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Background

Point-of-care testing (POCT) first arose in the 1970s, as self-calibrating blood gas measurement machines moved from the central lab to the ICU. Quality control factors, then as now, dictated operation by trained personnel. Sources of error reported in the literature are varied. Operator incompetence, nonadherence to procedures, and use of uncontrolled reagents or equipment are common issues.[1] Analysis-stage error can arise from expired test strips in glucose meters[2], plasma versus whole-blood samples in ABG analysis[3], and plasma osmolality in hematocrit measurements[4]. These errors are amplified through incoherent regulation, rapid result availability, and immediate clinical implications of the results[1]. We discuss POCT error in the context of two clinical cases.

How Does POCT ABG Device Function?[5]

•POCT ABG uses microfabricated electrodes of thin metal oxide films and an array of electrochemical sensors on silicon microchips. Each cartridge contains a calibrant solution with known concentration of each anylate. By comparing the sensors' response to the sample with that of the calibrant, the concentration of each analyte in the sample is calculated.
•Na, K, Cl, pH, i-Ca, pCO2 are all measured via ion-selective electrode potentiometry. Concentrations are calculated via Nernst equation using the measured potential.
•pO2 is measured amperometrically. Oxygen permeates through a gas permeable membrane from the blood sample into an internal electrolyte solution where it is reduced at the cathode. The oxygen reduction current is proportional to the dissolved oxygen concentration.
O2 saturation, HCO3, and hemoglobin are calculated values.

POCT ABG Accuracy

•O2 saturation is estimated from measured pH, pO_2, and hemoglobin utilizing empiric equations. These calculated estimates have been found to vary as much as 6% saturation from measured values[6].
•Self calibrating cartridges automatically control all functions of the testing cycle including fluid movement within the cartridge, calibration, and continuous quality monitoring. i-STAT analyzer automatically performs a quality check using an internal electronic simulator every 8 hours.
•Linear testing is performed periodically comparing POCT devices with central machines based on institutional policy.
•pO2 measurements are particularly sensitive to temperature error. The temperature corrected pH, pCO_2, and pO_2 are calculated using complex algorithms.
•Exposing the sample to air allows CO_2 to escape which causes pCO_2 to decrease and pH to increase. This causes HCO_3 and total CO_2 to be under-estimated.

Case Reports

Patient 1: 46 yo F admitted for peritonitis who underwent abdominal washout and resection of perforated bowel. SICU course significant for septic shock and difficulty with ventilator weaning. On several POCT ABGs drawn over a few days at different arterial sites, discrepancy was noted between pulse oximetry (SpO_2) values and oxygenation lab values (paO_2 and SaO_2) obtained from POCT ABG (figure 1). At the time care was delivered, the assumption was made that oxygenation as measured by pulse oximetry was less accurate than POCT ABG values, as we rarely have suspicion of ABG values but commonly experience spurious pulse oximetry values. An investigation of potential causes of a falsely elevated SpO_2 was undertaken (figure 2). This failed to reveal any reasonable explanation for the discrepancy between SpO_2 and the POCT ABG paO_2 values. On the 5th day described here, inconsistencies in patient 2's POCT ABG and SpO_2 were noted. After demonstrating the discrepancy on simultaneous draws from patient 2, patient 1's care was focused on SpO_2 values and POCT ABGs were no longer used (figure 3).

Day of draw	pH	pCO_2	paO_2 (SaO_2)	SpO_2	FiO_2
1 (POCT)	7.40	42	58 (90%)	96%	0.60
2 (POCT)	7.48	36	46 (85%)	94%	0.60
3 (POCT)	7.46	40	61 (92%)	97%	0.60
4 (POCT)	7.56	29	62 (95%)	99%	0.65
5 (central lab)	7.48	32	175 (99%)	99%	0.65

Figure 1. ABGs for patient 1 over several days. SaO_2 is calculated by lab device. SpO_2 is pulse oximetry reading. Note discrepancy between pulse oximetry and POCT ABG values.

Potential source of error – How source was ruled out
•Motion - finger held motionless
•High ambient light – probe finger wrapped in opaque material
•Penumbra effect - probe positioned correctly
•Dyshemoglobinemia - no history, no meds to cause this
•Nail polish - none
•Dark pigmented skin - very light complexion
•Hct <24% - hct >27%
•SpO_2 error is +/- 3% when value is >70% per Philips manual[7]

Figure 2. Exoneration of potential sources of pulse oximetry error for patient 1 and patient 2.

Figure 3. Patient 1 Care Before and After Recognition of POCT Errors

Care based on POCT	*Care after recognition of error*
ARDS diagnosis	ARDS diagnosis removed immediately on basis of central lab ABG
FiO_2 selection for goal paO_2 >60 mmHg (based on protocol)	FiO_2 selection for goal SpO_2 >88%
PEEP selection by ARDS protocol	PEEP weaned for goal SpO_2 >88%
Ventilator weaning non-existent. Patient could not meet criteria for spontaneous breathing trial.	FiO_2 and PEEP changed in 1 day to meet criteria for spontaneous breathing trial, extubated 3 days after POCT no longer utilized
Blood transfused based on POCT $ScVO_2$ (per surviving sepsis guidelines)	$ScVO_2$ checked only with central lab, no transfusions given based on these values

Patient 2. 59 yo M sustained polytrauma in an encounter with a forklift. On HD#3 serial POCT ABGs showed paO_2 in the 50-60 mmHg range while SpO_2 remained at 100% (figure 4). This apparent discrepancy in oxygenation values raised suspicion for error. Potential errors of SpO_2 were eliminated as in figure 2. Because of very high suspicion for erroneous ABG POCT values, a single ABG draw was tested simultaneously on several different POCT machines and central laboratory testing, demonstrating a notable difference in oxygenation values between the POCT and central lab, but consistency among the POCT (figure 5). This procedure was repeated with yet another POCT machine and again showed a large discrepancy in oxygenation. At this point oxygenation interventions were made to patient 1 and patient 2 based on pulse oximetry values. Central lab was used for repeat ABGs as necessary.

pH	$paCO_2$	paO_2 (SaO_2)	SpO_2	FiO_2
7.29	58	53 (82%)	100%	0.6
7.31	55	58 (86%)	100%	0.6
7.30	60	55 (84%)	100%	0.6

Figure 4. POCT ABG draws for patient 2. SaO_2 is calculated by lab device. 2-hour intervals between draws. Note discrepancy between POCT ABG values and pulse oximetry. This pattern raised suspicion for a POCT error.

Figure 6. Patient 2 Care Before and After Recognition of POC Errors

Care based on POCT	*Care based on central lab testing and SpO_2*
ARDS diagnosis	ARDS diagnosis removed
FiO_2 >0.6	FiO_2 weaned immediately to 0.5; 0.4 next day
PEEP 10-14	PEEP 5
Escalating ventilator settings	Met criteria for spontaneous breathing trial, extubated 4d later

	Test Type	pH	$paCO_2$	paO_2 (SaO_2)	SpO_2	FiO_2
Sample 1	POCT	7.28	62	86 (95%)	100%	0.7
	POCT	7.29	61	84 (94%)	100%	0.7
	POCT	7.29	61	87 (95%)	100%	0.7
	Central	7.31	60	170 (99%)	100%	0.7
Sample 2	POCT	7.34	55	94 (97%)	100%	0.7
	Central	7.34	55	135 (99%)	100%	0.7

Figure 5. Samples sent at two points in time demonstrate internal consistency of POCT and discrepancy between POCT and SpO_2. Differences are apparent between POCT and central laboratory ABG paO_2 values, despite the rest of the ABG values corresponding. This difference is clinically significant for ventilator management.

Discussion

In the two cases discussed here, POCT error led to an inappropriately aggressive course of respiratory support. These errors increased the risk of oxygen free-radical tissue damage because of high FiO_2, created a risk of barotrauma and hemodynamic instability with elevated PEEP, and prolonged exposure to intubation and thus increased the risk of ventilator-associated pneumonia. Additionally, a blood transfusion was given per surviving sepsis guidelines based on $ScVO_2$ <70% measured during the time of other suspect measurements. In both cases the recognition of error allowed alternative measurements to be preferred and changed the direction of care.

This error was reported to our lab and appropriately investigated. All suspect samples came from the same lot number of ABG cartridges. Further investigation was unable to consistently demonstrate a pattern of errors within a particular lot number, particular POCT devices, or specific operators. Quality control showed the devices in the ICU to be accurate. Cartridges of the suspicious lot number were removed from use. The conclusion was that a consistent operator error such as not allowing cartridges to come to room temperature or simply sporadic cartridge malfunctions within the lot number was responsible.

The serial and low-volume nature of the work makes pattern recognition very difficult, a recognized weaknesses of POCT versus central lab testing. Detecting POCT errors is typically a matter of using clinical judgment if the values are in discordance with the patient's presentation, and, perhaps more importantly, planned quality control measures such as operator training, device maintenance, and periodic sample comparison with central lab values.

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Abbreviations

POCT point of care testing
ABG arterial blood gas
Yo Year old
SpO_2 Pulse oximeter saturation
SaO_2 arterial blood oxygen saturation
Hct hematocrit
ARDS acute respiratory distress syndrome
PEEP positive end-expiratory pressure
FiO_2 fraction of inspired oxygen
$ScVO_2$ Central venous oxygen saturation