Short on Time and Short of Breath

Respiratory Medicine's Need for Speed

The complicated nature of respiratory patients

Patients in respiratory distress require immediate medical attention. The ability to quickly identify hypoxemia, a common respiratory symptom, and its cause is crucial for positive patient outcomes. However, there is a gap in the current cardiopulmonary assessment toolkit that leaves clinicians unable to quickly identify the cause and severity of hypoxemia. This assessment gap creates costly time delays in diagnosis and treatment decisions, which can have serious consequences for care path decisions and patient outcomes (Fig. 1). This often manifests as overcrowded emergency rooms, overworked medical staff, and ineffective utilization of healthcare resources.[1]

Fast, reliable, and actionable medical information is essential to deliver cost-effective healthcare. A single-test approach will help expedite the time to diagnosis and facilitate treatment decisions in a wide array of cardiopulmonary diseases. Fortunately, with the advent of new technologies, better options rooted in physiology are now available to detect the severity and source of hypoxemia immediately at the point-of-care.

Traditionally, multiple tests are available to narrow the differential diagnoses of respiratory conditions. Typically, each test eliminates or confirms a potential diagnosis, creating an approach that involves a process of elimination that delays diagnosis and treatment. As previously identified in "Beyond Pulse Oximetry to Pulmonary Gas Exchange Measurement in COVID-19" this approach is impractical and unsustainable for time-sensitive respiratory diseases.[3] With rising demand for medical services and limited supply of time and resources, more patients must be assessed and treated than ever before. Because of this, tools that improve health care efficiency are in high demand.

Key Takeaways

- Diagnosing the cause of hypoxemia can be complicated in patients with multiple co-morbidities.
- Efficient, non-invasive gas exchange measurements could vastly improve emergency room operations.

The MediPines AGM100 was architected to address this problem by providing a fast, non-invasive method for detecting hypoxemia and gas exchange impairment at the point-of-care.[5] The AGM100-based procedure requires only a 2-minute sample of a patient's resting breathing, so the patient is not subjected to painful or effort-dependent procedures requiring time intensive laboratory work. The AGM100 delivers immediate information about oxygenation, ventilation, and gas exchange efficiency, providing a complete picture of a patient's cardiopulmonary status. Measuring gas exchange efficiency is easy to perform for patients and staff, saving valuable resources in addition to time, while expediting diagnosis and treatment. Utilizing the MediPines AGM100 will drive efficiency with complicated patients in respiratory distress.

Hypoxemia and the importance of identifying its cause

Hypoxemia, or low blood oxygen, is a common symptom that can quickly develop into a life-threatening situation unless it is properly detected at the first signs of danger. Hypoxemia is defined as a partial pressure of oxygen (PaO_2) below 80 mmHg and the severity of hypoxemia will get worse as PaO_2 drops.[6] Hypoxemia is clinically important to detect as it can indicate a serious medical condition or complication, such as lung disease or heart failure. If left untreated, hypoxemia can lead to tissue damage, organ failure, and even death. However, diagnosing the cause of hypoxemia, shortness of breath, or dyspnea can be complicated in patients with multiple comorbidities (Fig 2). Early detection and treatment of hypoxemia will improve patient outcomes and reduce downstream complications. The gold standard method to diagnose hypoxemia is with PaO_2, historically obtained from an arterial blood gas puncture, but will likely require a combination of further testing to understand and effectively treat the source of hypoxemia.

When a patient presents with a chief complaint such as dyspnea or shortness of breath, the first step to the diagnosis and care path is to measure the patients' oxygenation status. Quick and accurate oxygen assessments in cardiorespiratory patients are critical for effective treatment.[1] Typically, a pulse oximeter is used to measure the oxygen levels in a patient as a convenient proxy (SpO_2) to PaO_2. However, recent FDA guidance states that "due to accuracy limitations at the individual level, SpO_2 provides more utility for trends over time instead of absolute thresholds."[7] Additionally, relying on SpO_2 alone can be misleading because the accuracy determined by pulse oximetry is more uncertain when a patient is acutely sick, and ventilation is abnormal (Fig 3). This was highlighted during the COVID-19 pandemic where overreliance on stand-alone pulse oximetry led to poor clinical outcomes.[3]

Alternatively, more accurate information can be obtained with an arterial blood gas (ABG) analysis. However, ABG tests are mostly used in critically ill patients due to the invasive and complicated nature of the test, and system wide ABG testing is not typically feasible due to the urgent nature of hypoxemia. The juxtaposition of the two methods leaves clinicians with the option of using a convenient proxy tool immediately or accurate information with a critical time delay.

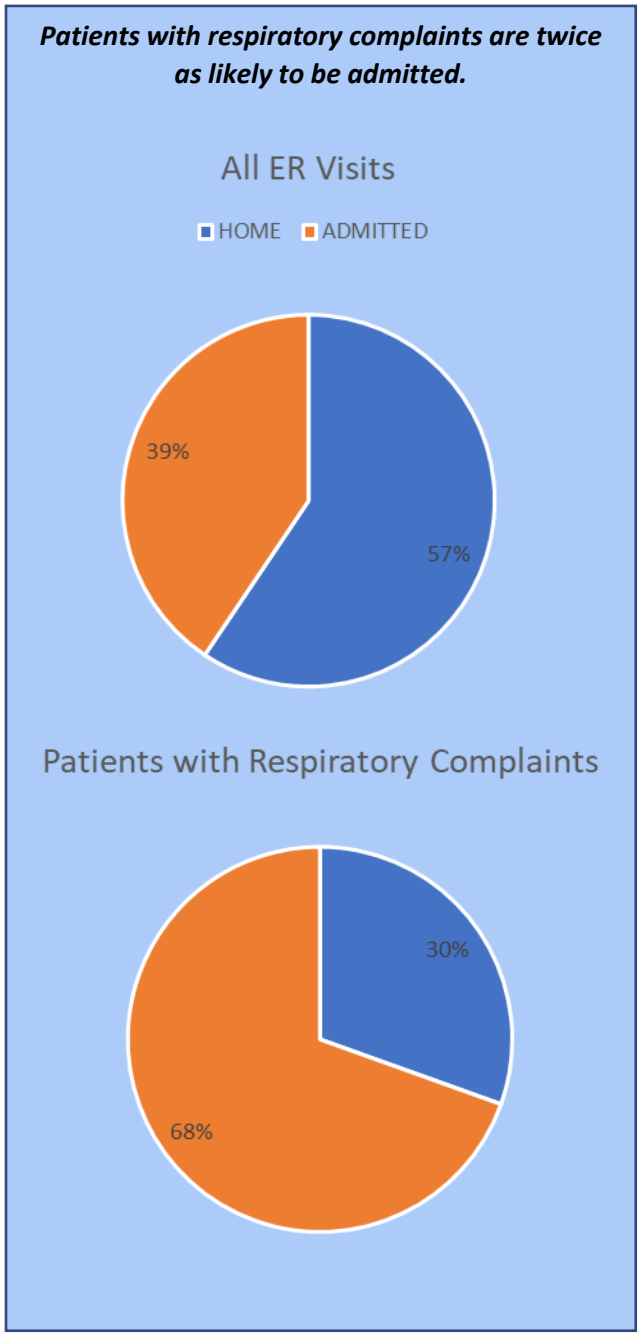


Figure 1: Patients with respiratory complaints are twice as likely to be admitted into the hospital when compared to all patients seen in the Emergency Department. All patient visits n=525,087 and respiratory patients n=25,538 taken from MIMIC database.[2]

Not only is it important to quickly recognize hypoxemia, but it is also necessary to know the source as prognosis, treatment and management of the patient will change based on the underlying cause. Clinical problems may be approached empirically by treating the most likely cause, but treatment of a patient with hypoxemia and multiple comorbidities may be suboptimal without understanding the underlying respiratory physiology. The rank ordering of a differential diagnosis can be influenced by the comorbidity considered to be the dominant contributor and the experience of the clinician.[1] Unfortunately, not all available medical tools to detect hypoxemia will give information about the cause or severity of hypoxemia. In addition to invasive ABG tests, clinicians will also perform a physical examination, take a patient's medical history, order pulmonary function testing, chest x-ray or CT scan, other blood work like D-dimer or a complete blood count, ultrasound assessment, or electrocardiogram to help diagnose and determine the cause of hypoxemia. This time-consuming process of untangling the source of hypoxemia leads to time delays in treatment and, in many cases, worse patient outcomes.

The root cause of hypoxemia can be elusive but understanding the cause is key to a proper diagnosis and will determine the best course of treatment. A typical protocol will call for several tests, and each test will provide a piece of information, but multiple tests are needed to put the various pieces of the respiratory puzzle together. The primary benefit of the AGM100 is that it measures gas exchange, which enables bypassing the need for series of tests to infer impairment of gas

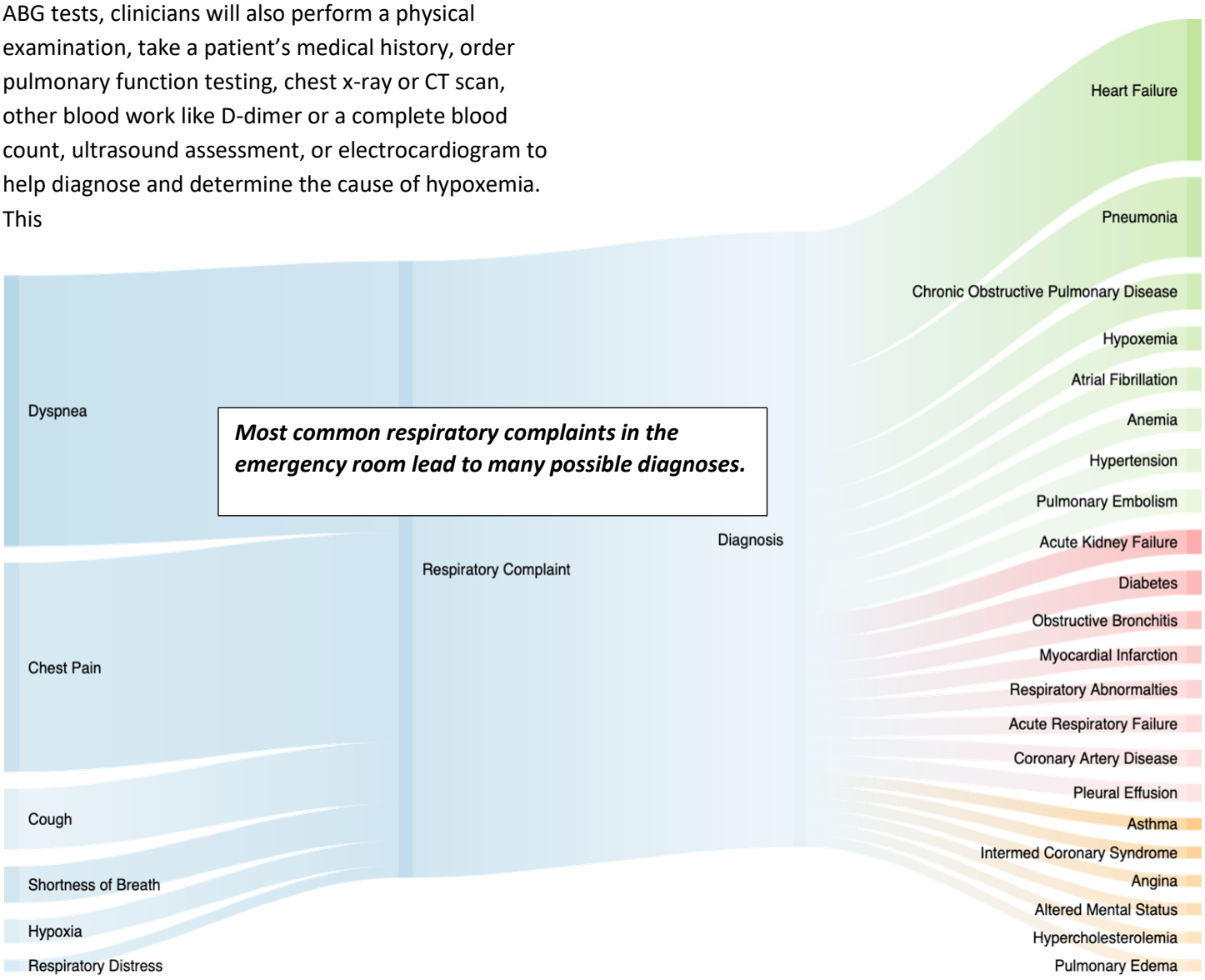


Figure 2: Respiratory complaints have diverse diagnostic outcomes.[2]

exchange. This allows the clinician to precisely assess a declining condition, confirm the diagnosis and start the correct treatment earlier. The novel non-invasive method used by the MediPines AGM100 can identify the underlying cause such as: V/Q mismatch, shunt, diffusion limitation, hypoventilation, or low-inspired oxygen levels (Fig 4.). Once the cause of hypoxemia is known, the most effective treatment option can be applied, reducing the risk of further downstream complications.

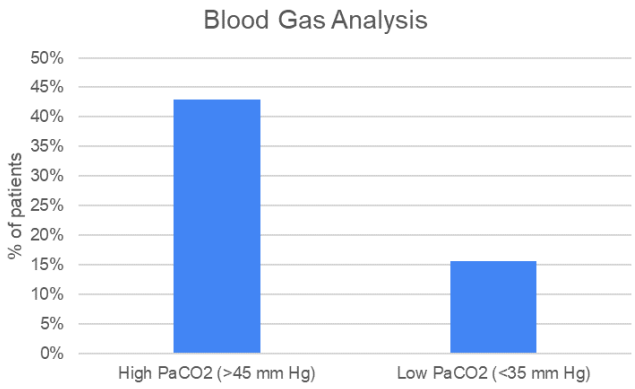


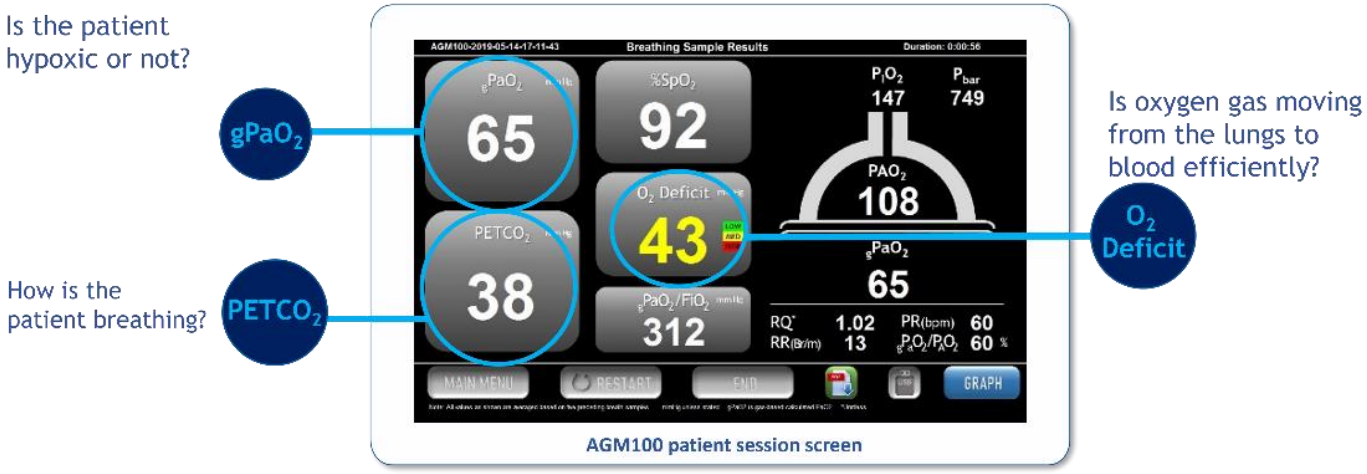
Figure 3: About 60% of acutely sick respiratory patients have abnormal CO2 (inadequate ventilation), which can compromise accuracy of oxygen saturation. Patient population n=3,439 taken from MIMIC database.[2]

MediPines AGM100 Optimized for gas exchange

The AGM100 calculates PaO_2 and A-a gradient (Oxygen Deficit) without the need for arterial blood samples. The AGM100 measures the end-tidal PCO_2 and oxygen saturation of a patient at rest and uses the values in conjunction with the oxygen dissociation curve to calculate PaO_2. The device then calculates the Oxygen Deficit (OD) from the previously calculated PaO_2 and the measured end-tidal PO_2. Importantly, additional information is gained by measuring the OD as opposed to simply measuring SpO_2. While both V/Q mismatch and shunt will serve to decrease PaO_2 and SpO_2 while increasing OD, so too will hypoventilation. Because the alveolar $PETCO_2$ is also measured, hypoventilation can readily be detected which may provide an important clinical distinction of the cause of hypoxemia in some patients. Further, the OD considers the effect of changes in $PETCO_2$ on the oxygen hemoglobin dissociation curve. Thus, the OD directly addresses the efficiency of gas exchange.[5]

The AGM100 has the potential to improve the quality of care for patients with cardiac and pulmonary disease. The AGM100 can be used at important treatment decision points in healthcare such as Emergency Department triage, ICU stepdown units, and on patients waiting to be discharged or to help clinicians make important treatment decisions earlier then they can with current tools and methodologies. Earlier care will lead to better patient outcomes and higher efficiency throughout the healthcare system.

Figure 4: The MediPines AGM100 identifies hypoxemia and provides information about the cause of hypoxemia through multiple measurements presented at the same time.[5]



Conclusion

It is commonly accepted that the sooner a patient gets to the right care in the right place with the right resources, the better the chances for a positive outcome, thus timely care leads to positive patient outcomes and less associated downstream costs. The National Academy of Medicine recommends healthcare delivery organizations should: "continuously improve health care operations to reduce waste, streamline care delivery, and focus on activities that improve patient health. Care delivery organizations should apply systems engineering tools and process improvement methods to improve operations and care delivery processes".[4] Adopting time saving technology like the AGM100 will help improve key performance indicators such as emergency department wait times, bed turnaround times, discharge times, and average lengths of stay. Pulling wasted time out of the patient flow continuum frees up bed space so throughput can be accelerated, which means more services can be performed and more patients can get the care they need.

Key Terms

SpO_2 – Oxygen saturation of hemoglobin obtained non-invasively from a pulse oximeter. A pulse oximeter utilizes a validated light-based method that relates light absorption to empirical oxygen saturation using the co-oximetry method.

PaO_2 – Partial pressure of arterial oxygen; the oxygen level in the blood, measured in mmHg, obtained from arterial blood gas (ABG) method.

$gPaO_2^{TM}$ – Partial pressure of arterial oxygen obtained non-invasively from calculations and breathing gas sampling methods. Measured in mmHg. Exclusively provided by FDA-cleared MediPines AGM100®.

$PETCO_2$ – End-tidal carbon dioxide, commonly denoted as $etCO_2$, a measure of ventilation; the partial pressure of carbon dioxide at the end of an exhaled breath, measured in mmHg.

Oxygen Deficit (O_2 Deficit) – A-a gradient ($AaDO_2$) equivalent measured non-invasively. The difference between the alveolar (lung) and arterial (blood) levels of oxygen that represents the degree of respiratory gas exchange inefficiency, a measurement of respiratory impairment, measured in mmHg.

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