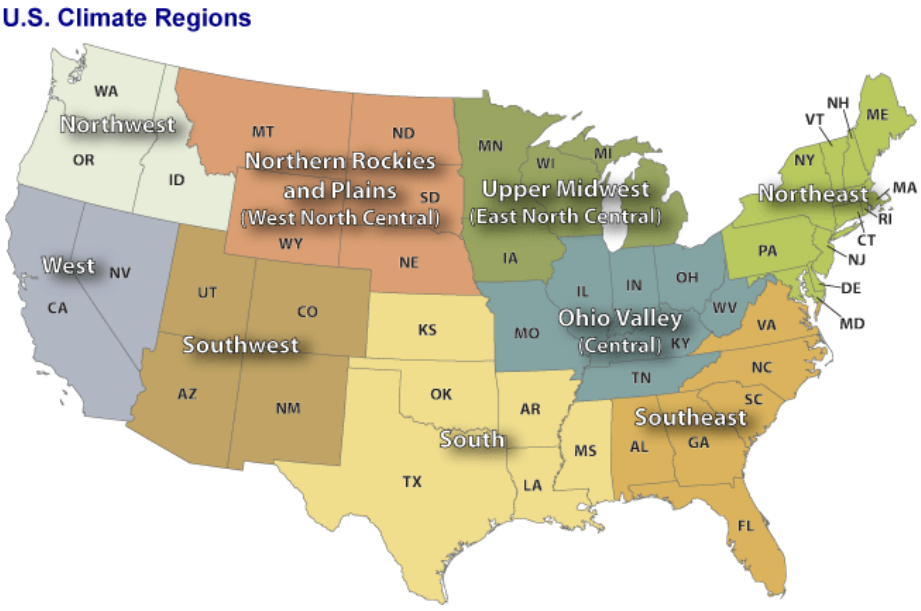
APPENDIX I

Supplementary Figures and Tables

Supplementary Figure S1. BP Track 12-month measurement periods chart with corresponding indexed quarter-year used for analysis, Q4-2017 – Q1-2020, Wave 5

		Quarter-year included within measurement period												
	Quarter-Year	Q1-2017	Q2-2017	Q3-2017	Q4-2017	Q1-2018	Q2-2018	Q3-2018	Q4-2018	Q1-2019	Q2-2019	Q3-2019	Q4-2019	Q1-2020
Measurement Period Indexed Quarter-Year	Q4-2017	12 month measurement period												
	Q1-2018													
	Q2-2018													
	Q3-2018													
	Q4-2018													
	Q1-2019													
	Q2-2019													
	Q3-2019													
	Q4-2019													
	Q1-2020													

Supplementary Figure S2. Nine climate regions of contiguous US



Courtesy: https://www.ncei.noaa.gov/monitoring-references/maps/us-climate-regions

Supplementary Table S1. Characteristics of health systems participating in BP Track, Wave 5

Health System Characteristics[1] (N=26)		**Distribution %**
Serving population		
	Urban	88%
	Suburban	81%
	Rural	50%
System Type		
	Academic	77%
	Non-Academic	31%
	FQHC	12%
Region		
	Northeast (NE)	19%
	Southeast (SE)	19%
	East North Central (ENC)	19%
	South (S)	19%
	Central (C)	12%
	Southwest (SW)	12%
	Northwest (NW)	8%
	West North Central (WNC)	4%
	West (W)	4%

[1] Most health systems fall under more than one characteristic, therefore the sum of the distributions will be over 100% for each category above.

Supplementary Table S2. Association between average temperature and BP Metrics

BP Metric	Temperature[1]	
	Estimate (95% CI)	P-value
% BP Control (<140/<90 mmHg)		
Unadjusted model[2]	0.15 (0.12, 0.18)	<.001
Adjusted model	-0.08 (-0.28, 0.11)	0.383
% Medication Intensification		
Unadjusted model[2]	-0.08 (-0.11, -0.04)	0.003
Adjusted model	-0.16 (-0.28, -0.04)	0.018

BP Metric	Temperature[1] below 50 degrees		Temperature[1] above 50 degrees	
	Estimate (95% CI)	P-value	Estimate (95% CI)	P-value
% Improvement in BP				
Unadjusted model[2]	0.61 (0.38, 0.85)	0.010	-0.12 (-0.27, 0.02)	0.075
Adjusted model	0.48 (0.24, 0.71)	0.014	-.30 (-0.53, -0.07)	0.005
Average SBP Reduction after Med Intensification				
Unadjusted model[2]	-0.01 (-0.09, 0.07)	0.886	0.03 (-0.04, 0.10)	0.378
Adjusted model	-0.00 (-0.23, 0.22)	0.967	0.09 (-0.06, 0.25)	0.255

BP Metric result is response. A general linear model with repeated measures and autoregressive correlation matrix was used.
Metric denominator is used as weight for first three metrics, and 1/SE for average SBP reduction after medication.

[1] Estimate reflects the change in BP Metric per 5 degree change in average temperature.
First two metrics are over the entire temperature domain and below/above 50 degrees Fahrenheit respectively for last two metrics.

[2] Unadjusted model: Average temperature only
Adjusted model: Average temperature+Region+Year+Race/Ethnicity+Sex+Age+Diabetes+Precipitation+Health System Factors+HF+CAD

Supplementary Table S3. Model-based means and estimated differences in secondary BP metric across quarters, Q4-2017 – Q1-2020

	Quarter 1		Quarter2[1]		Quarter 3		Quarter 4		
Outcome	**Mean (SD)**	**Δ Estimate (95% CI)**	**Mean (SD)**	**Δ Estimate (95% CI)**	**Mean (SD)**	**Δ Estimate (95% CI)**	**Mean (SD)**	**Δ Estimate (95% CI)**	**P-Value**
% BP Control (<130/<80 mmHg)									
Unadjusted model[2]	29.50 (1.13)	-1.13 (-1.26, -1.00)	30.63 (1.12)	0 (Ref)	31.13 (1.11)	0.49 (0.36, 0.62)	30.06 (1.08)	-0.57 (-0.82, -0.33)	<.001
Adjusted model 1	26.59 (2.24)	-1.20 (-1.32, -1.07)	27.79 (2.25)	0 (Ref)	28.51 (2.17)	0.73 (0.35, 1.10)	27.50 (2.11)	-0.28 (-0.91, 0.34)	<.001
Adjusted model 2	25.62 (1.95)	-2.76 (-7.51, 1.99)	28.38 (2.84)	0 (Ref)	29.76 (3.50)	1.38 (-0.34, 3.09)	27.07 (1.90)	-1.31 (-4.89, 2.27)	0.055

[1] Quarter 2 was used as reference to estimate differences between quarters

[2] Unadjusted model: Quarter Year only

Adjusted model 1: Unadjusted model +Race/Ethnicity+Sex+Age+Diabetes +HF+CAD

Adjusted model 2: Unadjusted model +Race/Ethnicity +Sex+Age+Diabetes +HF+CAD +Average Temperature

Supplementary Table S4. Association between average temperature and secondary BP metric

BP Metric	**Temperature[1]**	
	Estimate (95% CI)	**P-value**
% BP Control (<130/<80 mmHg)		
Unadjusted model[2]	0.18 (0.15, 0.20)	<.001
Adjusted model	0.10 (0.01, 0.18)	0.091

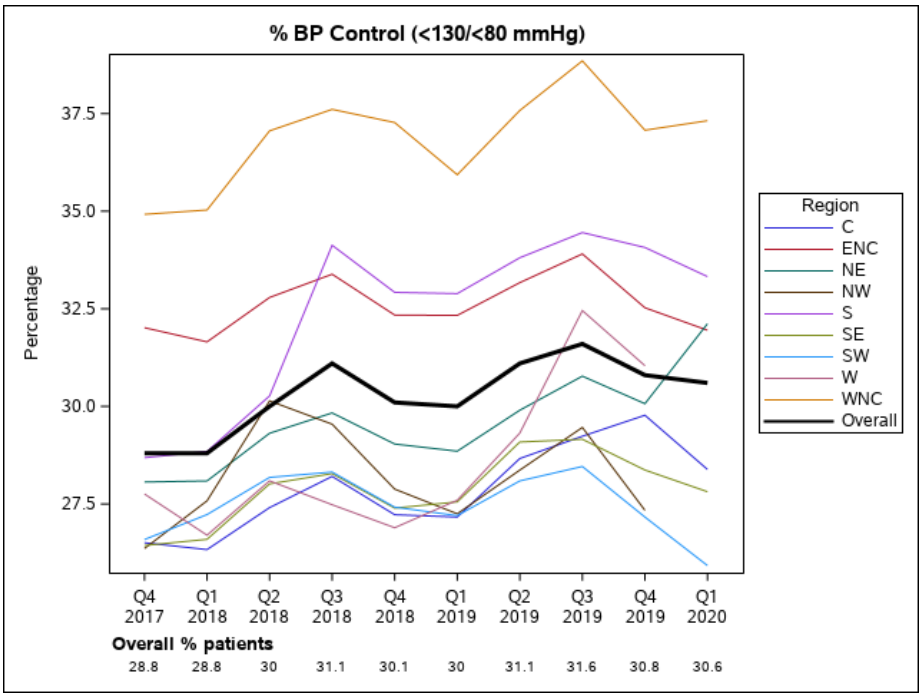
BP Metric result is response. A general linear model with repeated measures and autoregressive correlation matrix was used. Metric denominator is used as weight.

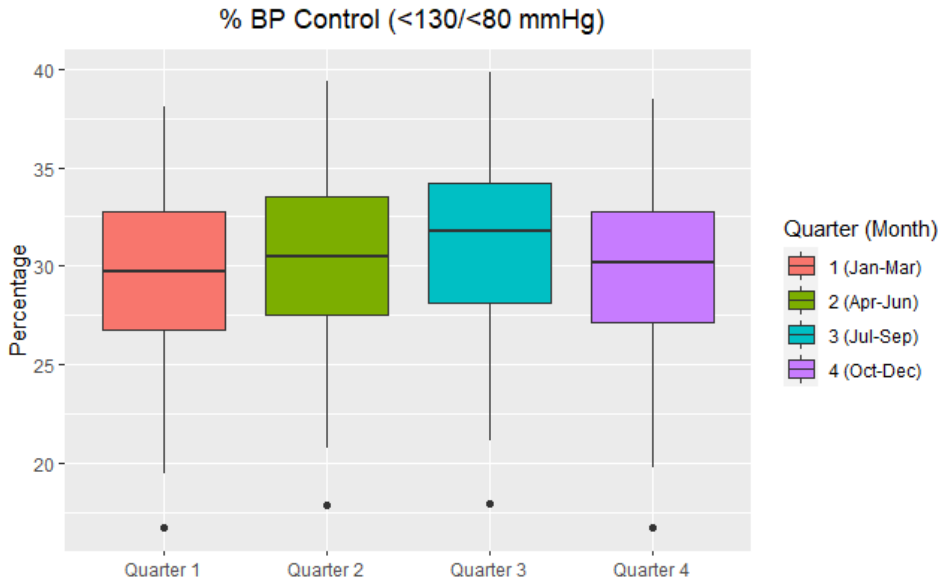
[1] Estimate reflects the change in BP Metric per 5 degree Fahrenheit change in average temperature.

[2] Unadjusted model: Average temperature only

Adjusted model: Average temperature+Region+Year+Race/Ethnicity+Sex+Age+Diabetes+Precipitation+Health System Factors+HF+CA

Supplementary Figure S3. Weighted secondary BP control over time by region and its distribution by quarter





Supplementary Table S5. Complete case analysis of estimated differences in BP control and related metrics across quarters, Q4-2017 – Q4-2019

	Quarter 1		Quarter 2[1]		Quarter 3		Quarter 4		Overall
Outcome	**Mean (SD)**	**Δ Estimate (95% CI)**	**Mean (SD)**	**Δ Estimate (95% CI)**	**Mean (SD)**	**Δ Estimate (95% CI)**	**Mean (SD)**	**Δ Estimate (95% CI)**	**P-Value**
% BP Control (<140/<90 mmHg)									
Unadjusted model[2]	60.71 (2.59)	-1.07 (-1.27, -0.87)	61.79 (2.57)	0 (Ref)	62.25 (2.55)	0.46 (0.21, 0.72)	61.51 (2.57)	-0.27 (-0.72, 0.18)	<.001
Unadjusted model (complete)	61.94 (6.36)	-1.06 (-1.30, -0.82)	63.00 (6.31)	0 (Ref)	63.43 (6.26)	0.43 (0.14, 0.72)	62.58 (6.21)	-0.42 (-0.91, 0.07)	0.002
Adjusted model	57.47 (2.44)	-1.25 (-1.47, -1.03)	58.72 (2.42)	0 (Ref)	59.65 (2.22)	0.93 (0.18, 1.68)	59.23 (2.17)	0.50 (-0.67, 1.67)	<.001
Adjusted model (complete)	57.51 (2.85)	-1.25 (-1.48, -1.03)	58.77 (2.84)	0 (Ref)	59.34 (2.87)	0.57 (0.20, 0.94)	58.66 (2.92)	-0.10 (-0.86, 0.66)	0.002
% Improvement in BP									
Unadjusted model[2]	29.22 (1.01)	-2.73 (-3.52, -1.93)	31.95 (0.90)	0 (Ref)	29.88 (0.79)	-2.07 (-2.49, -1.65)	28.93 (0.75)	-3.01 (-3.60, -2.43)	<.001
Unadjusted model (complete)	29.66 (1.26)	-2.95 (-3.81, -2.08)	32.60 (1.08)	0 (Ref)	30.46 (0.96)	-2.14 (-2.61, -1.67)	29.50 (0.90)	-3.10 (-3.74, -2.45)	<.001
Adjusted model	24.36 (1.47)	-2.90 (-3.83, -1.96)	27.25 (1.45)	0 (Ref)	25.17 (1.36)	-2.08 (-2.56, -1.61)	24.25 (1.35)	-3.00 (-3.59, -2.41)	<.001
Adjusted model (complete)	25.87 (1.72)	-3.12 (-4.15, -2.09)	28.99 (1.62)	0 (Ref)	26.82 (1.51)	-2.17 (-2.65, -1.69)	25.84 (1.50)	-3.15 (-3.75, -2.54)	<.001
% Medication Intensification									
Unadjusted model[2]	10.52 (0.54)	0.25 (-0.03, 0.53)	10.27 (0.59)	0 (Ref)	9.73 (0.60)	-0.54 (-0.73, -0.35)	10.23 (0.58)	-0.04 (-0.34, 0.26)	0.005
Unadjusted model (complete)	10.58 (0.51)	0.13 (-0.04, 0.29)	10.45 (0.51)	0 (Ref)	9.98 (0.48)	-0.48 (-0.64, -0.31)	10.30 (0.54)	-0.15 (-0.34, 0.03)	0.011
Adjusted model	13.66 (1.53)	0.22 (-0.03, 0.47)	13.44 (1.54)	0 (Ref)	13.25 (1.61)	-0.19 (-0.70, 0.32)	13.67 (1.66)	0.23 (-0.45, 0.91)	0.014
Adjusted model (complete)	12.40 (2.10)	0.12 (-0.05, 0.28)	12.28 (2.12)	0 (Ref)	11.81 (2.14)	-0.48 (-0.65, -0.30)	12.14 (2.16)	-0.14 (-0.33, 0.05)	0.013
Average SBP Reduction after Med Intensification (mmHg)									
Unadjusted model[2]	14.91 (0.22)	-0.73 (-1.01, -0.44)	15.63 (0.23)	0 (Ref)	14.75 (0.28)	-0.89 (-1.19, -0.58)	14.18 (0.25)	-1.46 (-1.76, -1.16)	<.001
Unadjusted model (complete)	15.21 (0.22)	-0.67 (-0.99, -0.35)	15.88 (0.21)	0 (Ref)	14.93 (0.28)	-0.95 (-1.29, -0.60)	14.32 (0.25)	-1.56 (-1.89, -1.22)	<.001
Adjusted model	10.69 (0.33)	-0.69 (-1.17, -0.21)	11.38 (0.33)	0 (Ref)	10.72 (0.46)	-0.67 (-1.16, -0.17)	9.77 (0.39)	-1.61 (-2.27, -0.96)	0.004
Adjusted model (complete)	11.01 (0.30)	-0.65 (-1.22, -0.08)	11.66 (0.34)	0 (Ref)	11.12 (0.43)	-0.54 (-1.03, -0.05)	9.95 (0.33)	-1.71 (-2.44, -0.97)	0.008

[1] Quarter 2 was used as reference to estimate differences between quarters

[2] Unadjusted model: Quarter Year only

Unadjusted model (complete): complete case analysis of Quarter Year only

Adjusted model: Unadjusted model +Race/Ethnicity+Sex+Age+Diabetes+HF+CAD

Adjusted model (complete): complete case analysis of Unadjusted model+Race/Ethnicity+Sex+Age+Diabetes+HF+CAD

APPENDIX II

PCORnet® Blood Pressure Control Laboratory Metric Specifications and Definitions

PCORnet® Blood Pressure Control Laboratory
Blood Pressure Control Metrics, v1.5

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.

Patient Eligibility Criteria

Patients are considered *hypertensive and eligible for BP control* if they meet all of the following criteria:

- At least one Visit during the Measurement Period at the Clinical Unit of interest (as per Glossary)
- Age 18-85 through the end of the Measurement Period
- A diagnosis of hypertension during the first six months of the Measurement Period or any time prior to the Measurement Period. ICD-9 and ICD-10 codes included are as follows:
    - I10 Essential (primary) hypertension
    - 401 Essential hypertension
    - 401 Malignant hypertension
    - 401.1 Benign hypertension
    - 401.9 Hypertension NOS
- NO hospice services given to the patient any time during the Measurement Period (HCPCS code G9740)
- NO diagnosis or evidence of end-stage renal disease, dialysis, or renal transplant during or prior to the Measurement Period
- NO diagnosis of pregnancy during the Measurement Period
- NOT age 65 or older in Institutional Special Needs Plans (SNP) or residing in long-term care with POS code 32, 33, 34, 54, or 56 any time during the Measurement Period (HCPCS code G9910)

Metric Specifications

1) Blood Pressure Control, % of patients

This overall measure of BP control implements CMS #236[ref], which defines BP Control as the percent of hypertensive patients 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.

Denominator Statement (Definition 1a): *Hypertensive and eligible for BP control*
Patients are considered *hypertensive and eligible for BP control* if they meet all of the criteria described above.

Numerator Statement (Definition 1b): *Controlled*
Patients are considered *controlled* if they meet all of the following criteria:

- *Hypertensive and eligible for BP control* (Definition 1a)
- At the most recent Visit at the Clinical Unit of interest, the SBP measurement was <140 mmHg; if there is more than one SBP measurement, use the lowest.
- At the most recent Visit at the Clinical Unit of interest, the DBP measurement was <90 mmHg; if there is more than one DBP measurement, use the lowest.

2) 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)

3) Average SBP reduction after a medication intensification visit, mmHg

This continuous metric describes the change in SBP observed between a visit with a medication intensification to the subsequent visit.

Qualifying Visit set (Definition 3a): *A recent Visit with medication intensification for uncontrolled HTN followed by a subsequent Visit*

A Visit is considered to be *a recent visit with medication intensification for uncontrolled HTN followed by a subsequent Visit* if it meets all 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
- At least one BP medication was prescribed at the Visit
- The class of one or more BP medications prescribed at the Visit was not prescribed to the patient in the 12 months prior to the prescribing date (medication intensification; see the Glossary for details on BP medication classes)
- A subsequent Visit with a SBP measurement was made at least 10 days after the Visit with medication intensification, occurring in months 9-12 of the Measurement Period at the Clinical Unit of interest

Calculation (Definition 3b): *Average SBP reduction after medication intensification*

Average SBP reduction after medication intensification is calculated as the average of the reduction, in mmHg, of SBP between these two measurements:

- The lowest SBP measured during the qualifying Visit with medication intensification
- The lowest SBP measured during the subsequent Visit at the Clinical Unit of interest; if there are multiple subsequent Visits, the earliest subsequent Visit occurring at least 10 days after the qualifying Visit with medication intensification will be used. Note that for the By Clinic Analysis, the Clinical Unit for the SBP *at* medication intensification and the Clinical Unit for the SBP *following* medication intensification must be the same.

Note that there may be more than one qualifying Visit with medication intensification for an individual patient. A SBP measurement from a qualifying Visit with medication intensification may be used as the subsequent Visit measurement if it is the earliest subsequent Visit occurring after a prior qualifying Visit with medication intensification.

4) Improvement in Blood Pressure, % of patients

This overall measure of BP improvement implements CMS065v7[], which defines BP improvement as either a reduction of 10 mmHg in SBP or achievement of SBP that is "adequately controlled" (SBP < 140 mmHg) in months 10-12 of the measurement period, among hypertensive patients not previously controlled.

Denominator Statement (Definition 4a): *Hypertensive and BP uncontrolled during months 1-9 of the Measurement Period*

Patients are considered *hypertensive and uncontrolled during months 1-9 of the Measurement Period* if they meet all of the following criteria:

- *Hypertensive and eligible for BP control* (Definition 1a) within the Measurement Period
- Lowest SBP ≥ 140 mmHg at the most recent Visit at the Clinical Unit of interest in months 1-9 of the Measurement Period

Numerator Statement (Definition 4b): *Improvement in blood pressure*
Patients are considered to have had an *improvement in blood pressure* if they meet all of the following criteria:

- *Hypertensive and uncontrolled BP during months 1-9 of the Measurement Period* (Definition 4a)
- Lowest SBP at the most recent Visit at the Clinical Unit of interest in months 10-12 of the Measurement Period is either <140 mmHg or ≥10 mmHg lower than the SBP at the most recent Visit in months 1-9 of Measurement Period

Glossary

BP 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).

Clinical Unit – The Clinical Unit is the PCORnet® datamart, unless health system data includes stratified results by participating clinic, which then the Clinical Unit is defined by a specific FACILITYID (or defined set of FACILITYIDs).

Measurement Period – 12-month period specified by the Query during which clinical data are available in the datamart (Ex. Query released March 15, 2019 might specify January 1, 2018-December 31, 2018 as the Measurement Period)

Visit – An Encounter designated as an ambulatory visit (ENC_TYPE = "AV") with a specified CPT code (99201, 99202, 99203, 99204, 99205, 99212, 99213, 99214, 99215, 99341, 99342, 99343, 99344, 99345) or a specified HCPCS code (G0402, G0438, G0439); associated with the Clinical Unit specified for the query.

Notes

Defining eligible BP measurements – BP measurements from a healthcare setting (VITAL_SOURCE of "HC", Healthcare delivery setting, or "HD", Healthcare device direct feed) are included. DBP measurements less than 50 mmHg or greater than 150 mmHg are assumed to be errors and were deleted. SBP measurements less than 70 mmHg or greater than 250 mmHg are assumed to be errors and were deleted.

Matching BP measurements to Encounters – In order to know that a given BP measurement in the VITAL table was performed in a particular setting/encounter type, the programming will need to join the VITAL table with the ENCOUNTER table. This can be done securely (i.e., without considering dates) when the ENCOUNTERID field is populated in the VITAL table, but this field is not always populated. When it is not populated, we will require the ADMIT_DATE in the ENCOUNTER table (for an ENCOUNTER with ENC_TYPE = "AV") to match the MEASURE_DATE in the VITAL table. It is likely that this will eliminate some valid BP measurements from consideration, but we feel that this error is preferable to allowing in BP

measurements that did not actually occur during a valid Visit. The programming will capture the % of Visits in which there is a valid BP measurement, and we can examine that quality metric across participating datamarts (along with the % of VITAL observations with missing ENCOUNTERID); if the numbers are low, we can consider making a broader window and different tradeoff.

Matching PRESCRIBING observations to Encounters – Likewise, we would like to match observations in the PRESCRIBING table for BP medication intensification to encounters where a BP measurement was high. Similarly, when the ENCOUNTERID field is populated for a given PRESCRIBING observation, this can be used (without consideration of dates) to match with an observation in the ENCOUNTER table (for an ENCOUNTER with ENC_TYPE = "AV"). However, some relevant prescribing in reaction to a high BP measurement may occur in the days following that encounter. We will therefore ALSO consider it a match if the PRESCRIBING observation for a BP medication has an RX_ORDER_DATE (or RX_START_DATE if RX_ORDER_DATE is not available) that is <=7 days following the ADMIT_DATE for the relevant AV encounter where BP was high.

Selecting PRESCRIBING records for medication intensification – All PRESCRIBING records will be considered if they fall within 7 days following the qualifying BP measurement. This is not limited to PRESCRIBING records from the Clinical Unit where the qualifying BP was measured.

Selecting BP measurements for BP Improvement and SBP reduction after medication intensification By Clinic Analysis – Only BP measurements from the same Clinical Unit for the initial qualifying BP and the follow-up BP will be considered.