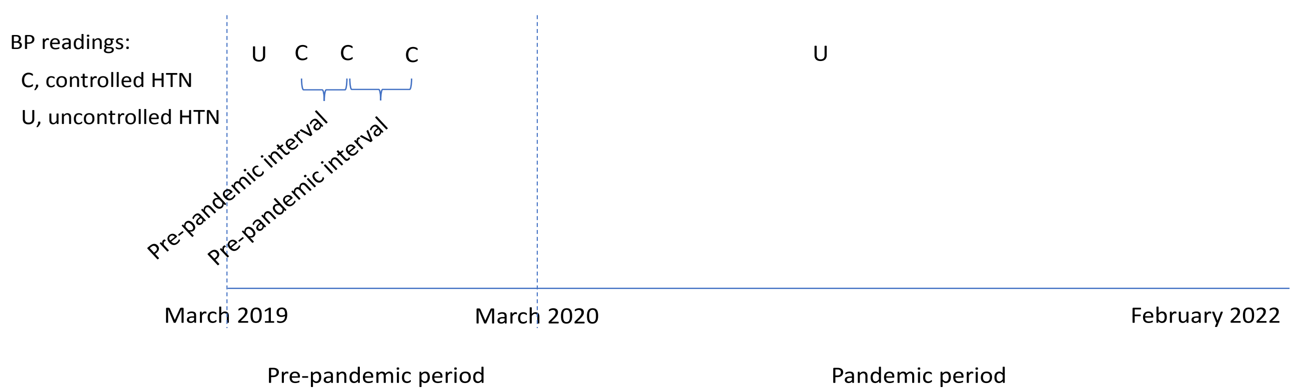
a)



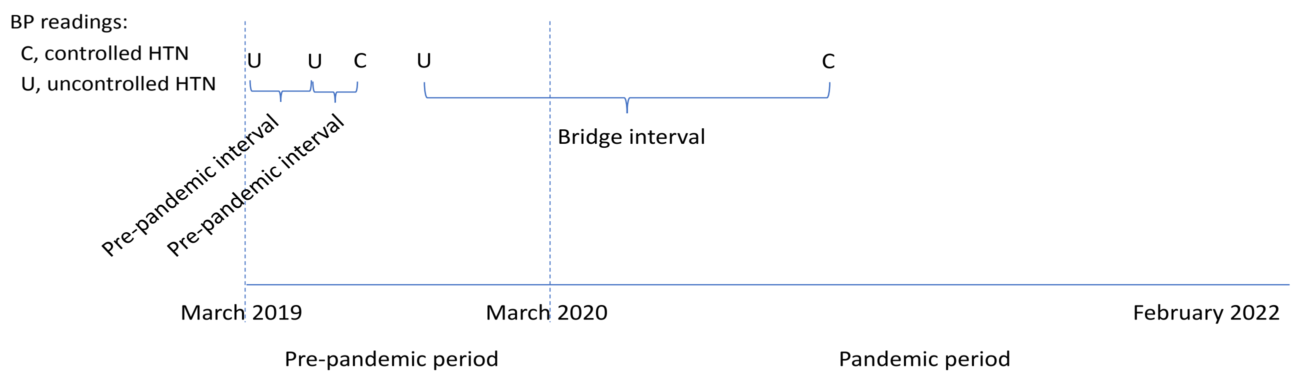
b)



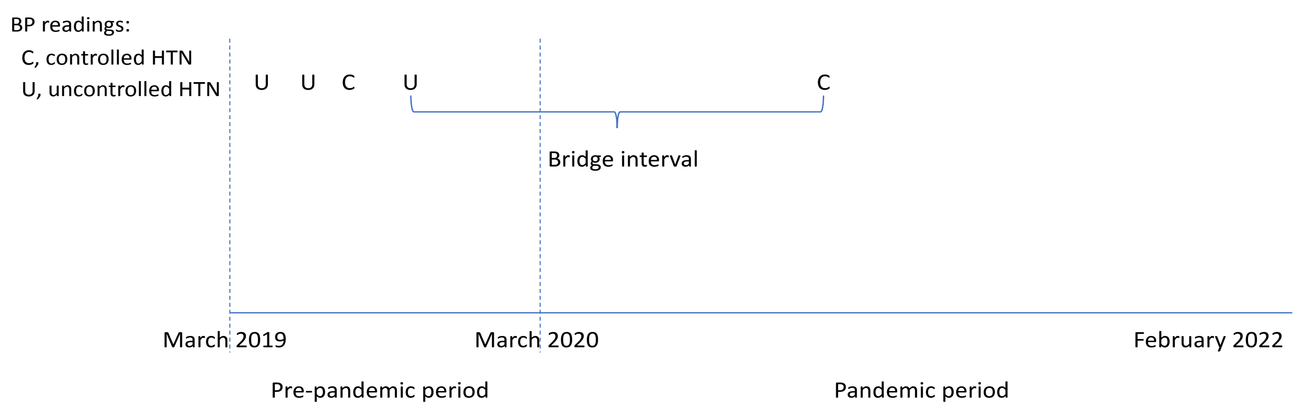
c)



d)


BP readings:
C, controlled HTN
U, uncontrolled HTN
U U C U C
Pre-pandemic interval
Pre-pandemic interval
Bridge interval
March 2019
March 2020
February 2022
Pre-pandemic period
Pandemic period

e)


BP readings:
C, controlled HTN
U, uncontrolled HTN
U U C U C
Bridge interval
March 2019
March 2020
February 2022
Pre-pandemic period
Pandemic period

f)

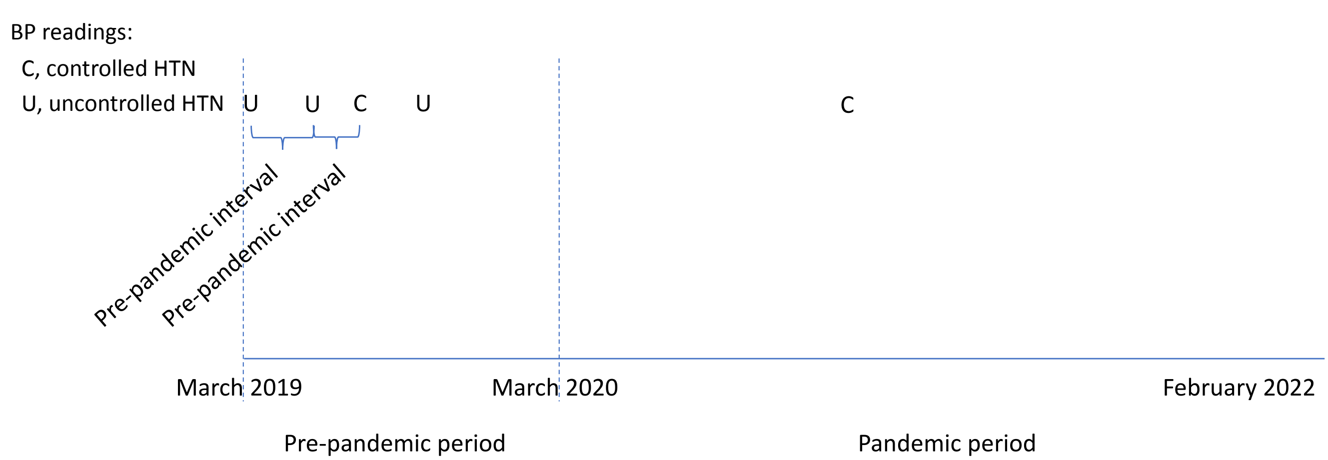

BP readings:
C, controlled HTN
U, uncontrolled HTN
U U C U C
Pre-pandemic interval
Pre-pandemic interval
March 2019
March 2020
February 2022
Pre-pandemic period
Pandemic period

Figure 2

Figure 2. Study cohort

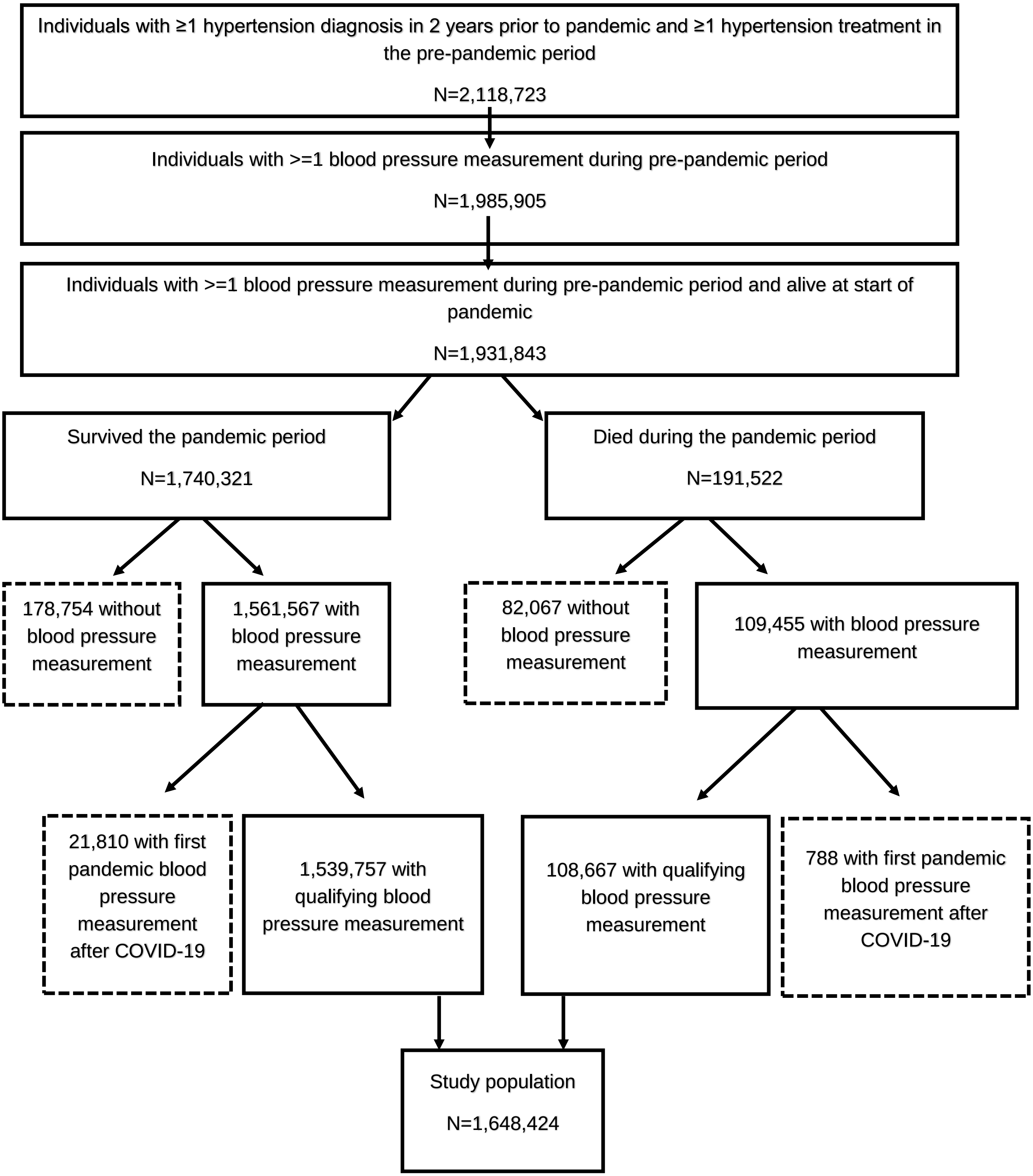
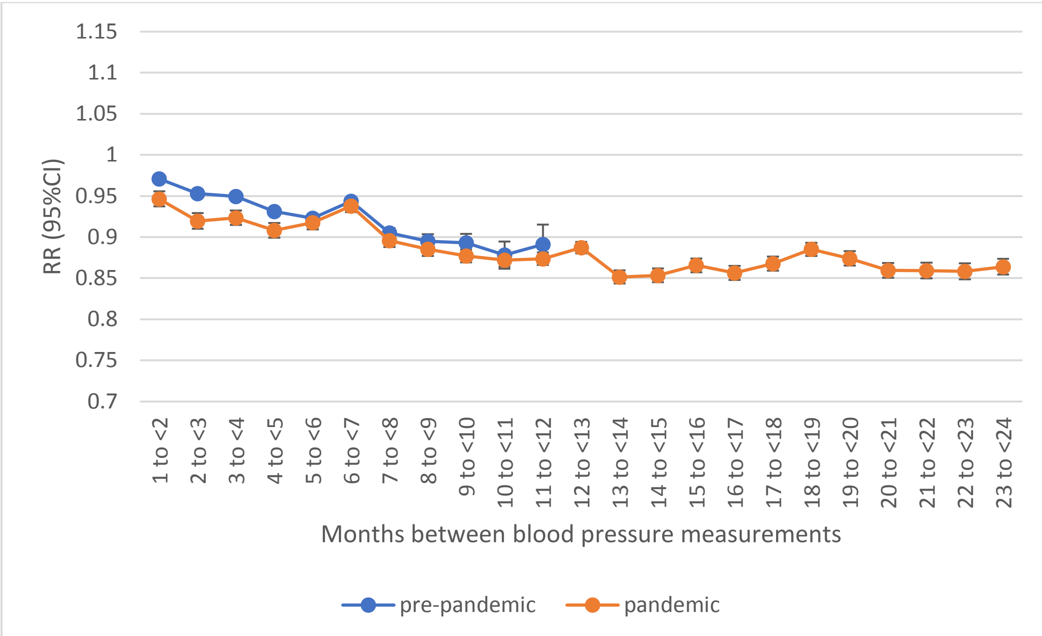


Figure 3

Figure 3. Association between time between blood pressure measurements and a) maintenance of hypertension control, b) gain of hypertension control

a.



b.

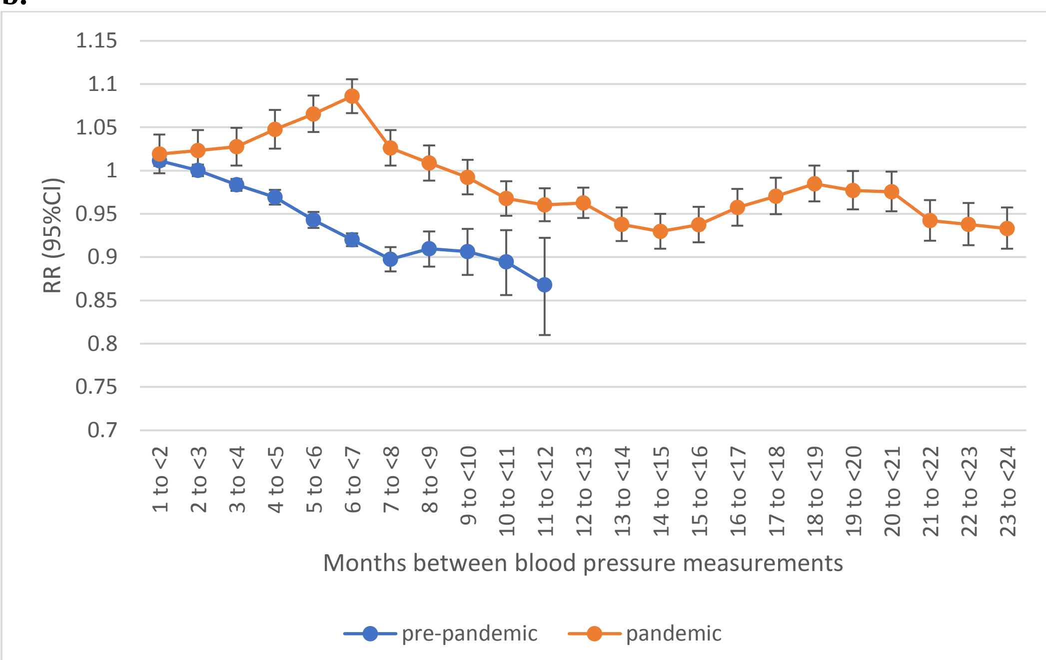


Table 1

Table 1. Demographic and clinical characteristics of individuals with controlled and uncontrolled hypertension at last pre-pandemic BP measurement

	Controlled hypertension **at last pre-pandemic blood pressure measurement** N=1,029,927	Uncontrolled hypertension **at last pre-pandemic blood pressure measurement** N=618,497
Hypertension stage		
Normal	281,549 (27.3)	n/a
Elevated	242,232 (23.5)	n/a
Stage 1	506,146 (49.1)	n/a
Stage 2	n/a	618,497 (100)
SBP, mm Hg (mean (standard deviation), median [IQR])	124.3 (10.7) 126 [118-133]	154.2 (13.5) 151 [145-161]
DBP, mm Hg (mean (standard deviation), median [IQR])	73.0 (8.7) 74 [67-80]	82.8 (11.2) 82 [75-90]
Age, years (mean (standard deviation))	69.9 (10.9)	70.1 (11.1)
Sex, n (%)		
Female	56,750 (5.5)	31,654 (5.1)
Male	973,177 (94.5)	586,843 (94.9)
Race, n (%)		
American Indian, Alaska Native	6,631(0.6)	3,850 (0.6)
Asian	7,796 (0.8)	4,348 (0.7)
Black	201,717 (19.6)	137,790 (22.3)
Native Hawaiian, Pacific Islander	9,138 (0.9)	5,527 (0.9)
White	749,468 (72.8)	433,403 (70.0)
Unknown/ missing	55,177 (5.4)	33,579 (5.4)

Hispanic ethnicity, n (%)		
Yes	59,226 (5.8)	33,106 (5.4)
No	918,764 (89.2)	554,005 (89.6)
Unknown/ missing	51,937 (5.0)	31,386 (5.1)
Rurality, n (%)		
Highly rural	14,861 (1.4)	9,186 (1.5)
Rural	381,071 (37.0)	228,098 (36.9)
Urban	632,430 (61.4)	380,288 (61.5)
Unknown/ missing	1,565 (0.2)	925 (0.1)
Current/ former smoking	103,094 (10.0)	60,003 (9.7)
Selected comorbidities, n (%)		
Asthma	175,273 (17.0)	91,177 (14.7)
Cancer	98,408 (9.6)	55,727 (9.0)
CHF	102,296 (9.9)	42,577 (6.9)
CKD	129,484 (12.6)	80,014 (12.9)
COPD	187,868 (18.2)	97,996 (15.8)
CVD	70,994 (6.9)	41,148 (6.7)
Diabetes	426,614 (41.4)	245,836 (39.7)
BMI (kg/mm^2)		
≤18.5	3,689 (0.4)	2,010 (0.3)
>18.5 to <25	89,906 (8.7)	53,709 (8.7)
25 to <30	241,148 (23.4)	141,991 923.0)
≥30	445,298 (43.2)	262,801 (42.5)
Missing	249,886 (24.3)	157,986 (25.5)

Abbreviations: BMI, body mass index; CHF, congestive heart failure; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; **DBP, diastolic blood pressure**; Hg, mercury; IQR, interquartile range; kg, kilogram; mm, millimeter; **SBP, systolic blood pressure**.

Table 2. Impact of pandemic period on controlled hypertension while accounting for interval between blood pressure measurements

	RR (95%CI)[1]
Pandemic vs. pre-pandemic	0.98 (0.98, 0.99)
Follow-up length (3-month intervals) during pre-pandemic	**0.96 (0.96, 0.96)**
Follow-up length (3-month intervals) during pandemic	**0.97 (0.97, 0.97)**
Age (years)	1.00 (1.00, 1.00)
Male (vs female)	0.98 (0.98, 0.99)
Black race (vs non-Black race)	**0.95 (0.95, 0.95)**
Hispanic ethnicity	0.99 (0.99, 0.99)
Former or current smoker (vs non-smoker)	**1.00 (1.00, 1.00)**
BMI (reference >18.5 to <25)	
≤18.5	1.02 (1.00, 1.03)
25 to <30	1.00 (0.99, 1.00)
≥30	0.99 (0.99, 1.00)
Missing	1.01 (1.01, 1.01)
Asthma	1.01 (1.01, 1.02)
CKD	0.99 (0.99, 0.99)
COPD	1.02 (1.01, 1.02)
CVD	1.00 (0.99, 1.00)
Diabetes	1.02 (1.02, 1.02)

Abbreviations: BMI, body mass index; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; **RR, relative risk**.

[1]The RR indicates the likelihood of maintaining hypertension control at the end of a follow-up interval between blood pressure measurements for the exposed versus reference category. A RR greater than 1.0 represents a larger likelihood of a desired outcome. A RR of 0.98 for pandemic vs pre-pandemic period indicates there was a 2% lower likelihood of maintaining hypertension control between blood pressure measurements during the pandemic vs pre-pandemic period. The RR for the follow-up length variable indicates the change in likelihood of maintaining hypertension control associated with a 3-month increase in follow-up length. Results are from the model shown in Appendix Methods regression 4.

Appendix

Methods

The SAS code for the regression models appear below. A table describing datasets and variables appear below these models.

Regression 1. Estimating the relative risk of maintaining hypertension control for the pandemic versus pre-pandemic period

```
proc genmod data=contst descending;

class patienticn bridge (ref='0') gen (ref='0') smoke (ref='0') bcat1 (ref='0') bcat2 (ref='0') bcat3 (ref='0') bcat4 (ref='0') conf_DMNOCX (ref='0') conf_CVD (ref='0') conf_COPD (ref='0') conf_ASTHMA (ref='0') conf_CKD (ref='0') hispanic (ref='0') brace (ref='0');

model htxn_cont= bridge age gen smoke bcat1 bcat2 bcat3 bcat4 conf_DMNOCX conf_CVD conf_COPD conf_ASTHMA conf_CKD hispanic brace / dist=bin link=log;

repeated subject=patienticn/ type=ind;

run;
```

Regression 2. Estimating the association between maintenance of hypertension control and time between blood pressure measurements during the pandemic period

```
proc genmod data=contpan descending;

class exp2 (ref='0') exp3 (ref='0') exp4 (ref='0') exp5 (ref='0') exp6 (ref='0') exp7 (ref='0') exp8 (ref='0') exp9 (ref='0') exp10 (ref='0') exp11 (ref='0') exp12 (ref='0') exp13a (ref='0') exp14a (ref='0') exp15a (ref='0') exp16a (ref='0') exp17a (ref='0') exp18a (ref='0') exp19a (ref='0') exp20a (ref='0') exp21a (ref='0') exp22a (ref='0') exp23a (ref='0') exp24a (ref='0') gen (ref='0') smoke (ref='0')  bcat1 (ref='0') bcat2 (ref='0') bcat3 (ref='0') bcat4 (ref='0') conf_DMNOCX (ref='0')  conf_CVD (ref='0') conf_COPD (ref='0') conf_ASTHMA (ref='0') conf_CKD (ref='0') hispanic (ref='0') brace (ref='0');

model htxn_cont=exp2 exp3 exp4 exp5 exp6 exp7 exp8 exp9 exp10 exp11 exp12 exp13a exp14a exp15a exp16a exp17a exp18a exp19a exp20a exp21a exp22a exp23a exp24a age gen smoke bcat1 bcat2 bcat3 bcat4 conf_DMNOCX conf_CVD conf_COPD conf_ASTHMA conf_CKD hispanic brace / dist=bin link=log;

run;
```

Regression 3. Estimating the association between maintenance of hypertension control and time between blood pressure measurements during the pre-pandemic period

```
proc genmod data=contpre descending;
```

```
class patienticn exp2 (ref='0') exp3 (ref='0') exp4 (ref='0') exp5 (ref='0') exp6 (ref='0') exp7 (ref='0') exp8
(ref='0') exp9 (ref='0') exp10 (ref='0') exp11 (ref='0') exp12 (ref='0') gen (ref='0') smoke (ref='0')
bcat1 (ref='0') bcat2 (ref='0') bcat3 (ref='0') bcat4 (ref='0') conf_DMNOCX (ref='0') conf_CVD (ref='0')
conf_COPD (ref='0') conf_ASTHMA (ref='0') conf_CKD (ref='0')  hispanic (ref='0') brace (ref='0');

model htxn_cont=exp2 exp3 exp4 exp5 exp6 exp7 exp8 exp9 exp10 exp11 exp12 gen smoke bcat1 bcat2
bcat3 bcat4 conf_DMNOCX conf_CVD conf_COPD conf_asthma conf_CKD hispanic brace / dist=bin
link=log;

repeated subject=patienticn/ type=ind;

run;
```

Regression 4. Estimating the relative risk of maintaining hypertension control for the pandemic versus pre-pandemic period while accounting for time between blood pressure measurements

```
proc genmod data=cont12tri descending;

class patienticn bridge (ref='0') gen (ref='0') smoke (ref='0') bcat1 (ref='0') bcat2 (ref='0') bcat3 (ref='0')
bcat4 (ref='0') conf_DMNOCX (ref='0') conf_CVD (ref='0') conf_COPD (ref='0') conf_ASTHMA (ref='0')
conf_CKD (ref='0') hispanic (ref='0') brace (ref='0');

model htxn_cont= bridge gaptri bridge*gaptri age gen smoke bcat1 bcat2 bcat3 bcat4 conf_DMNOCX
conf_CVD conf_COPD conf_ASTHMA conf_CKD hispanic brace / dist=bin link=log;

repeated subject=patienticn/ type=ind;

run;
```

Regression 5. Estimating the relative risk of gaining hypertension control for the pandemic versus pre-pandemic period

```
proc genmod data=uncst descending;

class patienticn bridge (ref='0') gen (ref='0') smoke (ref='0') bcat1 (ref='0') bcat2 (ref='0') bcat3 (ref='0') bcat4 (ref='0') conf_DMNOCX (ref='0') conf_CVD (ref='0') conf_COPD (ref='0') conf_ASTHMA (ref='0') conf_CKD (ref='0')  hispanic (ref='0') brace (ref='0');

model htxn_cont=bridge gen age smoke bcat1 bcat2 bcat3 bcat4 conf_DMNOCX conf_CVD conf_COPD conf_ASTHMA conf_CKD hispanic brace/ dist=bin link=log;

repeated subject=patienticn/  type=ind;

run;
```

Regression 6. Estimating the association between gain of hypertension control and time between blood pressure measurements during the pandemic period

```
proc genmod data=uncpan descending;

class exp2 (ref='0') exp3 (ref='0') exp4 (ref='0') exp5 (ref='0') exp6 (ref='0') exp7 (ref='0') exp8 (ref='0') exp9 (ref='0') exp10 (ref='0') exp11 (ref='0') exp12 (ref='0') exp13a (ref='0') exp14a (ref='0') exp15a (ref='0') exp16a (ref='0') exp17a (ref='0') exp18a (ref='0')exp19a (ref='0') exp20a (ref='0') exp21a (ref='0') exp22a (ref='0') exp23a (ref='0') exp24a (ref='0') gen (ref='0') smoke (ref='0') bcat1 (ref='0') bcat2 (ref='0') bcat3 (ref='0') bcat4 (ref='0') conf_DMNOCX (ref='0') conf_CVD (ref='0') conf_COPD (ref='0') conf_ASTHMA (ref='0') conf_CKD (ref='0') hispanic (ref='0') brace (ref='0');

model htxn_cont=exp2 exp3 exp4 exp5 exp6 exp7 exp8 exp9 exp10 exp11 exp12 exp13a exp14a exp15a exp16a exp17a exp18a exp19a exp20a exp21a exp22a exp23a exp24a age gen smoke bcat1 bcat2 bcat3 bcat4 conf_DMNOCX conf_CVD conf_COPD conf_ASTHMA conf_CKD hispanic brace /  dist=bin link=log;

run;
```

Regression 7. Estimating the association between gain of hypertension control and time between blood pressure measurements during the pre-pandemic period

```
proc genmod data=uncpre descending;

class patienticn exp2 (ref='0') exp3 (ref='0') exp4 (ref='0') exp5 (ref='0') exp6 (ref='0') exp7 (ref='0') exp8 (ref='0') exp9 (ref='0') exp10 (ref='0') exp11 (ref='0') exp12 (ref='0') gen (ref='0') smoke (ref='0') bcat1 (ref='0') bcat2 (ref='0') bcat3 (ref='0') bcat4 (ref='0') conf_DMNOCX (ref='0') conf_CVD (ref='0') conf_COPD (ref='0') conf_ASTHMA (ref='0') conf_CKD (ref='0')  hispanic (ref='0') brace (ref='0');
```

```
model htxn_cont=exp2 exp3 exp4 exp5 exp6 exp7 exp8 exp9 exp10 exp11 exp12 age gen smoke bcat1 bcat2 bcat3 bcat4 conf_DMNOCX conf_CVD conf_COPD conf_asthma conf_CKD hispanic brace / dist=bin link=log;

repeated subject=patienticn/ type=ind;

run;
```

Description of datasets and variables:

Dataset name	Description
const	Includes exposure, covariate and outcome variables for individuals who had controlled hypertension at the start of an interval between blood pressure measurements; includes intervals from pre-pandemic period and bridge interval (i.e., last pre-pandemic to first pandemic blood pressure measurement)
contpan	Dataset const restricted to observations from bridge interval (i.e., last pre-pandemic to first pandemic blood pressure measurement); follow-up interval is categorical
contpre	Dataset const restricted to observations from pre-pandemic intervals; follow-up interval is categorical
cont12tri	Includes exposure, covariate and outcome variables for individuals who had controlled hypertension at the start of an interval between blood pressure measurements; includes intervals from pre-pandemic period and bridge interval (i.e., last pre-pandemic to first pandemic blood pressure measurement); follow-up interval is continuous; includes intervals≤12 months
uncst	Includes exposure, covariate and outcome variables for individuals who had uncontrolled hypertension at the start of an interval between blood pressure measurements; includes intervals from pre-pandemic period and bridge interval (i.e., last pre-pandemic to first pandemic blood pressure measurement)
uncpan	Dataset uncst restricted to observations from bridge interval (i.e., last pre-pandemic to first pandemic blood pressure measurement); follow-up interval is categorical
uncpre	Dataset uncst restricted to observations from pre-pandemic intervals; follow-up interval is categorical
Variable name	
htxn_control	1=controlled hypertension at end of interval between blood measurements, 0=uncontrolled hypertension
bridge	1= pandemic period, 0=pre-pandemic period
age	age in years
gen	1=male, 0=female
smoke	1=current/former smoker, 0=not current/former smoker or unknown status

bcat1	missing BMI
bcat2	BMI ≤18.5
bcat3	BMI 25 to <30
bcat4	BMI ≥30
conf_DMNOCX	1= diabetes mellitus, 0=none or unknown
conf_CVD	1= cardiovascular disease, 0=none or unknown
conf_COPD	1= chronic obstructive pulmonary disease, 0=none or unknown
conf_asthma	1= asthma, 0=none or unknown
conf_CKD	1= chronic kidney disease, 0=none or unknown
hispanic	1= Hispanic ethnicity, 0= no or unknown
brace	1= Black race, 0= other or unknown
patienticn	Identifier unique to patient
exp2	1 = follow-up interval 1 to <2 months
exp3	1 = follow-up interval 2 to <3 months
…	…
exp24a	1 = follow-up interval 23 to <24 months
gaptri	Interval between blood measurements, 1 unit=3 months

Results

Regression 1. Estimating the relative risk of maintaining hypertension control for the pandemic period versus pre-pandemic period (number observations=3,094,868)

Variable	RR	95%CI	Chi-square	p-value
bridge	0.9304	(0.9289, 0.9318)	8273.3	<.0001
gen	0.9773	(0.974, 0.9807)	172.94	<.0001
smoke	1.0033	(1.0008, 1.0058)	6.53	0.0106
bcat1	1.0031	(0.9998, 1.0064)	3.37	0.0663
bcat2	1.018	(1.0047, 1.0315)	7.04	0.008
bcat3	0.9957	(0.9926, 0.9989)	6.83	0.009
bcat4	0.995	(0.992, 0.9981)	10.19	0.0014
age	1.0003	(1.0002, 1.0003)	35.65	<.0001
conf_CVD	1.0089	(1.0059, 1.0118)	34.72	<.0001
conf_COPD	1.0254	(1.0187, 1.0321)	56.35	<.0001
conf_asth	1.0133	(1.0066, 1.0201)	15.09	0.0001
conf_CKD	0.9979	(0.9955, 1.0002)	3.15	0.0761
conf_DMNOCX	1.0227	(1.021, 1.0244)	700.22	<.0001
hispanic	0.9937	(0.9904, 0.997)	14	0.0002
brace	0.9493	(0.9472, 0.9514)	2164	<.0001

Regression 2. Estimating the association between maintenance of hypertension control and time between blood pressure measurements during the pandemic period (number observations=946,559) (RRs for exp2 through exp24a appear in Figure 3a)

Variable	RR	95%CI	Chi-square	p-value
exp2	0.9464	(0.9374, 0.9555)	126.6	<.0001
exp3	0.9195	(0.9101, 0.9291)	253.71	<.0001
exp4	0.9234	(0.9147, 0.9322)	271.04	<.0001
exp5	0.9082	(0.8994, 0.9171)	378.7	<.0001
exp6	0.9175	(0.9095, 0.9256)	367.13	<.0001
exp7	0.9378	(0.9305, 0.9452)	258.43	<.0001
exp8	0.8959	(0.8879, 0.904)	573.67	<.0001
exp9	0.8851	(0.8771, 0.8931)	701.61	<.0001
exp10	0.877	(0.8691, 0.8849)	810.45	<.0001
exp11	0.8719	(0.8639, 0.88)	843.22	<.0001
exp12	0.8737	(0.8662, 0.8813)	931.65	<.0001
exp13a	0.8871	(0.8802, 0.894)	907.31	<.0001
exp14a	0.8515	(0.8437, 0.8594)	1165.5	<.0001
exp15a	0.8534	(0.8452, 0.8617)	1031.2	<.0001
exp16a	0.8656	(0.8572, 0.874)	852.02	<.0001
exp17a	0.8563	(0.8479, 0.8649)	936.7	<.0001
exp18a	0.8676	(0.8592, 0.8761)	817.79	<.0001

exp19a	0.885	(0.8769, 0.8931)	686.71	<.0001
exp20a	0.8739	(0.8652, 0.8827)	693.02	<.0001
exp21a	0.8594	(0.8504, 0.8686)	786.63	<.0001
exp22a	0.8592	(0.8498, 0.8687)	731.28	<.0001
exp23a	0.8584	(0.8487, 0.8682)	688.78	<.0001
exp24a	0.8639	(0.8543, 0.8736)	661.48	<.0001
gen	0.9688	(0.9632, 0.9744)	114.51	<.0001
smoke	0.9964	(0.9919, 1.0008)	2.55	0.1104
bcat1	0.9971	(0.9917, 1.0025)	1.14	0.2859
bcat2	1.017	(0.9948, 1.0397)	2.24	0.1346
bcat3	1.0002	(0.9949, 1.0056)	0.01	0.9329
bcat4	1.0039	(0.9988, 1.0091)	2.24	0.1342
age	1.0002	(1.0001, 1.0004)	10.04	0.0015
conf_CVD	1.0028	(0.9976, 1.008)	1.13	0.2877
conf_COPD	1.0066	(0.9947, 1.0186)	1.16	0.2813
conf_asth	1.0208	(1.0085, 1.0333)	11	0.0009
conf_CKD	0.9909	(0.9869, 0.995)	19.07	<.0001
conf_DMNOCX	1.0186	(1.0158, 1.0215)	168.68	<.0001
hispanic	0.9895	(0.9837, 0.9952)	12.72	0.0004
brace	0.9407	(0.9372, 0.9442)	1037.8	<.0001

Regression 3. Estimating the association between maintenance of hypertension control and time between blood pressure measurements during the pre-pandemic period (number observations=2,064,941) (RRs for exp2 through exp12 appear in Figure 3a)

Variable	**RR**	**95%CI**	**Chi-square**	**p-value**
exp2	0.971	(0.9686, 0.9734)	561.4	<.0001
exp3	0.9529	(0.9502, 0.9556)	1132	<.0001
exp4	0.9496	(0.9468, 0.9524)	1179.6	<.0001
exp5	0.9311	(0.9277, 0.9345)	1449.5	<.0001
exp6	0.9229	(0.9193, 0.9266)	1568.6	<.0001
exp7	0.9437	(0.9407, 0.9467)	1273.9	<.0001
exp8	0.9051	(0.8993, 0.911)	908.84	<.0001
exp9	0.895	(0.8866, 0.9034)	535.4	<.0001
exp10	0.8929	(0.8818, 0.9041)	314.8	<.0001
exp11	0.8781	(0.8618, 0.8947)	184.77	<.0001
exp12	0.8911	(0.8672, 0.9156)	69.13	<.0001
gen	0.9864	(0.9825, 0.9903)	46.12	<.0001
smoke	0.9993	(0.9965, 1.0022)	0.23	0.6321
age	1.0001	(1, 1.0002)	4.47	0.0345
bcat1	1.0097	(1.0058, 1.0136)	23.99	<.0001
bcat2	1.0171	(1.0021, 1.0323)	4.99	0.0256
bcat3	0.9962	(0.9925, 0.9999)	3.96	0.0467
bcat4	0.9923	(0.9888, 0.9958)	18.27	<.0001

conf_CVD	1.0022	(0.9989, 1.0055)	1.67	0.1958
conf_COPD	1.0212	(1.0138, 1.0286)	31.87	<.0001
conf_asth	1.0128	(1.0054, 1.0204)	11.35	0.0008
conf_CKD	0.9915	(0.9889, 0.9942)	39.22	<.0001
conf_DMNOCX	1.0178	(1.0158, 1.0198)	311.87	<.0001
hispanic	0.9924	(0.9886, 0.9962)	15.3	<.0001
brace	0.9528	(0.9504, 0.9553)	1383.6	<.0001

Regression 4. See Table 2 in manuscript for results

Regression 5. Estimating the relative risk of gaining control of hypertension for the pandemic period versus pre-pandemic period (number observations=1,885,876)

Variable	RR	95%CI	Chi-square	p-value
bridge	1.0103	(1.0068, 1.0138)	33.19	<.0001
gen	0.9543	(0.9467, 0.9619)	132.3	<.0001
smoke	1.0189	(1.0131, 1.0248)	41.1	<.0001
age	0.9993	(0.9991, 0.9995)	60.74	<.0001
bcat1	0.9813	(0.974, 0.9886)	24.77	<.0001
bcat2	1.0583	(1.0278, 1.0897)	14.39	0.0001
bcat3	1.0067	(0.9994, 1.014)	3.23	0.0721
bcat4	1.0082	(1.0012, 1.0153)	5.31	0.0213
conf_CVD	1.0249	(1.018, 1.0317)	51.78	<.0001
conf_COPD	1.0618	(1.0458, 1.0781)	59.96	<.0001
conf_asth	1.0178	(1.0021, 1.0338)	4.92	0.0266
conf_CKD	0.9735	(0.9683, 0.9787)	97.41	<.0001
conf_DMNOCX	1.0333	(1.0294, 1.0372)	290.62	<.0001
hispanic	1.0172	(1.0095, 1.025)	19.5	<.0001
brace	0.9281	(0.9239, 0.9324)	1006.7	<.0001

Regression 6. Estimating the association between gain of hypertension control and time between blood pressure measurements during the pandemic period (number observations=571,672) (RRs for exp2 through exp24a appear in Figure 3b)

Variable	RR	95%CI	Chi-square	p-value
exp2	1.019	(0.9968, 1.0417)	2.8	0.0941
exp3	1.0231	(0.9999, 1.0468)	3.82	0.0505
exp4	1.0274	(1.0057, 1.0494)	6.19	0.0129
exp5	1.0474	(1.0254, 1.07)	18.17	<.0001
exp6	1.0653	(1.0444, 1.0865)	39.34	<.0001
exp7	1.0859	(1.0665, 1.1056)	80.65	<.0001
exp8	1.0261	(1.0057, 1.0469)	6.35	0.0117
exp9	1.0086	(0.9884, 1.0291)	0.69	0.4077
exp10	0.9922	(0.9723, 1.0124)	0.58	0.4453

exp11	0.9675	(0.9476, 0.9877)	9.76	0.0018
exp12	0.9602	(0.9413, 0.9794)	16.19	<.0001
exp13a	0.9625	(0.9452, 0.9801)	17.14	<.0001
exp14a	0.9379	(0.9187, 0.9575)	36.84	<.0001
exp15a	0.9295	(0.9097, 0.9498)	43.97	<.0001
exp16a	0.9373	(0.917, 0.9581)	33.56	<.0001
exp17a	0.9573	(0.9364, 0.9786)	15.09	0.0001
exp18a	0.9704	(0.9494, 0.9918)	7.27	0.007
exp19a	0.9848	(0.9643, 1.0056)	2.06	0.1512
exp20a	0.977	(0.9553, 0.9993)	4.08	0.0434
exp21a	0.9755	(0.9529, 0.9986)	4.32	0.0377
exp22a	0.9421	(0.919, 0.9658)	22.09	<.0001
exp23a	0.9379	(0.9139, 0.9625)	23.58	<.0001
exp24a	0.9331	(0.9095, 0.9573)	28.12	<.0001
gen	0.9556	(0.9435, 0.968)	48.08	<.0001
smoke	1.0081	(0.9985, 1.0179)	2.71	0.0994
age	0.9995	(0.9993, 0.9998)	10.56	0.0012
bcat1	0.9853	(0.9739, 0.9968)	6.21	0.0127
bcat2	1.0799	(1.0296, 1.1328)	9.96	0.0016
bcat3	1.0132	(1.0015, 1.0251)	4.9	0.0269
bcat4	1.0228	(1.0115, 1.0343)	15.86	<.0001
conf_CVD	1.0162	(1.0048, 1.0277)	7.74	0.0054
conf_COPD	1.0279	(1.0009, 1.0555)	4.1	0.0428
conf_asth	1.0232	(0.9956, 1.0515)	2.71	0.0999
conf_CKD	0.9919	(0.9833, 1.0006)	3.34	0.0677
conf_DMNOCX	1.0231	(1.017, 1.0293)	55.59	<.0001
hispanic	1.0054	(0.9928, 1.0182)	0.7	0.4038
brace	0.9326	(0.9256, 0.9395)	338.61	<.0001

Regression 7. Estimating the association between gain of hypertension control and time between blood pressure measurements during the pre-pandemic period (number observations=1,267,293) (RRs for exp2 through exp12 appears in Figure 3b)

Variable	**RR**	**95%CI**	**Chi-square**	**p-value**
exp2	1.0111	(1.0054, 1.0168)	14.66	0.0001
exp3	1.0001	(0.9935, 1.0067)	0	0.9741
exp4	0.9834	(0.9765, 0.9904)	21.58	<.0001
exp5	0.9692	(0.9608, 0.9778)	48.43	<.0001
exp6	0.9429	(0.9338, 0.9521)	140.99	<.0001
exp7	0.9201	(0.9127, 0.9275)	410.88	<.0001
exp8	0.8976	(0.8835, 0.9119)	179.36	<.0001
exp9	0.9096	(0.8896, 0.9301)	69.59	<.0001
exp10	0.9063	(0.8802, 0.9331)	43.59	<.0001
exp11	0.8944	(0.8577, 0.9326)	27.33	<.0001
exp12	0.8678	(0.8135, 0.9257)	18.54	<.0001
gen	0.9604	(0.9512, 0.9696)	68.34	<.0001

smoke	1.0176	(1.0107, 1.0245)	25.21	<.0001
age	0.9992	(0.999, 0.9994)	48.29	<.0001
bcat1	0.9859	(0.9768, 0.995)	9.12	0.0025
bcat2	1.0489	(1.0133, 1.0857)	7.36	0.0067
bcat3	1.0057	(0.9968, 1.0147)	1.57	0.2102
bcat4	1.0019	(0.9934, 1.0105)	0.19	0.6607
conf_CVD	1.0199	(1.0119, 1.0279)	24.23	<.0001
conf_COPD	1.0629	(1.0444, 1.0817)	46.25	<.0001
conf_asth	1.0199	(1.0017, 1.0384)	4.58	0.0324
conf_CKD	0.9582	(0.9521, 0.9643)	171.97	<.0001
conf_DMNOCX	1.0296	(1.0248, 1.0344)	152.07	<.0001
hispanic	1.0195	(1.0103, 1.0287)	17.47	<.0001
brace	0.9261	(0.9209, 0.9313)	720.37	<.0001