Systolic blood pressure measured at hospital discharge and post-discharge outcomes- a framework for quantifying risk.

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**Keywords:** Post-discharge outcomes, Readmissions, Mortality, Hospitalization.

**Abbreviations:**

**AST: Aspartate Amino Transferase**

**ALT: Alanine Amino Transferase**

**AHRQ: Agency for Health Care Research and Quality**

**EMR: Electronic Medical Record**

**Potassium: K+**

**Glomerular Filtration rate: GFR**

**Odds Ratio: OR**

**Word count (excluding abstract):**

**Introduction**

Clinicians often encounter abnormal blood pressure at hospital discharge. However, few existing studies quantify the association risk short-term post-discharge outcomes and the discharge SBP value. In order to construct such a frame -work we study the association between the last SBP measured during a hospitalization and the odds of 30-day readmission and/or death. We hypothesize that the lowest risk would occur at normo-tensive SBP readings and the odds of an adverse post-discharge outcomes would increase progressively at higher and lower levels of discharge SBP.

**Methods:**

The institutional review board approved this study. A clinical data-warehouse with electronic medical record derived dataset of 94,974 emergent hospital admissions for 57,063 patients within a 6-hospital network in the Minneapolis/ St Paul area, Minnesota was used. The encounters spanned a 4-year period ranging from 2012-2016. The hospital system consists of one 450-bed university tertiary care center and 5 community hospitals ranging from 100-450 beds. Patients were excluded if they were non-emergent admissions, less than 18 years of age, did not consent to their medical record being used for research purposes or had less than thirty one days of follow-up mortality data. We included hospitalizations to all units and services as long as they met the above criterion. Our database had the complete death record issued from 2011 onwards for deceased individuals who were born in Minnesota, had died in Minnesota, or had ever had a permanent address in the state. In order to avoid bias introduced by repeated measurements from a patient — we randomly sampled the original dataset to include only one encounter for each patient. SBP were binned into the following group concentrations: <80 mmHg, 80-100 mmHg, 100-120 mmHg, 120-140 mmHg, 140-160 mmHg, 160-180 mmHg, 180-200 mmHg, > 200mmHg. The odds of death or readmission as a function of the final SBP  were modeled using logistic regression. The lowest unadjusted rates of adverse events were observed when the systolic blood pressure is in the 120-140 mmHg range and this range was used as the baseline to compute the odds ratio. The primary outcome was death or readmission within 30-days of the index hospitalization. We adjusted the models for age, sex, race and AHRQ comorbidities and estimated glomerular filtration rate (eGFR). Observations with missing values were excluded from the modeling. Analysis was done using R-Studio. R packages tidyverse, icd, nephro, ggplot2, tableone were used.

**Results:**

Patient demographic, clinical, and laboratory characteristics are shown in Table 1. Comorbidity profiles are shown in Supplementary Table 1. The results of the logistic regression are tabulated in Table 1.

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|  |  |  |  |  |  |
|  |  | Stratified by death or readmission within 30 days. |  |  |  |
|  |  |  | false | true |  |
|  |  | Number of patients |  |  |  |
|  |  |  | 50556 | 5834 |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  | Age in years (mean (sd)) | 58.86 (20.13) | 68.59 (17.24) | <0.0 |
|  |  | Albumin (mean (sd)) | 3.51 (0.7) | 2.84 (0.75) | <0.0 |
|  |  | ALT (mean (sd)) | 53.16 (114.9) | 120.33 (517.7) | <0.0 |
|  |  | Anion Gap (mean (sd)) | 7.82 (2.97) | 8.62 (4.3) | <0.0 |
|  |  | AST (mean (sd)) | 46.6 (90.97) | 198.25 (1000.4) | <0.0 |
|  |  | Total Bilirubin (mean (sd)) | 0.86 (1.34) | 2.55 (5.69) | <0.0 |
|  |  | Carbon Dioxide (mean (sd)) | 26.26 (3.64) | 25.63 (5.91) | <0.0 |
|  |  | Chloride (mean (sd)) | 104.81 (4.64) | 104.74 (6.81) | 0.37 |
|  |  | Creatinine (mean (sd)) | 0.99 (0.87) | 1.41 (1.29) | <0.0 |
|  |  | Glucose (mean (sd)) | 112.42 (39.18) | 125.38 (55.36) | <0.0 |
|  |  | Potassium (mean (sd)) | 3.97 (0.44) | 4.09 (0.67) | <0.0 |
|  |  | Sodium (mean (sd)) | 138.82 (3.53) | 138.87 (5.62) | 0.4 |
|  |  | Blood Urea Nitrogen mean (sd)) | 16.32 (11.66) | 29.21 (24.33) | <0.0 |
|  |  | Hemoglobin (mean (sd)) | 11.99 (2.23) | 10.51 (2.25) | <0.0 |
|  |  | Mean Corpuscular Volume (mean (sd)) | 90.21 (6.29) | 91.86 (7.37) | <0.0 |
|  |  | Platelet Count (mean (sd)) | 220.58 (91.74) | 197.96 (112.59) | <0.0 |
|  |  | White Blood Count (mean (sd)) | 8.29 (4.82) | 11.72 (13.11) | <0.0 |
|  |  | Length of stay in days (mean (sd))" & 3.73 (3.97) & 5.84 (7.05) & <0.0& & & & && & Discharge Disposition (%) & & & <0.0& & Acute Rehab Facility & 721 (1.43) & 33 (0.57) && & Expired & 19 (0.04) & 1803 (30.91) && & Home IV Drug Therapy & 430 (0.85) & 47 (0.81) && & Home or Self Care & 34241 (67.73) & 1429 (24.49) && & Home-Health Care Svc & 4426 (8.75) & 535 (9.17) && & Hospice/Home & 350 (0.69) & 387 (6.63) && & Left Against Medical Advice & 493 (0.98) & 30 (0.51) && & Psychiatric Hospital & 625 (1.24) & 40 (0.69) && & Short Term Hospital & 1093 (2.16) & 241 (4.13) && & Skilled Nursing Facility & 6913 (13.67) & 978 (16.76) && & Other & 1245 (2.46) & 311 (5.33) && & Systolic Blood Pressure (mmHG, mean (sd)) & 127.25 (18.64) & 119.55 (26.21) & <0.0& & Diastolic Blood Pressure(mmHG, mean (sd)) & 72.5 (12.73) & 66.87 (16.61) & <0.0& & Temperature (Farenheight, mean (sd)) & 97.89 (0.87) & 97.96 (1.6) & <0.0& & Pulse(beats per minute, mean(sd)) & 79.46 (16.74) & 86.88 (20.88) & <0.0& & Pulse oxymetry (mean (sd)) & 96.14 (2.91) & 92.02 (13.06) & <0.0& & Respiratory rate (mean (sd)) & 17.35 (2.69) & 18.39 (7.33) & <0.0& & Body Mass Index (mean (sd)) & 36.62 (442.05) & 31.44 (291.7) & 0.39& & White & 42836 (84.73) & 5081 (87.09) & |  |  |  |

**Table 1. Demographic, clinical and laboratory characteristics of the cohort.**

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|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | Systolic Blood Pressure (mmHg) | Adjusted Odds Ratio | Unadjusted Odds Ratio | Systolic Blood Pressure (mmHg) | Adjusted Odds Ratio | Unadjusted Odds Ratio | Systolic Blood Pressure (mmHg) | Adjusted Odds Ratio | Systolic Blood Pressure (mmHg) | Adjusted Odds Ratio |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | <80 | 36.72 (29.63-45.51) | 54.2 (47.6-61.7) | <81 | 36.72 (29.63-45.51) | 54.2 (47.6-61.7) | <82 | 36.72 (29.63-45.51) | <81 | 36.72 (29.63-45.51) |
|  |  | 80-100 | 3.27 (3.04-3.52) | 3.25(3.1-3.4) | 80-101 | 3.27 (3.04-3.52) | 3.25(3.1-3.4) | 80-102 | 3.27 (3.04-3.52) | 80-101 | 3.27 (3.04-3.52) |
|  |  | 100-120 | 1.3 (1.23-1.38) | 1.23 (1.18-1.27) | 100-121 | 1.3 (1.23-1.38) | 1.23 (1.18-1.27) | 100-122 | 1.3 (1.23-1.38) | 100-121 | 1.3 (1.23-1.38) |
|  |  | 140-160 | 0.84 (0.78-0.9) | 1.06 (1.01-1.11) | 140-161 | 0.84 (0.78-0.9) | 1.06 (1.01-1.11) | 140-162 | 0.84 (0.78-0.9) | 140-161 | 0.84 (0.78-0.9) |
|  |  | 160-180 | 0.88 (0.77-1.0) | 1.32 (1.22-1.42) | 160-181 | 0.88 (0.77-1.0) | 1.32 (1.22-1.42) | 160-182 | 0.88 (0.77-1.0) | 160-181 | 0.88 (0.77-1.0) |
|  |  | 180-200 | 1.43 (1.06-1.93) | 2.71 (2.31-3.18) | 180-201 | 1.43 (1.06-1.93) | 2.71 (2.31-3.18) | 180-202 | 1.43 (1.06-1.93) | 180-201 | 1.43 (1.06-1.93) |
|  |  | >200 | 10.75 (5.92-19.5) | 8.12 (5.57-11.86) | >201 | 10.75 (5.92-19.5) | 8.12 (5.57-11.86) | >202 | 10.75 (5.92-19.5) | >201 | 10.75 (5.92-19.5) |

 **Table 2. Results of the logistic regression.**The primary outcome was death or readmission within 30-days of the index hospitalization. The model for age, sex, race and AHRQ comorbidities. The120-140 mmHg range was treated as the baseline reference for calculating the odds ratio).

 **Discussion**

Currently there are no guidelines as to what constitutes a ‘safe’ discharge SBP. In our study, a SBP of 120-160 mmHg is associated with the lowest risk of adverse events in the initial 30-days after a hospitalization. The odds of adverse outcomes steeply increased below SBP’s of 100 mmHg and above 160 mmHg.  Prior studies report increased risk of adverse outcomes when the systolic blood pressure is less than 90 -100 mmHg — we note a significantly increased in risk in when the SBP was below 120 mmHg. It is important to note the observational nature of our study. We do not claim a causal relationship between abnormal SBP at discharge and adverse events. It is likely that patient cohorts with markedly abnormal SBP are qualitatively different than the cohort of normotensive patients.  Although we have tried to adjust for a number of the most relevant variables, many unmeasured variables could be potential confounders. In the future, causal approaches such as propensity matching may shed light on the nature of the observed association.

Our findings may not be applicable for subgroups such as patients with heart failure, end stage liver disease, or post-acute stroke populations.  There may have been variations in the method of inpatient blood pressure measurements.  Furthermore, blood pressure measurements may be falsely elevated due to factors such as withdrawal, anxiety, pain, and urinary retention.   Finally, we do not have information on readmissions outside our large hospital network, thus our rate of readmissions may be underestimated.Despite these limitations, our study documents an interesting observation and reminds clinicians to be cognizant of abnormal discharge systolic blood pressure and its association with increased 30-day mortality and readmission.  Further randomized controlled trials are needed to elucidate the relationship between discharge systolic blood pressure and post discharge outcomes.

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Supplementary Comorbidity distributions in the dataset

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|  |  |  |  |  |
|  | Stratified by death or readmission within 30 days |  |  |  |
|  |  |  |  |  |
|  | false |  |  |  |
|  | true |  |  |  |
|  | P-Value |  |  |  |
|  |  |  |  |  |
|  | Number of patients | 50556 | 5834 |  |
|  | CHF = TRUE (%) | 2929 ( 5.79) | 591 (10.13) | <0.0 |
|  | Valvular = TRUE (%) | 1431 ( 2.83) | 223 ( 3.82) | <0.0 |
|  | PHTN = TRUE (%) | 1421 ( 2.81) | 235 ( 4.03) | <0.0 |
|  | PVD = TRUE (%) | 1739 ( 3.44) | 271 ( 4.65) | <0.0 |
|  | HTN = TRUE (%) | 5906 (11.68) | 771 (13.22) | 0.0 |
|  | Paralysis = TRUE (%) | 288 ( 0.57) | 37 ( 0.63) | 0.6 |
|  | NeuroOther = TRUE (%) | 5127 (10.14) | 825 (14.15) | <0.0 |
|  | Pulmonary = TRUE (%) | 2466 ( 4.88) | 369 ( 6.33) | <0.0 |
|  | DM = TRUE (%) | 3022 ( 5.98) | 398 ( 6.82) | 0.01 |
|  | DMcx = TRUE (%) | 1329 ( 2.63) | 205 ( 3.52) | <0.0 |
|  | Hypothyroid = TRUE (%) | 1184 ( 2.34) | 141 ( 2.42) | 0.75 |
|  | Renal = TRUE (%) | 2592 ( 5.13) | 448 ( 7.68) | <0.0 |
|  | Liver = TRUE (%) | 1152 ( 2.28) | 351 ( 6.02) | <0.0 |
|  | PUD = TRUE (%) | 17 ( 0.03) | 6 ( 0.1) | 0.03 |
|  | HIV = TRUE (%) | 94 ( 0.19) | 11 ( 0.19) | 1 |
|  | Lymphoma = TRUE (%) | 724 ( 1.43) | 169 ( 2.9) | <0.0 |
|  | Mets = TRUE (%) | 899 ( 1.78) | 344 ( 5.9) | <0.0 |
|  | Tumor = TRUE (%) | 3336 ( 6.6) | 774 (13.27) | <0.0 |
|  | Rheumatic = TRUE (%) | 728 ( 1.44) | 96 ( 1.65) | 0.24 |
|  | Coagulopathy = TRUE (%) | 684 ( 1.35) | 135 ( 2.31) | <0.0 |
|  | Obesity = TRUE (%) | 954 ( 1.89) | 64 ( 1.1) | <0.0 |
|  | WeightLoss = TRUE (%) | 773 ( 1.53) | 138 ( 2.37) | <0.0 |
|  | FluidsLytes = TRUE (%) | 2855 ( 5.65) | 589 (10.1) | <0.0 |
|  | BloodLoss = TRUE (%) | 181 ( 0.36) | 20 ( 0.34) | 0.95 |
|  | Anemia = TRUE (%) | 3753 ( 7.42) | 749 (12.84) | <0.0 |
|  | Alcohol = TRUE (%) | 2909 ( 5.75) | 189 ( 3.24) | <0.0 |
|  | Drugs = TRUE (%) | 1716 ( 3.39) | 74 ( 1.27) | <0.0 |
|  | Psychoses = TRUE (%) | 4527 ( 8.95) | 326 ( 5.59) | <0.0 |
|  | Depression = TRUE (%) | 2277 ( 4.5) | 132 ( 2.26) | <0.0 |