

Automating shunt calculation improves analytical quality

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Agnes Ivanov

is quality manager at the United Laboratories of Tartu University Hospital
United Laboratories of Tartu University Hospital
L. Puusepa 1a
50406 Tartu
Estonia



Agnes Ivanov

is director at the United Laboratories of Tartu University Hospital
United Laboratories of Tartu University Hospital L.
Puusepa 1a 50406 Tartu Estonia.

Tartu University Hospital has improved the quality of blood gas testing in its clinical laboratory and critical care units by introducing an automatic system for blood gas analysis.

Not only did the quality of processes in the preanalytical phase improve, but also the automatic calculation of $pO_2(A-a)$, for APACHE scoring as a measure of the quality of the analytical phase, was more accurate than manual calculation.

Measuring the quality of the analytical phase

There are several scoring systems for the estimation of the effectiveness and quality of critical care units; one of them is APACHE II (*“Acute Physiology and Chronic Health Evaluation”*) [1, 2].

After admission of a patient to an intensive care unit,

an integer score from 0 to 71 is computed, based on several measurements: higher scores imply a more severe disease and a higher risk of death. The point score is calculated from 12 routine physiological measurements (such as blood pressure, body temperature, heart rate, etc.) during the first 24 hours of admission, information about previous health status and some information obtained at admission.

Of the 12 measurements, seven are performed by the laboratory: serum sodium, serum potassium, serum creatinine, packed cell volume, white blood cell count, arterial pH, oxygenation (pO_2 if $FO_2(I) < 50\%$ and $pO_2(A-a)$ if $FO_2(I) > 50\%$).

The Anesthesiology and Intensive Care Clinic of Tartu University Hospital, Estonia (see End-note), has been using the *“Quality Reporting and Benchmarking Service for Healthcare”* program, provided by Intensium iQR, since 2006 [3].

The APACHE II form in Intensium contains a special equation for calculation of $pO_2(A-a)$ (the difference in the partial pressure of oxygen of the alveolar air and arterial blood, an indicator of the efficacy of the oxygenation process in the lung).

There are several problems with this equation, since the result may vary depending on the analyzer configuration, manufacturer of the analyzer and quality control service used.

Manual calculation

The difference in the partial pressure of oxygen in the alveolar air and arterial blood is calculated [4] as follows:

$$pO_2(A-a) = pO_2(A) - pO_2(a) \quad (\text{equation 1})$$

where $pO_2(A)$ is the partial pressure (or tension) of oxygen in alveolar air, and $pO_2(a)$ is the partial pressure (or tension) of oxygen in blood.

The $pO_2(a)$ is measured by an analyzer and $pO_2(A)$ calculated by the "alveolar air equation":

$$pO_2(A) = FO_2(I)(p(\text{amb}) - p_{H_2O}) - pCO_2/RQ \quad (\text{equation 2})$$

where $FO_2(I)$ is the fraction of oxygen in inspired air, $p(\text{amb})$ is the ambient barometric pressure, p_{H_2O} is the saturated vapor pressure of water (47mmHg), pCO_2 is the partial pressure (or tension) of carbon dioxide in blood and RQ is the respiratory quotient.

RQ is a ratio indicating the relation of the volume of CO_2 production to the oxygen consumption in the body. The range of RQ for organisms in metabolic balance usually is from 1.0 to 0.7 [5]. RQ is an input parameter, such as patient temperature or $FO_2(I)$, and in case the value is not given by the nurse, the analyzer uses a "standard" value of RQ.

The $p(\text{amb})$ equation using Dalton's law may be written for room air as:

$$p(\text{amb}) = pO_2 + pCO_2 + pN_2 + p_{H_2O} + pX \quad (\text{equation 3})$$

where pN_2 is the partial pressure of nitrogen and pX is the partial pressure (or tension) of any other gas in the air sample.

However, in blood gas work, the standard is for measurement of partial pressure always at body temperature (usually 37 °C), and in the presence of saturated water vapor ($p_{H_2O} = 47$ mmHg). [6]

With a $p(\text{amb})$ of 760 mmHg, p_{H_2O} as 47 mmHg and RQ as 1, the equation will be (1):

$$pO_2(A-a) = FO_2(I)(713) - pCO_2 - pO_2 \quad (\text{equation 4})$$

The same equation is used by Intensium.

Automatic calculation

The equation used by the automatic blood gas system is:

$$pO_2(A-a) = FO_2(I)(p(\text{Amb}) - p_{H_2O}) - pCO_2(RQ - 1 - FO_2(I) - 1(RQ - 1)) \quad (\text{equation 5})$$

Default value for RQ is 0.86.

With an RQ of 0.86 the equation will be:

$$pO_2(A-a) = FO_2(I)(p(\text{Amb}) - p_{H_2O}) - pCO_2(1.16 - (0.16) FO_2(I)) \quad (\text{equation 6})$$

Comparison of automatic and manual result calculations

In our critical care units, using the manual system, nurses calculated manually

- the $pO_2(A-a)$ difference value using the values of pCO_2 , pO_2 and $FO_2(I)$
- the $pO_2/FO_2(I)$ values, using the values of pO_2 and $FO_2(I)$

In the automatic system, the $pO_2(A-a)$ difference and

the $pO_2/FO_2(I)$ values are calculated automatically.

We have compared the results of 101 patients for $pO_2(A-a)$ difference with an $FO_2(I)$ above 50 %, using automatic and manual calculations. The results were compared with mean differences paired t-test and linear regression.

The regression line was: automatic = $(- 4.4) + 0.99 \times$ manual with a confidence interval of 95 %. Mean difference was 8.3 mmHg.

The results indicate that the automatically calculated $pO_2(A-a)$ difference values were significantly lower than the values derived from manual calculation. For example, a sample with an automatic calculation (equation 5) of $pO_2(A-a)$ of 480 mmHg gives a score (according Table I) of +3 points; the manual calculation (equation 4) of $pO_2(A-a)$ of the same sample was 501 mmHg, giving a score of +4 points.

The automatic equation (equation 5) is not only faster to calculate than the manual one (equation 4), but the $pO_2(A-a)$ values from the automatic system are more accurate because they are based on measured parameters rather than default values.

Definitely, the one-point difference is not clinically important, since according to equation 7, the APACHE II points are multiplied by 0.146 and a difference of one point is not significant. However, the accurate estimation of APACHE II score points should be very important for research studies and quality control reports [1].

Conclusion

In our experience the automatic system improved the quality of the analytical phase. The automatic calculation of $pO_2(A-a)$, for APACHE scoring as a measure of quality control, has both improved the precision of the reports and has reduced the time for documentation.

End-note

Estonia's largest hospital is Tartu University Hospital (TUH), comprising a consortium of 16 clinics. The largest clinic, the Anesthesiology and Intensive Care Clinic, is composed of eight departments including 30 operating rooms.

TUH receives around 418,000 outpatient visits per year of which 13 % are made to the emergency medicine units. Of 43,700 inpatients, 78 % of them are admitted due to emergency reasons [8].

	+4	+3	+2	+1	0	+1	+2	+3	+4
pO_2	<55	55-60		61-70	>70				
$pO_2(A-a)$					<200		200-349	350-499	>500

The total number of APACHE II points gives a score ranging from 0 to 71, with an increasing score representing a rising severity of illness.

Logit = $-3.517 + 0.146$ (Apache II) + diagnostic category weight [7] (equation 7)

Probability of death = $e^{\text{logit}} / 1 + e^{\text{logit}}$ (equation 8)

A ratio (equation 8) greater than 1.0 may reflect poor care and a ratio below 1.0 may reflect good care [1].

TABLE 1: APACHE II scores for pO_2 and $pO_2(A-a)$

The number of blood gas analyses is constantly increasing. In 2006 more than 40,000 blood gas analyses were performed in the United Laboratories (UL), the clinical laboratory of the TUH.

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