Published in final edited form as:

Med Care. 2015 June ; 53(6): 480–484. doi:10.1097/MLR.0000000000000349.

Clinical Operations Variables are Associated with Blood Pressure Outcomes

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Abstract

Background—Uncontrolled blood pressure (BP), among patients diagnosed and treated for the condition, remains an important clinical challenge; aspects of clinical operations could potentially be adjusted if they were associated with better outcomes.

Objectives—To assess clinical operations factors' effects on normalization of uncontrolled BP.

Research Design—Observational cohort study.

Subjects—Patients diagnosed with hypertension from a large urban clinical practice (2005–2009).

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Disclaimer: The opinions expressed in this manuscript do not necessarily represent the official views of the Department of Veterans Affairs, Boston University, the University of Massachusetts, Northeastern University or the National Institutes of Health.

We appreciate comments from Dan Berlowitz, MD, MPH, on earlier versions of this work, which were presented at the Society of General Internal Medicine's 2012 annual meeting.

Measures—We obtained clinical data on BP, organized by person-month, and administrative data on PCP staffing. We assessed the resolution of an episode of uncontrolled BP as a function of time-varying covariates including practice-level appointment volume, individual clinicians' appointment volume, overall practice-level primary care provider (PCP) staffing and number of unique PCPs.

Results—Among 7,409 unique patients representing 50,403 person-months, normalization was less likely for patients with episode starts during months when the number of unique PCPs was high (the top quintile of unique PCPs was associated with a 9 percentage point lower probability of normalization ($P < 0.01$) than the lowest quintile). Practice appointment volume negatively affected the likelihood of normalization (episodes starting in months with the most appointments were associated with a 6 percentage point reduction in the probability of normalization ($P = 0.01$)). Neither clinician appointment volume nor practice clinician staffing levels were significantly associated with the probability of normalization.

Conclusions—Findings suggest that clinical operations factors can affect clinical outcomes like BP normalization, and point to the importance of considering outcome effects when organizing clinical care.

Keywords

Hypertension; normalization of uncontrolled blood pressure; clinical operations

Introduction

Hypertension (HTN) affects nearly 33% of American adults and is a major risk factor for cardiovascular, cerebrovascular, and renal disease¹. Many diagnosed and treated patients have uncontrolled HTN¹. Improving blood pressure (BP) control remains an important public health goal².

BP control is a widely used epidemiologic or quality metric. Normalization of uncontrolled BP after an episode of poor control may be a useful quality improvement outcome for health systems³. BP normalization is likely sensitive to aspects of clinical operations such as clinician staffing or appointment volume, which influence access to good primary care (e.g., repeated BP measurements, prescribed medication, ongoing medication changes in response to poor control)³. In economic productivity models, health care is produced when a series of 'inputs' (finite resources, e.g., clinician staffing) are deployed to produce 'outputs' (better patient health, e.g., controlled BP). When increased inputs lead to less than proportional increases in output, organizations experience 'decreasing returns to scale' (e.g., the number of patient appointments increases despite finite numbers of clinicians, limiting the pace at which patients can be seen). Thus, we posit that clinician staffing and appointment volume may affect BP care and outcomes.

Prior efforts to improve BP care through systematic programs and interventions (e.g., clinical pharmacist monitoring, counseling and medication titration) have had some success⁴⁻⁷, but not all care systems can implement such programs. Nonetheless, if they led to better outcomes, some aspects of clinical operations could be adjusted. Thus, we

examined, in a cohort of HTN patients, relationships between aspects of clinical operations and the probability of BP normalization (hereafter, “normalization”) following an episode of elevated BP^{3, 8}

Methods

Data sources and organization

We obtained deidentified data, organized by person-month, from the clinical data system of the multi-clinic General Internal Medicine practice of a single, urban, safety-net hospital, using i2b2 software⁹. BP data was from the EMR, as entered and used by clinical staff. Individual providers were linked to patients at the start of an episode of uncontrolled hypertension (defined below). We obtained administrative data on Primary Care Provider (PCP) staffing – numbers of full time equivalent (FTE) and unique PCPs, including both MDs and Nurse Practitioners; there were no Physician’s Assistants.

Sample and definitions

BP measurements were taken routinely in internal medicine (87% of visits). We selected all adults with a diagnosis of essential hypertension (entered by clinicians on the problem list or as a billing code in the EMR) between 1/1/05 and 12/31/09. We defined an episode of uncontrolled hypertension as two consecutive primary care visits (for any reason; concurrent with or following a diagnosis of hypertension) with uncontrolled BP (either Systolic BP $\geq$ 140 or Diastolic BP $\geq$ 90) within a 90-day period. The episode starts on the date of the 2nd visit and we counted calendar months. If the patient normalized in the same month their episode began, that was considered “month 1”.

We followed each patient for 12 months after episode start or until BP normalization, whichever came first. BP normalization occurs on the earliest date when the average of the two most recent systolic/diastolic BP measures (from two separate dates) fell below 140 (and 90).

We used two consecutive elevated BP measurements to start an episode and a moving average of two to end it because individual measures of BP are highly variable and averages more accurately reflect BP-related health status¹⁰. For patients with more than one eligible episode we selected one at random. Accrual of patients into the study cohort is depicted in the Figure.

Variables

Four independent variables captured aspects of clinical operations for each calendar month, categorized into quintiles for modeling:

1. Number of kept appointments for individual PCPs (“clinician volume”) by month, measuring the *individual* case load of the patient’s clinician;
2. Practice-wide kept-appointment volume (“practice volume”) by month, measuring the *total* practice case load;

3. Number of PCP FTEs (full time equivalents) for the entire practice (“staffing levels”) obtained at an annual frequency and linearly interpolated by month, and
4. Number of distinct PCPs in the entire practice (“unique PCPs”) by month. Note that 1 FTE could reflect more than 1 part-time PCP.

Covariates—We included sociodemographic indicators previously associated with BP outcomes (age, sex, race, language). We also included co-morbid conditions that might affect BP management or make control more difficult, either because of direct effects of the conditions, associated risk factors, or medications used to treat them (Benign Prostatic Hypertrophy, Coronary Artery Disease, Congestive Heart Failure, Cerebrovascular Disease, Diabetes, Hyperlipidemia, Peripheral Vascular Disease, Renal Disease, Tobacco use).

We included indicators for calendar month to recognize seasonal variations in BP¹¹; calendar year to control for secular trends in BP management¹, and a count of the number of months since episode start (reasoning that the more time elapsed without having previously achieved control, the lower the odds of achieving it later).

Analyses

We examined the probability of BP normalization in any given month, modeled as a function of the four clinical operations variables included simultaneously and adjusted for covariates; the dependent variable was an indicator set to one in the month when BP normalized and zero otherwise. We used discrete time duration analysis, a technique which creates separate observations for each person-month, facilitating inclusion of time-varying covariates like clinical operations variables, and allowing for estimation by probit regression¹².

Straightforward estimation of the above-described model would generate biased results due to BP data that is missing not at random with respect to the outcome. BP is only observed at clinic visits, and health status is likely to affect both the probability of having a clinic visit and normalization. To address this, following accepted econometric techniques¹³ we use a two-equation statistical model, one estimating the probability of BP normalization (“BP normalization equation”) and the second, simultaneously estimating by maximum likelihood the probability of observing BP (“BP observation equation”); disturbance terms were correlated across models.

Estimating both equations simultaneously requires that the predictor variables differ between the two equations, to “identify” the model. Thus, the BP observation equation included two additional variables: distance from patient residence to clinic, and number of days between the two primary care visits with elevated BP defining the episode start. We reasoned that 1) living farther away leads to fewer visits and less likelihood of being seen in any month, and 2) patients with longer intervals between their first two visits may also see their PCPs less often in the future. The model was estimated in STATA (version 10) using the ‘heckprob’ command, clustering on individuals.

Results

The sample of 50,403 person-months reflected experiences of 7,409 distinct patients (Table 1). They were 61% African American, 11% Hispanic, 15% white and 13% other race; 8% spoke Spanish, and 14%, Haitian Creole. Common comorbidities included diabetes (28%), coronary artery disease (8%), renal disease (7%), and tobacco use (10%).

Table 2 describes the person-months data. Mean clinician appointments per person-month were 115.8, mean overall appointments were 6,641.1, mean staffing was 30.3 and mean unique PCPs was 69.3. The mean time to normalization was 5 months (median: 4 months), and 4% did not normalize within 12 months. The total number of individual clinician appointments was not strongly correlated with the clinic-level variables (max $r=0.09$). Clinic-level FTEs were only moderately correlated with clinic-level appointments and unique PCPs (max $r=0.47$), ameliorating concerns about collinearity.

BP normalization was less likely for episodes of uncontrolled BP starting in months when the number of unique PCPs was high (Table 3). The marginal effect of the top quintile of number of unique PCPs indicates that the probability of normalization was reduced by 9 percentage points ($p<0.01$) from the lowest quintile.

Practice appointment volume also negatively affected likelihood of normalization. The marginal effect for episodes of uncontrolled BP starting in months with the most appointments (top quintile) was a 6 percentage point decrease in the probability of normalization ($p=0.01$). Marginal effects for the 4th, 3rd, and 2nd quintiles of this variable were also negative and declining in magnitude (4, 3, and 3 percentage points, respectively, all p 's >0.05).

Neither clinician volume nor practice staffing levels was significantly associated with probability of normalization.

Several patient covariates affected the probability of normalization. Older patients – especially those over 65 – and those with renal dysfunction were less likely to normalize; however, patients with benign prostatic hypertrophy and tobacco use were more likely to normalize.

Results from the BP observation model (Table 4) show that BP values were more likely to be observed in months in which the patient's clinician had high appointment volume, with high numbers of unique PCPs, and with high practice appointment volume. Older patients, females and patients with high cholesterol, peripheral vascular disease, or renal disease were more likely to have BP values observed.

Patients living farther from the clinic were less likely to have observed BP values ($p<0.01$), as were those with more days between the first two primary care visits ($p<0.01$). The estimated correlation between disturbance (error) terms in the two equations was (-0.78 ($p<0.01$)), indicating that unobservable factors making BP observation more likely tended to make BP normalization less likely. The magnitude and statistical significance of this correlation, and a sensitivity analysis in which a single equation that did not correct for

observation bias found no significant effects of any clinical observation variables, both indicate the need to estimate the two equations simultaneously.

Discussion

We examined aspects of clinical operations and the probability of BP normalization following an episode of elevated BP among a cohort of HTN patients. Lower likelihood of BP normalization in months with higher numbers of unique PCPs suggests that increasing the absolute number of PCPs (holding FTEs constant) does not necessarily lead to better clinical outcomes. The association of higher practice appointment volume with lower likelihood of BP normalization, even after controlling for individual clinicians' appointment volume, suggests that when practices are busier, BP care may suffer.

The greater likelihood of *observing* BP in months with higher clinician or practice appointment volume or with high numbers of unique PCPs, indirectly suggests better access to care, but the negative associations of the latter two with BP normalization suggests decrements in such care. The few prior studies on clinical operations factors' effects on BP outcomes found an association between more clinic visits/day per physician and higher Systolic BPs¹⁴; another study found no association between practice caseload and BP control¹⁵. We know of no studies simultaneously examining the effects of appointment volume and clinician staffing on BP outcomes, nor any accounting for the likelihood of having BP observed — an important methodological limitation of prior research.

Our findings and economic productivity models suggest that health care organizations should be wary of increasing practice-level appointment volume without adjusting administrative and clinical capacity. Also, caution is warranted for practices considering augmenting provider staffing levels with additional part-time providers, which, though common in academic medical centers, may erode care continuity¹⁶.

Comprehensive efforts to improve BP control through home BP monitoring and pharmacist medication management may succeed by delegating BP management to others⁷. However, our results suggest that, apart from such programs, levels of PCP staffing and practice appointment volume may also independently affect BP outcomes.

This study was limited by its use of data from a single, albeit large, clinical practice, and by its reliance on administrative staffing data and clinical data from the electronic medical record, which were not collected for research. We also had no additional data about clinician characteristics, provider continuity, or patient adherence to BP therapy. Yet, the combination of data sources, the identification of associations in data spanning five years, together with a modelling approach that accounts for the fact that BPs are only available when visits occur, suggests that this methodological approach may be valuable for others interested in examining associations between clinical operations and clinical outcomes in similar settings which may also have such readily available data.

A heightened understanding of these relationships through analysis of available observational data may inform clinical leaders' efforts to improve care through support for

evidence-based appointment volume standards and better understanding of the implications of provider staffing arrangements.

Acknowledgments

Funding Disclosure: This research was supported by funding from the NIH/NHLBI (U01HL105342, N. Kressin, PI). Dr. Kressin is supported in part by a Research Career Scientist award from the Veterans Affairs Health Services Research and Development Service (RCS- 02-066-1). The sponsors had no role in the design and conduct of the study; the collection, management, analysis, and interpretation of the data; or the preparation, review, and approval of the manuscript.

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Figure. Accrual of patients into study cohort and assessment of BP normalization

The figure provides examples of three types of patients: (Patient 1) a patient who has uncontrolled hypertension that does not normalize after a year but is censored at 12 months; (Patient 2) a patient who has uncontrolled blood pressure that does normalize within a year; (Patient 3) a patient with uncontrolled blood pressure who was enrolled late in the cohort accrual process, and followed into the period when no new patients were enrolled; (Patient 4) a patient who was not eligible for enrollment into the cohort.

Table 1Characteristics of Study Patients¹ (N=7,409)

Age (mean)	58.9
Female	54.2%
Black	60.2%
Hispanic	11.4%
Other race	12.5%
Creole language	12.4%
Spanish language	8.0%
Benign prostatic hypertrophy	3.3%
Coronary artery disease	8.9%
Heart failure	4.9%
Cardiovascular disease	5.1%
Diabetes	28.3%
High cholesterol	19.9%
Peripheral vascular disease	5.8%
Renal disease	7.2%
Tobacco use	10.4%
Mean (SD) distance to clinic (km)	9.3 (12.3)
Mean (SD) Time from BP1 to BP2 (days)	37.3 (23.9)

¹Note: Analyses were not conducted at the individual patient level, but rather at the level of person-months. We provide descriptive information at the patient level here for reference only; see Table 2 for descriptive information about the person-month variables included in the analyses.

Table 2

Descriptive Statistics for Variables Included in Discrete Time Duration Analysis (Probit regression) Models
(N=50,403 person-months)

Variable	Mean	SD
Patient characteristics(in person-months)		
Age 50–59	26.65%	44.21%
Age 60–65	16.48%	37.10%
Age 66 and up	32.10%	46.69%
Female	52.76% ¹	49.92%
Black	60.80%	48.82%
Hispanic	10.87%	31.12%
Other race	12.67%	33.26%
Creole language	13.47%	34.14%
Spanish language	7.66%	26.60%
Benign prostatic hypertrophy	3.15%	17.47%
Coronary artery disease	8.08%	27.25%
Heart failure	4.45%	20.62%
Cardiovascular disease	4.86%	21.51%
Diabetes	27.48%	44.64%
High cholesterol	18.14%	38.54%
Peripheral vascular disease	5.24%	22.29%
Renal disease	6.55%	24.75%
Tobacco use	9.71%	29.61%
Clinical Operations Variables		
Clinician volume ^a	115.837	79.365
Practice volume ^b	6641.130	510.909
Unique PCPs ^c	69.267	3.743
Staffing levels ^d	30.341	2.804

Note: percentages may differ slightly from those in Table 1, because these are person-months instead of persons.

^aNumber of appointments for an individual provider

^bNumber of appointments for entire practice

^cNumber of distinct PCP clinicians for entire practice

^dNumber of PCP FTEs for entire practice

Table 3

Discrete Time Duration Analysis (Probit Regression ^a) of Clinical Operations Factors Affecting BP Normalization

Variable	Coefficient	Standard Error	z statistic	P> z	Marginal Effect
Clinician volume 2 nd quintile (q) ^d	0.022185	0.027406	0.81	0.418	0.008589
Clinician volume 3 rd q	0.031128	0.027522	1.13	0.258	0.012044
Clinician volume 4 th q	0.041621	0.028235	1.47	0.14	0.01609
Clinician volume 5 th q	-0.01906	0.02809	-0.68	0.497	-0.0074
Practice volume 2 nd q ^b	-0.07584	0.032627	-2.32	0.02	-0.02956
Practice volume 3 rd q	-0.0722	0.037027	-1.95	0.051	-0.02813
Practice volume 4 th q	-0.10971	0.048879	-2.24	0.025	-0.04284
Practice volume 5 th q	-0.14529	0.058024	-2.5	0.012	-0.05684
Unique PCPs 2 nd q ^c	0.032677	0.030027	1.09	0.276	0.012641
Unique PCPs 3 rd q	-0.03072	0.03122	-0.98	0.325	-0.01194
Unique PCPs 4 th q	-0.05757	0.031891	-1.81	0.071	-0.0224
Unique PCPs 5 th q	-0.2253	0.06904	-3.26	0.001	-0.08862
Staffing levels 2 nd q ^d	-0.02661	0.04934	-0.54	0.59	-0.01034
Staffing levels 3 rd q	0.035807	0.053398	0.67	0.502	0.01385
Staffing levels 4 th q	0.085119	0.0737	1.15	0.248	0.03279
Staffing levels 5 th q	-0.0218	0.067611	-0.32	0.747	-0.00847
Unique patients	7,409	Patient-months	50,403		

^a Standard errors clustered on individuals. Results adjusted for effects of sociodemographics and comorbidities.^d Number of appointments for an individual provider^b Number of appointments for entire practice^c Number of distinct PCP clinicians for entire practice^d Number of PCP FTEs for entire practice

Table 4

Discrete Time Duration (Probit Regression) Analysis of Clinical Operations Factors Affecting BP Observation*

Variable	Coefficient	Standard Error	z statistic	P> z
Clinician volume 2 nd quintile (q)	−0.00388	0.022132	−0.18	0.861
Clinician volume 3 rd q	−0.01479	0.022241	−0.66	0.506
Clinician volume 4 th q	−0.03103	0.022244	−1.39	0.163
Clinician volume 5 th q	0.04931	0.022886	2.15	0.031
Practice volume 2 nd q	0.051322	0.022422	2.29	0.022
Practice volume 3 rd q	0.072736	0.022316	3.26	0.001
Practice volume 4 th q	0.145762	0.026535	5.49	<0.001
Practice volume 5 th q	0.127338	0.02772	4.59	<0.001
Staffing levels 2 nd q	0.003792	0.036394	0.1	0.917
Staffing levels 3 rd q	0.001332	0.036214	0.04	0.971
Staffing levels 4 th q	−0.13412	0.051374	−2.61	0.009
Staffing levels 5 th q	−0.0707	0.047034	−1.5	0.133
Unique PCPs 2 nd q	−0.007620	0.019748	−0.39	0.700
Unique PCPs 3 rd q	0.038422	0.020887	1.84	0.066
Unique PCPs 4 th q	0.061425	0.022938	2.68	0.007
Unique PCPs 5 th q	0.197514	0.049144	4.02	<0.001
Correlation =	−0.7786	P> z =	0.005	

* Standard errors clustered on individuals. Results adjusted for effects of sociodemographics and comorbidities. Effects omitted for elapsed months, calendar quarters and calendar years.