SHYAM GANTI, MD
Division of Pulmonary, Critical Care, and Sleep Medicine. Wayne State University School of Medicine, Detroit, MI

RAVINDER D. BHANOT, MD
Division of Pulmonary and Critical Care, Ascension St. Mary's, Saginaw, MI

JASLEEN KAUR, MD
Department of Internal Medicine, Wayne State University School of Medicine, Detroit, MI

CASSONDRA CRAMER-BOUR, MD
Department of Medicine, Boston University School of Medicine, Boston, MA

AYMAN O. SOUBANI, MD
Professor of Medicine, Wayne State University School of Medicine; Medical Director, Medical ICU, Harper University Hospital; Service Chief, Pulmonary and Critical Care, and Medical Director, Critical Care Service, Karmanos Cancer Center; Division of Pulmonary, Critical Care and Sleep Medicine. Wayne State University School of Medicine, Detroit, MI

ONE MINUTE CONSULT

BRIEF ANSWERS TO SPECIFIC CLINICAL QUESTIONS

Q: Are daily chest radiographs and arterial blood gas tests required in ICU patients on mechanical ventilation?

A: No, they are not required or needed, but daily radiography and arterial blood gas testing are common practice: eg, 60% of intensive care unit (ICU) patients get daily radiographs,[1] even though results provide low diagnostic yield and are unlikely to alter patient management compared with testing only when indicated.

The Choosing Wisely campaign,[2] a collaborative effort of a number of professional societies, advises against ordering these diagnostic tests daily because routine testing increases risks to patients and burdens the healthcare system. Instead, testing is recommended only in response to a specific clinical question, or when the test results will affect the patient's treatment.

Although common, routine daily imaging and testing are not needed

CHEST RADIOGRAPHS: DAILY VS CLINICALLY INDICATED

Chest radiographs enable practitioners to monitor the position of endotracheal tubes and central venous catheters, evaluate fluid status, follow up on abnormal findings, detect complications of procedures (such as a pneumothorax), and identify otherwise undetected conditions.

And daily chest radiographs often detect abnormalities. A 1991 study by Hall et al[3] of 538 chest radiographs in 74 patients on mechanical ventilation reported that 30% of daily routine chest radiographs disclosed a new but minor finding (eg, a small change in endotracheal tube position or a small infiltrate). The new findings were major in 13 (17.6%) of the 74 patients (95% confidence interval [CI] 9%–26%). These included findings that required an immediate diagnostic or therapeutic intervention (eg, endotracheal tube below the tracheal carina, malposition of a catheter, pneumothorax, large pleural effusion).

But most studies say daily radiographs are not needed. In a large prospective study published in 2006, Graat et al[4] evaluated the clinical value of 2,457 routine chest radiographs in 754 patients in a combined surgical and medical ICU. Daily chest radiographs revealed new or unexpected findings in 5.8% of cases, but only 2.2% warranted a change in therapy. No differences were found between the medical and surgical patients. The authors concluded that daily routine radiographs in ICU patients seldom reveal unexpected, clinically relevant abnormalities, and those findings rarely require urgent intervention.

A 2010 meta-analysis of 8 studies (7,078 patients) by Oba and Zaza[5] compared on-demand and daily routine strategies of performing chest radiographs. They estimated that eliminating daily routine chest radiographs would not affect death rates in the hospital (odds ratio [OR] 1.02, 95% CI 0.89–1.17, $P = .78$) or the ICU (OR 0.92, 95% CI 0.76–1.11, $P = .4$). They also found no significant differences in length of stay or duration of mechanical ventilation. This meta-analysis suggests that routine radiographs can be eliminated without adversely affecting outcomes in ICU patients.

A larger meta-analysis (9 trials, 39,358 radiographs, 9,611 patients) published in 2012 by Ganapathy et al[6] also found no harm associated with restrictive radiography protocols. These investigators compared a daily chest radiography protocol against a protocol based

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on clinical indications. The primary outcome was the mortality rate in the ICU; secondary outcomes were the mortality rate in the hospital, the length of stay in the ICU, and duration of mechanical ventilation. They found no differences between routine and restrictive strategies in terms of ICU mortality (risk ratio [RR] 1.04, 95% CI 0.84–1.28, *P* = .72), hospital mortality (RR 0.98, 95% CI 0.68–1.41, *P* = .91), or other secondary outcomes.

Clinically indicated testing is better

The conclusion from these studies is that routine chest radiographs in patients undergoing mechanical ventilation does not improve patient outcomes, and thus, a clinically indicated protocol is preferred.

Furthermore, routine daily radiographs have adverse effects such as more cumulative radiation exposure to the patient[7] and greater risk of accidental removal of devices (eg, catheters, tubes).[8] Another concern is a higher risk of hospital-associated infections from bacterial spread from caregivers' hands.[9]

Finally, daily radiographs increase the use of healthcare resources and expenditures. In a 2011 study, Gershengorn et al[1] estimated that adopting a clinically indicated radiography strategy could save more than $144 million annually in the United States.

The ACR agrees. Appropriateness criteria published by the American College of Radiology (ACR) in 2015[10] recommend against routine daily chest radiographs in the ICU, in keeping with the findings of the critical care community. The ACR recommends an initial radiograph at admission to the ICU. However, follow-up radiographs should be obtained only for specific clinical indications, including a change in the patient's clinical condition or to check for proper placement of endotracheal or nasogastric or orogastric tubes, pulmonary arterial catheters, central venous catheters, chest tubes, and other life-support devices.

Ultrasonography as an alternative

Ultrasonography is widely available and provides an alternative to chest radiography for detecting significant abnormalities in patients on mechanical ventilation without exposing them to radiation and using relatively fewer resources.

A 2012 meta-analysis (8 studies, 1,048 patients) found that bedside ultrasonography reliably detects pneumothorax.[11] It can also provide a rapid diagnosis of the cause of acute respiratory failure such as pneumonia or pulmonary edema.[12] Ultrasonography, with the appropriate expertise, can also confirm the position of an endotracheal tube[13] or central venous catheter.[14]

ARTERIAL BLOOD GAS TESTING: DAILY VS CLINICALLY INDICATED

Arterial blood gas testing has value for managing patients undergoing mechanical ventilation, and it is one of the most commonly performed diagnostic tests in the ICU. It provides reliable information about the patient's oxygenation and acid-base status. It is commonly requested when changing ventilator settings.

Downsides. Arterial blood gas measurements account for 10% to 20% of the cost incurred during ICU stay.[15] In addition, they require an arterial puncture—an invasive procedure associated with potentially serious complications such as occlusion of the artery, digital embolization leading to digital ischemia, local infection, pseudoaneurysm, hematoma, bleeding, and skin necrosis.

Ultrasonography is widely available and may be an alternative to chest radiography

Is daily testing needed?

Guidelines say no. The 2013 American Association for Respiratory Care[16] guidelines suggest that arterial blood gas testing should be based on the clinical assessment of the patient. They recommend blood gas analysis to evaluate the patient's ventilatory status (reflected by the partial pressure of arterial carbon dioxide [$Paco_2$], acid-base status (reflected by pH), arterial oxygenation (partial pressure of arterial oxygen [Pao_2] and oxyhemoglobin saturation), oxygen-carrying capacity, and whether the patient likely has an intrapulmonary shunt. They state that testing is useful to quantify the response to therapeutic or diagnostic interventions such as cardiopulmonary exercise testing, to monitor severity and progression of documented disease, and to assess the adequacy of circulatory response.

Studies agree

The ACR recommendation to test "as clinically indicated" is supported by studies showing

that patient outcomes are not inferior for arterial blood gas testing when clinically indicated instead of daily, and that this practice is associated with fewer complications, less resource use, and reduced overall patient care costs.

A 2015 study compared the efficacy and safety of obtaining arterial blood gases based on clinical assessment vs daily in 300 critically ill patients.[17] Overall, fewer samples were obtained per patient in the clinical assessment group than in the daily group (all patients 3.7 vs 5.5; ventilated patients 2.03 vs 6.12; $P < .001$ for both). In ventilated patients, there was a 60% decrease in arterial blood gas orders without affecting patient outcomes and safety, including a lower risk of complications and overall cost of care.

In another study, Martinez-Balzano et al[18] evaluated the effect of guidelines they developed to optimize the use of arterial blood gas testing in their ICUs. These guidelines encouraged testing of arterial blood gases after an acute respiratory event or for a rational clinical concern, and discouraged testing for routine surveillance, after planned changes of positive end-expiratory pressure or inspired oxygen fraction on mechanical ventilation, for spontaneous breathing trials, or when a disorder was not suspected.

Arterial blood gas testing accounts for 10%–20% of ICU costs

Compared with data collected before implementation, these guidelines reduced the number of arterial blood gas tests by 821.5 per month (41.5%), or approximately 1 test per patient per mechanical-ventilation day for each month (43.1%; $P < .001$). Appropriately indicated testing rose to 83.4% from a baseline of 67.5% ($P = .002$). Additionally, this approach was associated with saving 49 liters of blood, reducing ICU costs by $39,432, and freeing up 1,643 staff work hours for other tasks. There were no significant differences in days on mechanical ventilation, severity of illness, or mortality between the 2 periods.[18]

Extubation effects. Routine arterial blood gas testing has not been shown to affect extubation decisions in patients on mechanical ventilation. In a study of 83 patients who completed a spontaneous breathing trial (total of 100 trials), Salam et al[19] found arterial blood gas values obtained during the trial did not change the extubation decision in 93% of the cases.

In a study of 54 extubations in 52 patients,[20] 65% of the extubations were performed without obtaining an arterial blood gas test after the patient completed a trial of spontaneous breathing. The extubation success rate was 94% for the entire group, and it was the same regardless of whether testing was done (94.7% vs 94.3%, respectively).

Alternatives to arterial blood gases

There are less-invasive means to obtain the information that comes from an arterial blood gas test.

Pulse oximetry is a rapid noninvasive tool that provides continuous assessment of peripheral arterial oxygen saturation as a surrogate marker for tissue arterial oxygenation. However, it cannot measure Pa_{O_2} or Pa_{CO_2}.[21]

Transcutaneous carbon dioxide (P_{TCO_2}) monitoring is another continuous noninvasive alternative. The newer P_{TCO_2} devices are useful in patients with acute respiratory failure and in critically ill patients on vasopressors or vasodilators. Studies have shown good correlation between P_{TCO_2} and Pa_{CO_2}.[22,23]

End-tidal carbon dioxide (P_{ETCO_2}) is another alternative to estimate Pa_{CO_2}. It can also be used to confirm endotracheal tube placement, during transportation, during procedures in which the patient is under conscious sedation, and to monitor the effectiveness of cardiopulmonary resuscitation and return of circulation after cardiac arrest. P_{ETCO_2} measurements are not as accurate as arterial blood gas testing owing to a difference of approximately 2 to 5 mm Hg between Pa_{CO_2} and P_{ETCO_2} in normal lungs due to alveolar dead space. This difference may be much higher depending on the clinical condition and the degree of alveolar dead space.[21,24,25]

Venous blood gases, which can be obtained from a peripheral or central venous catheter, are adequate to assess pH and partial pressure of carbon dioxide (P_{CO_2}) in hemodynamically stable patients. Walkey et al[26] found that the accuracy of venous blood gas measurement to predict arterial blood gases was 90%. They recommended adjusting the venous pH up by 0.05 and the P_{CO_2} down by 5

mm Hg to account for the positive bias of venous blood gases. A limitation of this method is that the values are not reliable in patients who are in shock.

These alternatives can be used as a substitute for daily arterial blood gases. However, in certain clinical scenarios, arterial blood gas measurement remains a necessary and useful clinical tool.

TAKE-HOME MESSAGE

Most scientific evidence suggests that chest radiographs and arterial blood gas measurement in patients undergoing mechanical ventilation—and critically ill, in general—are best done when clinically indicated rather than routinely on a daily basis. This will reduce cost and harm to patients that may result from these unnecessary tests and not adversely affect outcomes.

REFERENCES

1. **Gershengorn HB, Wunsch H, Scales DC, Rubenfeld GD**. Trends in use of daily chest radiographs among US adults receiving mechanical ventilation. JAMA Netw Open 2018; 1(4):e181119. doi:10.1001/jamanetworkopen.2018.1119
2. **American Board of Internal Medicine Foundation**. Choosing Wisely. http://www.choosingwisely.org/clinician-lists/critical-care-societies-collaborative-regular diagnostic-tests/. Accessed August 18, 2019.
3. **Hall JB, White SR, Karrison T**. Efficacy of daily routine chest radiographs in intubated, mechanically ventilated patients. Crit Care Med 1991; 19(5):689–693. pmid:2026031
4. **Graat ME, Choi G, Wolthuis EK, et al**. The clinical value of daily routine chest radiographs in a mixed medical-surgical intensive care unit is low. Crit Care 2006; 10(1):R11. doi:10.1186/cc3955
5. **Oba Y, Zaza T**. Abandoning daily routine chest radiography in the intensive care unit: meta-analysis. Radiology 2010; 255(2):386–395. doi:10.1148/radiol.10090946
6. **Ganapathy A, Adhikari NK, Spiegelman J, Scales DC**. Routine chest x-rays in intensive care units: a systematic review and meta-analysis. Crit Care 2012; 16(2):R68. doi:10.1186/cc11321
7. **Krishnan S, Moghekar A, Duggal A, et al**. Radiation exposure in the medical ICU: predictors and characteristics. Chest 2018; 153(5):1160–1168. doi:10.1016/j.chest.2018.01.019
8. **Hejblum G, Chalumeau-Lemoine L, Ioos V, et al**. Comparison of routine and on-demand prescription of chest radiographs in mechanically ventilated adults: a multicentre, cluster-randomised, two-period crossover study. Lancet 2009; 374(9702):1687–1693. doi:10.1016/S0140-6736(09)61459-8
9. **Levin PD, Shatz O, Sviri S, et al**. Contamination of portable radiograph equipment with resistant bacteria in the ICU. Chest 2009; 136(2):426–432. doi:10.1378/chest.09-0049
10. **Suh RD, Genshaft SJ, Kirsch J, et al**. ACR Appropriateness Criteria® Intensive Care Unit Patients. J Thorac Imaging 2015; 30(6):W63–W65. doi:10.1097/RTI.0000000000000174
11. **Alrajhi K, Woo MY, Vaillancourt C**. Test characteristics of ultrasonography for the detection of pneumothorax: a systematic review and meta-analysis. Chest 2012; 141(3):703–708. doi:10.1378/chest.11-0131
12. **Lichetenstein DA, Meziere GA**. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. Chest 2008; 134(1):117–125. doi:10.1378/chest.07-2800
13. **Das SK, Choupoo NS, Haldar R, Lahkar A**. Transtracheal ultrasound for verification of endotracheal tube placement: a systematic review and meta-analysis. Can J Anaesth 2015; 62(4):413–423. doi:10.1007/s12630-014-0301-z
14. **Ablordeppey EA, Drewry AM, Beyer AB, et al**. Diagnostic accuracy of central venous catheter confirmation by bedside ultrasound versus chest radiography in critically ill patients: a systematic review and meta-analysis. Crit Care Med 2017; 45(4):715–724. doi:10.1097/CCM.0000000000002188
15. **DellaVolpe JD, Chakraborti C, Cerreta K, et al**. Effects of implementing a protocol for arterial blood gas use on ordering practices and diagnostic yield. Healthc (Amst) 2014; 2(2):130–135. doi:10.1016/j.hjdsi.2013.09.006
16. **Davis MD, Walsh BK, Sittig SE, Restrepo RD**. AARC clinical practice guideline: blood gas analysis and hemoximetry. Respir Care 2013; 58(10):1694–1703. doi:10.4187/respcare.02786
17. **Blum FE, Lund ET, Hall HA, Tachauer AD, Chedrawy EG, Zilberstein J**. Reevaluation of the utilization of arterial blood gas analysis in the intensive care unit: effects on patient safety and patient outcome. J Crit Care 2015; 30(2):438.e1–e5. doi:10.1016/j.jcrc.2014.10.025
18. **Martínez-Balzano CD, Oliveira P, O'Rourke M, Hills L, Sosa AF; Critical Care Operations Committee of the UMass Memorial Healthcare Center**. An educational intervention optimizes the use of arterial blood gas determinations across ICUs from different specialties: a quality-improvement study. Chest 2017; 151(3):579–585. doi:10.1016/j.chest.2016.10.035
19. **Salam A, Smina M, Gada P, et al**. The effect of arterial blood gas values on extubation decisions. Respir Care 2003; 48(11):1033–1037. pmid:14585115
20. **Pawson SR, DePriest JL**. Are blood gases necessary in mechanically ventilated patients who have successfully completed a spontaneous breathing trial? Respir Care 2004; 49(11):1316–1319. pmid:15507165
21. **Soubani AO**. Noninvasive monitoring of oxygen and carbon dioxide. Am J Emerg Med 2001; 19(2):141–146. doi:10.1053/ajem.2001.21353
22. **Nicolini A, Ferrari MB**. Evaluation of a transcutaneous carbon dioxide monitor in patients with acute respiratory failure. Ann Thorac Med 2011; 6(4):217-–220. doi:10.4103/1817-1737.84776
23. **Bendjelid K, Schütz N, Stotz M, Gerard I, Suter PM, Romand JA**. Transcutaneous PCO2 monitoring in critically ill adults: clinical evaluation of a new sensor. Crit Care Med 2005; 33(10):2203–2206. pmid:16215371
24. **Huttmann SE, Windisch W, Storre JH**. Techniques for the measurement and monitoring of carbon dioxide in the blood. Ann Am Thorac Soc 2014; 11(4):645–652. doi:10.1513/AnnalsATS.201311-387FR
25. **McSwain SD, Hamel DS, Smith PB, et al**. End-tidal and arterial carbon dioxide measurements correlate across all levels of physiologic dead space. Respir Care 2010; 55(3):288–293. pmid:20196877
26. **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

***ADDRESS**: Ayman O. Soubani, MD, Division of Pulmonary, Critical Care and Sleep Medicine. Wayne State University School of Medicine, 3990 John R-3 Hudson, Detroit, MI 48201; asoubani@med.wayne.edu*