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Persistent hypoxia in a pediatric patient following a house fire

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Abstract

A 5-year-old female presented to the pediatric emergency department from a community emergency department for persistent hypoxia in the setting of inhalational exposure due to a house fire. The patient had refractory hypoxia despite routine interventions in the referring emergency department. After a thorough physical exam, and further lab work-up, it was determined that the child had complex congenital heart disease that was yet undiagnosed, and her hypoxia was unrelated to her inhalational exposure. This case demonstrates the risk of anchoring bias and premature closure in the emergency department. By maintaining a broad differential diagnosis, this patient received the appropriate care for her complex congenital heart condition. Providers should self-evaluate for early closure and anchoring bias to minimize morbidity and mortality risk to patients. Through an understanding of adult learning and thought-processing patterns, providers can assess their biases and maintain broad differential diagnoses when presented with information contrary to their first impression.

Key words: heuristics, adult learning, anchoring bias, congenital heart disease, pediatric emergency medicine.

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Introduction

Thermal injuries are the fourth most common cause of traumatic death in the United States.[1] Burns represent the second-most common cause of accidental death in children ages one to four years, with increased rates occurring among patients living in low-income, multiple-family housing environments.[2] Additionally, those children whose primary residence is in a rural area show a higher rate of more severe burns, compared to those in urban areas, which may be due, in part, to lack of timely access to medical care, lack of access to a dedicated burn center, and less defined or structured emergency response procedures and infrastructure.[3] The presence of inhalational injury dramatically increases morbidity and mortality by placing patients at risk of airway edema and obstruction, resulting in the need for airway interventions, including invasive mechanical ventilation. Often, patients with inhalational injury will present with elevated carboxyhemoglobin levels, resulting in hypoxia necessitating oxygen administration.[4] The risk of progression to secondary infection, acute respiratory distress, pulmonary dysfunction, and chronic changes to airway structure associated with inhalational injury make early intervention and supportive management of the utmost importance.[5]

However, it is important to keep in mind that pediatric patients may have other etiologies for hypoxia, even when being evaluated for inhalational injury following burns. While inhalational injury may be the top differential diagnosis, other causes of hypoxia should be entertained when standard evaluation and intervention does not produce improvement. In this case, a pediatric patient presented for evaluation of persistent hypoxia attributed to inhalational injury but was instead found to have undiagnosed complex congenital heart disease.

Case Report

A reportedly healthy 5-year-old female presented to the Pediatric Emergency Department (PED) for hypoxia after being involved in a house fire. She was first transferred from a nearby community Emergency Department (ED), where she was noted to have hypoxia, which was attributed to smoke inhalation. The referring ED treated the patient with albuterol and dexamethasone, presumably in attempt to minimize bronchospasm or tracheal edema, although this decision was not explained in the transfer documentation. She continued to have oxygen saturations in the high 80s while breathing room air despite these interventions. She was started on 15 liters of oxygen by non-rebreather, which raised her oxygen saturations to the low 90s, at which time she was transferred to a tertiary care center for definitive pediatric management.

On arrival, the patient was awake and oriented, with oxygen saturations of 90-92% on 15 liters of oxygen by non-rebreather. She was noted to have desaturations to the low 80s while upset or crying, despite continued supplemental oxygen. The patient was mildly tachycardic, with heart rates of approximately 130, but had otherwise normal vital signs. Her physical exam was notable for a loud, grade 4/6, holosystolic murmur with palpable thrill at the left lower sternal border. Pulmonary auscultation revealed scattered bilateral crackles. She was noted to have no soot in her mouth or nares and was breathing without retractions or tachypnea. Exam of her extremities revealed a circular 3 cm (about 1.18 in) partial thickness burn of the right forearm, without other evidence of thermal injury. Note was made of clubbing of the fingernails of both hands.

The patient's laboratory testing obtained on arrival, listed in the table, did not provide evidence of inhalation as the cause of hypoxia. She had no lactic acidosis to suggest cyanide poisoning, nor did she have elevated carboxyhemoglobin levels to suggest carbon monoxide exposure. Blood gas lab showed an elevated hematocrit to 47%, which suggested chronic accommodative changes to improve oxygenation. She had a low bicarbonate level of 15, suggesting a metabolic acidosis. Her chloride was mildly elevated, which was considered an incidental finding. However, taken in conjunction, a hyperchloremic metabolic acidosis may represent a secondary Renal Tubule Acidosis (RTA) in the setting of chronic hypoxia.[6] She was noted to have an elevated glucose at 125, which was attributed to her recent dose of steroids by the referring hospital (Table 1).

The presence of both a loud holosystolic murmur in a child with no reported medical history, and nail clubbing to suggest a chronic hypoxic state, led providers to consider a congenital heart condition as the source of her hypoxia, rather than a possible inhalational injury. Based on her normal work-up and her loud murmur, Cardiology was consulted who presented to the PED to perform Transthoracic Echocardiogram (TTE). The TTE showed severe Ebstein's anomaly with a large Ventricular Septal Defect (VSD), and other associated congenital abnormalities. Electrocardiogram showed normal sinus rhythm with bi-atrial enlargement and right bundle branch block.

Based on these studies, it was concluded that the hypoxia noted at the initial ED's assessment was most likely chronic, and associated with her complex, undiagnosed, congenital heart disease, rather than an acute inhalational injury. With newly established goal saturations of 75-85%, the patient was easily weaned off supplemental oxygen without precipitation of respiratory distress. The patient was admitted to the cardiovascular intensive care unit. Her hospital course was uncomplicated, aside from an incidental note made of dental caries. She was discharged after 5 days with a plan in place for close out-patient follow up, cardiac catheterization, and ultimate surgical repair.

Table 1. Lab results obtained for a pediatric patient referred for management to a pediatric emergency department due to persistent hypoxia following a house fire.

Variable	Value	Reference range
Basic Metabolic Panel		
Sodium	141	136-145 mmol/L
Potassium	4.5	3.3-4.7 mmol/L
Chloride	113	100-112 mmol/L
Carbon Dioxide	15 (low)	18-27 mmol/L
Blood Urea Nitrogen	12	7-18 mg/dL
Creatinine	0.3	0.1-0.7 mg/dL
Glucose	125 (high)	70-105 mg/dL
Calcium	9.3	8.5-10.7 mg/dL
Blood Gas Lab		
Hematocrit	47% (high)	34-40%
Carboxyhemoglobin	1.4%	0-1.5%
Methemoglobin	1.3%	0.4-15%
Lactate	1.9	0.5-2.2 mmol/L

Mmol/L, millimoles per liter; mg/dL, milligrams per deciliter.

Discussion

This case is a demonstration of the risks of narrowing a differential diagnosis too early in the setting of the emergency care of a pediatric patient. While the history makes the initial concern for inhalational injury high, further causes of hypoxia in a pediatric patient needed to be addressed when the data was not aligned with the preliminary impressions. Early commitment to a diagnosis, or "premature closure," can result in diagnostic error and missed opportunity for proper treatment by failing to consider alternative explanations. This case demonstrates the risk of anchoring bias, in which initial assumptions can lead to incorrect impression formation, despite accumulation of data to the contrary.[7] In Mamede et al (2024), the attachment to characteristics in a story that reinforce the initial impression are termed "Salient Distracting Factors" (SDF).[8] Adherence to these factors demonstrates physicians' tendency to acknowledge data sources that support their initial impression, and thus downgrade or ignore data that may suggest an alternative.

While anchoring bias is not the only cause of cognitive error in the ED, it is certainly a common cause of missed diagnoses. In a setting in which speed and pattern-recognition are emphasized, it is natural to slip into strategies that support efficiency and patient throughput. In Ly *et al*. (2023), it was found that patients presenting with the chief complaint of shortness of breath with diagnosis of Congestive Heart Failure (CHF) were less likely to be evaluated for Pulmonary Embolism (PE), resulting in delayed diagnosis.[9] This puts patients at increased risk of both morbidity and mortality, as a result of anchoring on their pre-existing diagnosis of CHF.

Certainly, other types of cognitive bias may be at play. For example, diagnostic momentum is the tendency to accept a prior diagnosis without scrutiny.[10] In the case presented here, if the tertiary care hospital had continued to manage the patient as a smoke inhalation case, rather than investigating further, it would be an error rooted in diagnostic momentum. Another type of bias to consider is self-satisfying bias, in which the answer accepted tends to satisfy the pre-existing belief of the clinician regarding the patient. This is closely related to premature closure, as it often includes decisive diagnoses without considering plausible alternatives, in this case, because it aligns with a preconceived notion of the patient. Premature closure and self-satisfaction bias may be complicated by confirmation bias, which is the tendency to look for information that aligns with that decided diagnosis, and not look for information that may suggest a contrary alternative.

According to cognitive psychologists, diagnostic thinking and decision-making occur with input from two primary thought-processing systems or heuristics. The first heuristic, "System 1", is pattern recognition, which is commonly applied in the initial evaluation of a patient in the ED. Pattern recognition, or "illness scripts", can allow providers to rapidly triage, evaluate, and disposition patients in the acute setting.[7,11] In this processing system, providers call on their experiences with prior patients, ability to recognize patterns of history or physical exam findings, and overall clinical instincts to influence their decision-making. However, it can lead to premature closure, resulting in missed opportunities and patient morbidity and/or mortality.

Conversely, the second heuristic, "System 2", is characterized by analytic thinking, which necessitates time and thoughtful consideration of the information obtained, through review of history, physical exam findings, lab data, and imaging results. Through careful evaluation of all the data points, accurate interpretation of the patient may be achieved. When engaged in evaluation of many patients in a busy ED, pediatric or general, this can be a difficult task for which to allot time.[7] As a result, in situations where the findings are not in alignment with the differential diagnosis or proposed conclusion, it may be prudent to rely on either in-patient or out-patient colleagues to continue the work-up where appropriate. In the ED, application of rapid bedside tests may be of utility when considering diagnoses, as a method to avoid bias in line with System 2. For example, use of a bedside ultrasound to rule out cardiac etiology for a hypoxic patient may be helpful, requiring only a few minutes. However, this does assume the availability of an ultrasound machine, in addition to adequate training to perform such a test.

Strategies have been proposed that may be helpful in identifying and addressing propensity toward diagnostic errors, particularly anchoring bias.[12] Metacognition, a method that suggests clinicians "think about thinking," enforces the idea that when stuck in the first thought-processing stream, one considers switching to the second-thought processing stream. That is, if there is concern for anchoring error, thoughtfully considering the data at hand with an objective stance may improve diagnostic accuracy.

Debiasing strategies have also been suggested as a method to decrease diagnostic error.[13] These methods primarily purport that providers must be aware of this type of error, recognize that these errors may be avoided, and apply solutions to reduce errors. Education is the most important method in debiasing providers, and it is suggested that such education be provided early in medical training and reiterated often. Through frequent education and reflection, providers may be able to reduce the risk of anchoring bias and diagnostic error. The establishment of a curriculum for clinical educators may be of use in reducing bias and encouraging more contemplative evaluation of patients in learners at all levels.

While individual decision-making may certainly result in bias or diagnostic error, it is important to consider the influence that systems may have on decision-making in the Emergency Department. A fast-paced environment does not lend itself to thoughtful, time-consuming contemplation of data. The pressure of a rapid workplace often necessitates rapid decisions, which can influence the thought process that leads to those choices. Additionally, organizational constraints may influence the evaluation of patients.[14] For example, in this case, if no echocardiography tech was available to perform an echocardiogram, that would have limited the ability to make the appropriate diagnosis, not due to a lack of clinician suspicion, but a lack of diagnostic testing accessibility. Another consideration should be the application of protocols which allow nursing or other ancillary staff to place and execute orders under the name of a physician. These are often implemented to expedite care, but may be untaken without specific clinician assessment, and, therefore, may not be indicated for a specific patient. While protocols are useful, patients still need careful assessment and consideration to make sure they are adequately managed.

In addition to considering methods of reducing bias in diagnostic decision-making, this case also sheds light on the importance of routine screenings in obstetric and pediatric medicine. While the birth history in this case is not well-known, a routine prenatal ultrasound may have caught this severe congenital lesion, allowing the patient to receive immediate cardiac care at birth. Also, most infants born in a hospital will have a critical congenital heart disease screen prior to discharge to identify if a hypoxia-inducing cardiac lesion is present at birth. This screening utilizes pre-ductal (right hand) and post-ductal (either foot) measurements of pulse oximetry to determine whether further work-up for critical congenital heart disease may be indicated. A result of a measurement of <90% in either site should trigger immediate clinical assessment.[15] Lastly, this child may have been referred to a Cardiologist much earlier if a work-up could be initiated when seen at their primary care provider for health supervision visits, or when seen for acute visits, either in the PED or clinic.

While it may seem that there were many missed opportunities to diagnose this patient, it is important to remember that there are significant barriers that may reduce access to care. The social determinants of health should be considered in this and similar cases. Access to appropriate medical care can be complicated or prevented by a number of factors, including limited access to transportation, insurance constraints, residence in a rural community, poor staffing of primary care providers, parental conditions that limit mobility, limited access to subspecialty testing opportunities, and lack of general medical knowledge of the family. Social bias is always important to consider when caring for any patient, as the social determinants of health may severely complicate the ability of patients to get the care they need.

Care of pediatric patients in the Emergency Department is certainly complicated. They are scared, crying, and in pain. They may be non-verbal or refuse to answer questions. Parents may not be present to assist in the history and physical process. Presenting signs and symptoms may be less obvious, as a result. Integration of multiple sources of information must be conducted to get at the true presenting problem of the patient. These sources may be historical (parent, EMS, friend), behavioral (anger, agitation, somnolence), or non-verbal (refusal to speak, hitting at examiners, screaming). However, by incorporating these factors, and applying sound medical decision-making with minimized bias, premature closure and diagnostic error may be minimized by a thoughtful clinician.

Conclusions

This case demonstrates the importance of maintaining a broad differential diagnosis when approaching patients in the pediatric emergency department. While this patient had exposure to a house fire and was at risk for inhalation injury and associated toxicities, her resultant injuries were relatively minimal. The patient's hypoxia appeared out of proportion to her presenting symptoms. When the conclusion assigned was noted to be at odds with the data obtained, further work-up was conducted. Premature closure in this case could have put the patient at serious risk. Ultimately, this child had a significant reduction in morbidity and mortality risk associated with her complex congenital heart disease due to thorough contemplation of the causes of hypoxia through a broader lens. Through frequent reassessment of though-processing systems and debiasing strategies, providers can reduce the risk of premature closure and anchoring bias, thereby reducing morbidity and mortality in their patient populations.

There are several methods for avoiding anchoring bias in diagnosis. The first is to acknowledge the possibility of bias and its ability to affect clinical objectivity. Self-awareness of situations that may result in bias for an individual practitioner is pivotal. It is also imperative that clinicians broaden their perspectives by frequently assessing knowledge base and decision-making patterns. Consultation with specialists, independent research, and frequent reassessment of individual processes may reduce bias. Routine employment of objective decision-making processes through structured assessment tools or checklists may serve to minimize bias in diagnostic conclusions by avoiding early closure. Collaboration with colleagues in the form of consultation, mentorship, or case review with constructive criticism can significantly reduce the risk of anchoring bias by maintaining thoughtful consideration of differential diagnoses with the added benefit of outside, objective input. Lastly, frequent reassessment of knowledge gaps and maintenance of continuing education minimizes cognitive biases by encouraging the maintenance of a broad differential diagnosis while highlighting blind spots in a clinician's diagnostic practices.

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