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THINGS WE DO FOR NO REASON

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Things We Do for No Reason™: Arterial blood gas testing to screen for hypercarbic respiratory failure

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Abstract

Venous blood gases (VBGs) are safe and effective at screening for hypercarbic respiratory failure. Multiple studies have validated that a VBG with a $PvCO_2$ less than 45 reliably rules out hypercarbia. The use of VBGs for the initial screening of hypercarbia when hypercarbic respiratory failure is suspected can reduce the overall use of arterial blood gases which are more painful and take more time and expertise to perform.

CLINICAL SCENARIO

A 68-year-old woman with chronic obstructive pulmonary disease had a colonoscopy earlier in the day. Her nurse informs you that she cannot wake her despite two doses of naltrexone and that she currently has an oxygen saturation of 96% on room air. Suspecting the prolonged effects of anesthesia causing hypercarbic respiratory failure (RF), you debate whether to order a stat arterial blood gas (ABG) or venous blood gas (VBG).

INTRODUCTION

Hospitalists use blood gas analysis to evaluate respiratory and metabolic conditions. Information from blood gas testing can confirm or rule out diagnoses, assess the severity of conditions, and monitor treatments. Blood gases measure the pH, PCO_2 (partial pressure of carbon dioxide) and PO_2 (partial pressure of oxygen); and provide calculated values including bicarbonate and base excess. Hypercarbia (or hypercapnea) may be identified on a blood gas and can be the result of respiratory failure.[1] Acute exacerbations of COPD were the ninth most common primary discharge diagnosis in 2018 and are a frequent cause of hypercarbic respiratory failure.[2] Collectively, this results in the regular use of a blood gas to screen for hypercarbic respiratory failure in the hospital setting.

WHY YOU MIGHT THINK AN ABG IS THE BEST TEST TO ORDER

Many physicians learn about blood gas testing during their preclinical years. Lecture material and test questions refer to ABG analysis as a crucial step in determining the primary acid base disturbance and assessing for appropriate compensation. For instance, "First Aid for the USMLE Step 1" makes no mention of VBGs.[3]

ABG analysis, the gold standard for measurement of acid–base, oxygenation and ventilation status, provides the PCO_2 of arterial blood, which is proportional to CO_2 production and inversely proportional to alveolar ventilation.[4] PCO_2 measurement is often useful

to hospitalists assessing a patient's respiratory status or response to a metabolic process.

While VBGs can obtain all the values of an ABG, hospitalists cannot interchange them. A review of 13 studies comparing ABG and VBG values for 2009 patients found a weighted mean difference in pH of −0.033 for a VBG compared to an ABG. The study found a 95% limits of agreement (LOA) of approximately ±0.1, suggesting good agreement between ABG and VBG. Therefore, adding 0.033 to a VBG pH can estimate an ABG pH.[5] On the other hand, VBGs do not accurately predict PCO_2 as well as ABGs. In the same review, 8 studies assessing 965 patients found a weighted mean difference of 6.2 mmHg (a $PvCO_2$ typically reports approximately 6.2 mmHg higher than a $PaCO_2$), but the 95% LOA vary widely, falling between −17.4 to 23.9 mmHg. Even though these two values correlate well, hospitalists cannot uniformly convert the partial pressure of venous CO_2 ($PvCO_2$) to a $PaCO_2$.[5]

WHY YOU SHOULD ORDER A VBG TO SCREEN FOR ACUTE HYPERCARBIC RESPIRATORY FAILURE

Hospitalists often order blood gases to evaluate patients with RF for the presence of hypercarbia. Hypercarbic RF occurs when ventilatory lung dysfunction leads to excess CO_2 in the blood. Many mechanisms lead to hypercarbia, including central nervous system depression and respiratory neuromuscular/thoracic cage dysfunction. It is important to note that patients can have hypercarbia without acute hypercarbic respiratory failure. Increases in physiologic dead space account for CO_2 accumulation in chronic obstructive pulmonary disease (COPD) exacerbation. Timely diagnosis may prevent delayed treatment or unnecessary low-value care, such as a neurological workup for altered mentation from hypercarbia.

Studies comparing blood gas analysis have shown promising results when looking at $PvCO_2$ as a screening tool for hypercarbia. A 2002 prospective study first reported data on the efficacy of VBG screening for hypercarbic RF. Investigators compared 196 paired samples of VBG and ABG of patients presenting with RF (including COPD exacerbation, pneumonia, heart failure, and asthma). In this study, a $PvCO_2$ of 45 mmHg or greater identified all 56 cases of arterial hypercarbia ($PaCO_2$ > 50 mmHg) with 100% sensitivity and 57% specificity.[6] A prospective validation study assessed 107 patients who presented with acute COPD exacerbations. When comparing ABG and VBG samples using the screening cut-off of $PvCO_2$ of 45 mmHg or greater, VBG detected all 43 cases of arterial hypercarbia with 100% sensitivity and 47% specificity. Investigators concluded that employing the VBG screening test would decrease ABG orders by 29%.[7]

In another study of 89 patients presenting with acute exacerbation of COPD, a screening $PvCO_2$ cut-off of 45 mmHg for hypercarbia also showed a 100% sensitivity and a specificity of 34%.[8] Expanding further on the specificity of the $PvCO_2$, the original prospective study by Kelly et al. noted that greater a $PvCO_2$ greater than 55 mmHg was over 88% specific for hypercarbia. A low pH on VBG, which is highly specific for acidosis, and a normal bicarbonate, would further support the case for hypercarbia. Said another way, a $PvCO_2$ of less than 45 mmHg safely excludes hypercarbia as a reason for a patient's somnolence. A $PvCO_2$ value of 45 mmHg or greater may prompt the hospitalist to treat the patient or confirm the presence of hypercarbia with an ABG depending on the clinical picture (see Figure 1).

VBGs can also evaluate the impact of hypercarbia treatments. While investigators have found that trending $PvCO_2$ does not correlate precisely with changes in $PaCO_2$,[9] a study using VBG and ABG information showed very limited differences in clinical interpretation and no differences in respiratory management in intubated patients in the emergency department.[4] Established hospital COPD protocols include serial VBG testing to assess the benefit of NPPV.[10]

Additionally, obtaining an ABG has associated risks and can lead to patient discomfort.[9] The VEINART study randomized 113 patients to ABG or VBG and measured patients' reports of pain on the visual analog scale. This study demonstrated a statistically and clinically significant reduction in patient-reported pain with VBGs (14.3 mm difference, 95% confidence interval 8.1–25.3 mm).[11,12] ABG sampling also carries risks of hematoma, aneurysm formation, thrombosis or embolization, and needlestick injuries.[4,7,13] In many institutions, only specifically trained medical personnel draw ABGs, which creates a challenge for urgent samples. It is difficult to place a precise

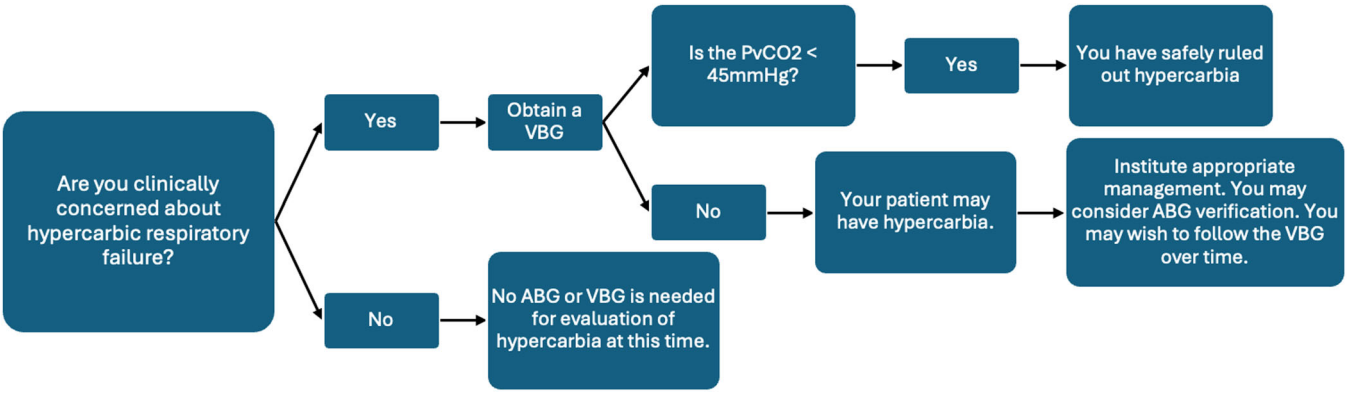

FIGURE 1 Recommended algorithm for evaluation of hypercarbic respiratory failure in the hospitalized adult.

monetary value on the impact of reducing the number of ABGs ordered given that some of the benefits are indirect (less use of specialized providers to obtain the labs) or patient-care centered (less pain, less risk of complications). Certainly, the benefits of testing reduction are in line with the broader discussions around high value care which appropriately focus on quality, cost, and overuse.

WHAT YOU SHOULD DO INSTEAD

When a patient has suspected hypercarbic RF, hospitalists should obtain a VBG due to the ease, safety, and relative comfort of an VBG as compared to an ABG. Depending on the clinical case and pre-test probability, hospitalists may proceed with treatment directed towards hypercarbic RF or obtain an ABG to confirm and quantify the hypercarbia. Hospitalists can rule out hypercarbic respiratory failure by finding a normal venous pH and PCO_2.

RECOMMENDATIONS

- Obtain a VBG as a screening tool when suspecting hypercarbic RF. A $PvCO_2$ of less than 45 mmHg safely rules out hypercarbia.
- Initiate treatment or further work-up for hypercarbic RF when a VBG returns a $PvCO_2$ of greater than 45 mmHg.

CONCLUSIONS

Hospitalists frequently consider the diagnosis of hypercarbic RF. Hospitalists can safely reduce the number of medically unnecessary and uncomfortable ABGs by substituting VBGs. In revisiting the case, the hospitalist should order the easily obtained VBG testing as an initial screen for hypercarbic RF. If normal, this can rule out hypercarbic RF.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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REFERENCES

1. Weinberger SE, Schwartzstein RM, Weiss JW. Hypercapnia. *N Eng J Med*. 1989;321(18):1223-1231. doi:10.1056/NEJM198911023211804
2. Salah HM, Minhas AMK, Khan MS, et al. Causes of hospitalization in the USA between 2005 and 2018. *Eur Heart J Open*. 2021;1(1):oeab001. doi:10.1093/ehjopen/oeab001
3. Le T, Bhushan V, Sochat M, et al. First Aid for the USMLE Step 1 *2018*. McGraw-Hill Medical; 2018.
4. Schütz N, Roth D, Schwameis M, Röggla M, Domanovits H. Can venous blood gas be used as an alternative to arterial blood gas in intubated patients at admission to the emergency department? a retrospective study. *Open Access Emerg Med OAEM*. 2019;11:305-312. doi:10.2147/OAEM.S228420
5. Kelly AM. Can VBG analysis replace ABG analysis in emergency care? *Emerg Med J EMJ*. 2016;33(2):152-154. doi:10.1136/emermed-2014-204326
6. Kelly AM, Kyle E, McAlpine R. Venous pCO2 and pH can be used to screen for significant hypercarbia in emergency patients with acute respiratory disease. *J Emerg Med*. 2002;22(1):15-19. doi:10.1016/S0736-4679(01)00431-0
7. Kelly AM, Kerr D, Middleton P. Validation of venous pCO2 to screen for arterial hypercarbia in patients with chronic obstructive airways disease. *J Emerg Med*. 2005;28(4):377-379. doi:10.1016/j.jemermed.2004.10.017
8. McCanny P, Bennett K, Staunton P, McMahon G. Venous vs arterial blood gases in the assessment of patients presenting with an exacerbation of chronic obstructive pulmonary disease. *Am J Emerg Med*. 2012;30(6):896-900. doi:10.1016/j.ajem.2011.06.011
9. Weber M, Cave G. Trending peripheral venous PCO2 in patients with respiratory failure using mathematically arterialised venous blood gas samples. *BMJ Open Respir Res*. 2021;8(1):e000896. doi:10.1136/bmjresp-2021-000896
10. Sagana RL, Wesorick DH, Byrne BT, et al. *Care of the Hospitalized Patient With Acute Exacerbation of COPD*. Michigan Medicine University of Michigan; 2022. Accessed July 22, 2024. http://www.ncbi.nlm.nih.gov/books/NBK582288/
11. Chauvin A, Javaud N, Ghazali A, et al. Reducing pain by using venous blood gas instead of arterial blood gas (VEINART): a multicentre randomised controlled trial. *Emerg Med J*. 2020;37(12):756-761. doi:10.1136/emermed-2019-209287
12. Gallagher EJ, Liebman M, Bijur PE. Prospective validation of clinically important changes in pain severity measured on a visual analog scale. *Ann Emerg Med*. 2001;38(6):633-638. doi:10.1067/mem.2001.118863
13. Walkey AJ, Farber HW, O'Donnell C, Cabral H, Eagan JS, Philippides GJ. The accuracy of the central venous blood gas for acid-base monitoring. *J Intensive Care Med*. 2010;25(2):104-110. doi:10.1177/0885066609356164

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