**ROUGH DRAFT**

*Rough drafts can be very rough and should be very fast - just try to get the ideas out on to paper.  Ideally, letting the draft flow as best as possible, taking a break, then revisiting with editing. Short sentences. Punch intro sentences to paragraphs, end paragraphs that collect the important points then transition to the next. One idea per paragraph.*

*Good overall how-to*[*https://x.com/nicholaszaorsky/status/1479549305623035904?s=11*](https://x.com/nicholaszaorsky/status/1479549305623035904?s=11)

**Title:**

Comparing Venous Blood Gas and Arterial Blood Gas in Hypercapnic Respiratory Failure

**Introduction:**

*“Problem, Gap, Hook” Heuristic:*[*https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4602011/pdf/40037\_2015\_Article\_211.pdf*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4602011/pdf/40037_2015_Article_211.pdf)

Arterial blood gases (ABGs) are considered the gold standard for assessing acid-base balance, oxygenation and ventilation status, and remain essential in the management of hypercapnic respiratory failure. However, obtaining an ABG can be uncomfortable for patients, time-consuming and technically challenging, often requiring multiple attempts. Potential complications include arterial injury, thrombosis, air or clotted blood embolism, arterial occlusion, hematoma, and aneurysm formation.

Hypercapnia results from lungs’ inability to adequately remove carbon dioxide from the bloodstream, leading to its accumulation. On ABG, hypercapnia is defined as greater than 45 mmHg while on VBG, hypercapnia is usually defined as greater than 50 mmHg. VBGs are increasingly used in emergency settings as a screening tool for hypercapnia due to ease of collection and reduced risk, though they are less precise in measuring arterial pCO2 compared with ABGs.

Despite their growing use, there has been limited studies comparing VBG versus ABG in diagnosis of hypercapnic respiratory failure, and billing and device qualification guidance does not admit venous blood gas as sufficient evidence of hypercapnic respiratory failure. In a study by Davies et. al, hospitalized patients with known or suspected hypercapnic respiratory failure underwent near-simultaneous ABG and VBG testing. Results demonstrated close agreement in PaCO2 values between ABG and calculated values derived from VBGs, supporting the use of VBGs in monitoring hypercapnic patients. Similarly, a review by Lacy et. al analyzed a prospective study which found VBG to have 100% sensitivity in identifying hypercapnia in those with respiratory failure due to COPD exacerbation, pneumonia, heart failure and asthma using Pv CO2 greater than 45 mmHg. Ak et. al published an additional prospective study in COPD patients in acute exacerbation that found VBG to identify hypercapnia in 100%. In contrast, McKeever found wide variability between arterial and venous CO₂ levels in COPD patients with acute exacerbations, underscoring the limitations of VBG precision. Most prior studies have emphasized the analytical agreement between venous and arterial blood gases. Few have examined whether hypercapnia identified by each method carries similar prognostic weight, or whether observed differences reflect patient selection rather than biology. If venous hypercapnia predicts outcomes adverse outcomes such as the need for ventilatory support, this would support using VBGs as diagnostic evidence of hypercapnic respiratory failure.

The objective of this study was to determine the associations of hypercapnia by ABG and VBG with hypercapnia-related outcomes, such as receipt of a diagnosis code for hypercapnic respiratory failure, receipt of invasive mechanical ventilation, receipt of non-invasive ventilation (NIV), and 60-day any-cause mortality, after adjusting for propensity to redeive each type of blood gas sampling.

**Methods:**

<https://www.equator-network.org/reporting-guidelines/record/>

1. *How did we get the dataset:  Requested all data from 2022 from TriNetX research network that had at least 1 criteria that would indicate hypercapnia may be present*
2. *What data cleaning did we do: ensured institution was submitting all data.*
3. *A “Table 1” to describe the variables in the dataset*

<https://theeffectbook.net/ch-DescribingVariables.html>

*Guide to help make figures of Table 1 (to show distribution)*

<https://jthomasmock.github.io/gtExtras/articles/plotting-with-gtExtras.html>

1. *Description of correlations with the outcomes of interest*

<https://theeffectbook.net/ch-DescribingRelationships.html>*(the rest of the book looks pretty good, too)*

This multicenter retrospective cohort study using de-identified patent data from the 2022 TriNetX research network (TriNetX, LLC. Cambridge, MA), which aggregates electronic health record data from participating health systems. which provides deidentified individual-level patient data from 76 medical centers across the US serving roughly 115 million patients at the time of data requisitionThe University of Utah Institutional Review Board reviewed the study protocol and determined the project met criteria for exemption (IRB #00184622).

**Study Population**

Patients were eligible for inclusion if they had at least one reason indicatying a reasonable suspicion might suspect hypercapnia (see e-appendix 4 figure) during Emergency or Inpatient encounter from Jan 1 to Dec 31 2022.

A table of medical records

AI-generated content may be incorrect.

Patients with missing key demographic or outcome data were excluded.

**Exposure:**

Arterial and Venous blood gas samples from the calendar day of the encounter start were included.

The following LOINC codes were used to identify arterial (LOINC: 2019-8, LOINC: 2026-3, LOINC: 32771-8 ) and venous (LOINC: 115577-6, LOINC: 2021-4) blood gasses

For patients with VBGs, a “calculated ABG” partial pressure of carbon dioxide (pCO₂) was also estimated using the Farkas equation: Estimated arterial pCO₂=VBG pCO₂−0.22×(93%−VBG O₂ saturation).

CO₂ was represented in two ways. First, as a categorical variable: low (PaCO₂ < *, PvCO₂ < ), normal (–* mmHg), and high (PaCO₂ ≥ 45 mmHg, PvCO₂ ≥ 50 mmHg). Second, as a continuous variable using a restricted cubic spline with \*\*\* knots, allowing flexible non-linear shapes such as bends or curves.

**Outcomes**

* Hypercapnic respiratory failure diagnosis code: ICD-10-CM codes E66.2, J96.02, J96.12, J96.22, and J96.92
* Receipt of non-invasive ventilation procedure code at any time during the hospitalization
* Receipt of an invasive mechanical ventilation procedure code at any time during the hospitalization
* All-cause mortality within 60 days of encounter start. The 60-day window was selected based on ARDS literature, where this time point captures the greatest intervention-related mortality differences, reflecting the period when deaths attributable to respiratory failure and its management are most apparent.”

**Statistical Modeling:**

Separate simple logistic regression models were fit to evaluate the association between pCO₂ category (below normal, normal, above normal) and each of the four outcomes listed above and no adjustment for additional variables. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated, using the normal pCO₂ group as the reference. Odds ratios from categorical models were displayed using forest plots on a logarithmic scale, stratified by cohort. An additional set of 4 simple logistic regression models were fit usingrestricted cubic splines. Conditional predicted probabilities of each outcome were estimated across the full observed range of pCO₂ values, with 95% confidence intervals.

To address differences in the types of patients who receive arterial versus venous blood gas sampling, we applied inverse probability of selection weights (IPSWs). This approach estimates each patient’s likelihood of receiving a blood gas based on observed covariates. Patients who were unlikely to be tested but nonetheless had a blood gas drawn are up-weighted, representing similar patients in the population who were not sampled. Separate models were created to model propensity to receive ABG testing and propensity to receive VBG testing. Patients who received ABG testing were then re-weighted by the ABG propensity to approximate the target population of patients with any reason to suspect hypercapnia. Patients who underwent VBG testing were then reweighted to the same population. The resulting reweighted samples ot the same target populations allows for comparisons of prognostic significance while adjusting for differences in the types of patients sampled.

Propensity scores were estimated by modeling the likelihood of obtaining an arterial or venous blood gas, belonging to each cohort based on demographic variables (age, sex, race, ethnicity, BMI, location), comorbid conditions diagnosed on or before the index encounter(COPD, asthma, OSA, CHF, neuromuscular disorders, pulmonary hypertension, CKD, diabetes) and other objective data including triage vital signs and basic initial labs. Propensities were estimated using extreme gradient boosting machines (XGBoost; \*\*\* parameter settings), a machine learning algorithm that natively handles non-linearities and missing data. Weights were windsorized (truncated) at the 1st percentiles to avoid unstable weights and patients who may have had no realistic chance of receiving blood gas sampling. Covariate balance was evaluated using standardized mean differences, with <0.1 indicating acceptable balance. Additionally, propensity score distributions were compared graphically to assess overlap between groups before and after weighting.

Software: R version \*\*\*, using packages rms, weightit \*\*\*

Code is available at \*\*\*

**Results:**

* *Results from cleaning and inclusion – Dr. Locke*

*Guidance on table formatting:*[*https://x.com/carlislerainey/status/1799022485733875770?s=46&t=5eJ6uoTQrbbYTlHIOnRYRg*](https://x.com/carlislerainey/status/1799022485733875770?s=46&t=5eJ6uoTQrbbYTlHIOnRYRg)

*Options of how to display data: https://www.data-to-viz.com/*

A total of \*\*\* patients met inclusion criteria for the study, see figure CONSORT. Patients were categorized according to blood gas type and the presence or absence of hypercapnia, resulting in six analytic groups. Baseline demographic and clinical characteristics for these groups are summarized in Table 1A and 1B. Table 1A and 1B provides a summary of the dataset. The table divides the data into six groups: patients who had 1) no ABG, 2) hypercapnia on ABG, 3) no hypercapnia on ABG, 4) no VBG, 5) hypercapnia on VBG, 6) no hypercapnia on VBG. It includes the mean and standard deviation for age and BMI, as well as the percentage of sex and the distribution of race, ethnicity and region in the United States. Additionally, the table presents the prevalence of key comorbidities, including obstructive sleep apnea (OSA), asthma, chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), neuromuscular disorders, pulmonary hypertension, chronic kidney disease (CKD) and diabetes. Furthermore, the minimum, maximum, median, mean, and standard deviation of pCO2 levels from both VBGs and ABGs are also reported.

<Create paragraphs the narrate the key findings illustrated by each table or figure – and then reference them. The captions of the tables should stand alone (ie. If someone just reads the tables, it should make sense) so they can be somewhat repetitive of the main text but should have a bit more explanation.>

**Table 1A: Description of Variables by ABG Group.**

**Table 1B: Description of Variables by VBG Group.**

Figure 1 displays the adjusted odds ratios with 95% confidence intervals, comparing below-normal and above-normal pCO₂ groups to the normal reference group fort invasive mechanical ventilation, noninvasive ventilation, 60-day mortality, and hypercapnic respiratory failure.

**Figure 1: Inverse Propensity Weighted Odds Ratio of Outcomes by PCO2 Category**

To further examine the continuous relationship between PCO2 and clinical outcomes, restriced cubic spline models were constructed. Figure 2A, 2B and 2C present the predicted probabilities for each outcome across pCO2 values, stratified by ABG, VBG and calculated ABG groups.

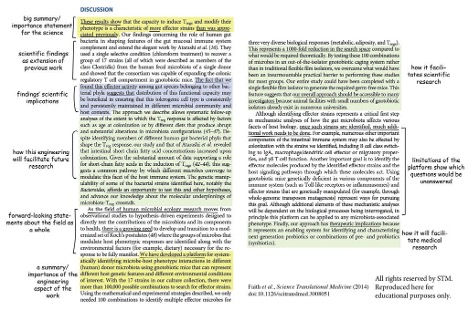
**Figure 2A: Inverse Propensity Weighted Predicted Probability by ABG.**

**Figure 2B: Inverse Propensity Weighted Predicted Probability by VBG.**

**Figure 2C: Inverse Propensity Weighted Predicted Probability by Calculated ABG.**

**Discussion:**

Once you have the results together, take a stab at the discussion – can be super rough and dirty and does not have to be completed all in 1 swing…. But focus on the big summary statement paragraph, and the strengths and limitations paragraphs. We can interate on those and go from there.



* *Restate the high level results*
* *Compare to prior studies*
* *Highlight consistencies and differences*
* *Strengths & Limitations*
* *Clinical implications*

**References:**

Supplement:

Things like the propensity diagnostics could be included in the supplement.