

COMPARISON BETWEEN A CLINICAL SHORT-CUT METHOD AND A PRECISE LABORATORY ESTIMATION OF INTRAPULMONARY SHUNT AND A-aDO₂

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ABSTRACT

This study shows the application to 20 patients of a very simple formula to estimate A-aDO₂ and intrapulmonary shunt, from data commonly available in patients with oxygenation disorders. The values obtained by the "clinical short cut" method and the more sophisticated one are in statistically significant correlation.

KEY WORDS: MEASUREMENT TECHNIQUES; LUNG, Shunting.

RESPIRATORY INSUFFICIENCY is mainly the consequence of hypoventilation or impairment of the ventilation perfusion-ratio. Hypoventilation by itself is relatively easy to diagnose. On the other hand, impairment of the ventilation-perfusion ratio is more intricate to evaluate. It is seen with an intrapulmonary shunt¹ or imbalance of the alveolo-arterial gradient. These two parameters can be estimated precisely with proper laboratory instrumentation.² This apparatus is not generally available to the clinician. However it would certainly be helpful to be able to estimate these two values accurately³ from clinical data commonly measured. We have tried to find a method of estimation which will give results close to the values which would be obtained by sophisticated laboratory measurements.

MATERIAL AND METHODS

The study was conducted on twenty intensive care adult patients who needed respiratory assistance following major surgery or for severe cardiac disease.

All these patients had a catheterisation of the pulmonary artery with a Swan-Ganz catheter. Radial artery puncture was done on each of them for blood gas analysis using an Astrup Radiometer blood analyser. Total haemoglobin was determined by Coleman jr. spectrophotometer.

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A-aDO₂ (Precise Laboratory Estimation)

Formula: Alveolo-arterial gradient was obtained using the following equation:

$$A-aDO_2 = PA_{O_2} - Pa_{O_2}$$

where

$$PA_{O_2} = PI_{O_2} - Pa_{CO_2} \left[\frac{F_{I_{O_2}} (1 - F_{I_{O_2}})}{R} \right]$$

(alveolar air equation).⁴

For PI_{O_2} , R and $F_{I_{O_2}}$ determinations, respiratory gases were sampled with 50 ml glass syringes, previously washed with mineral oil or lactic acid. The inspiratory gases were sampled directly in the inspiratory tube of the MA-1 ventilator with the syringe and expiratory gases were gathered from a five litre bag to insure adequate mixing of the expiratory air. This bag was attached to a three-way directional valve placed in the expiratory tube, before the MA-1 manifold, in order to have pure expiratory gases. The few patients who were not intubated were connected to this system through a facial mask. Expiratory minute volume was measured with a Wright spirometer at flow corresponding to normal ventilation for each patient.

A-aDO₂ ("Clinical Short-Cut" Method)

For the clinical estimation of A-aDO₂, we used the same equation as used for the precise laboratory estimation but with the following simplification⁵ of the alveolar air equation:

$$PA_{O_2} = PB - PH_2O - PCO_2 - PN_2$$

This last equation requires only clinical data commonly available:

TABLE I
COMMONLY MEASURED VALUES NEEDED TO ESTIMATE A-aDO₂ AND Q_s/Q_t

# pt	F _I O ₂	P _a O ₂		P _a CO ₂		Hb g%
		mmHg	kPa	mmHg	kPa	
1	0.50	73	9.71	37.2	4.95	10.0
2	0.30	90	11.97	34.2	4.55	13.5
3	0.35	90	11.97	36.5	4.85	10.5
4	0.30	89	11.84	31	4.12	10.4
5	0.60	49	6.52	32.6	4.34	9.5
6	0.80	57	7.58	31.8	4.23	4.8
7	0.60	46	6.12	25	3.33	9.0
8	0.30	81	10.77	20.9	2.78	8.1
9	0.21	85	11.31	30.5	4.06	13.2
10	0.21	53	7.05	28.2	3.75	9.0
11	0.30	80	10.64	45.2	6.01	8.7
12	0.40	95	12.64	35.3	4.69	12.2
13	0.40	100	13.30	31.3	4.16	10.7
14	0.40	78	10.37	36.8	4.89	10.0
15	0.40	83	11.04	26.1	3.47	10.0
16	0.40	70	9.31	36.3	4.83	11.0
17	0.30	68	9.04	25.5	3.39	11.0
18	0.30	85	11.31	28	3.72	9.4
19	0.21	96	12.77	45	5.99	12.7
20	0.45	75	9.98	35	4.66	11.5

Barometric pressure = P_B = 760 mmHg (101 kPa).

Alveolar water vapor pressure = P_{H₂O} = 47 mmHg (6.2 kPa).

Blood carbon dioxide = measured P_{CO₂}.

Alveolar air nitrogen tension = P_{N₂} = 713 mmHg (94.8 kPa) × F_{I_{N₂}} (F_{I_{N₂}} = 1 - F_{I_{O₂}})

Shunt (Precise Laboratory Estimation)

Formula: Intrapulmonary shunt was obtained using the following equation:

$$\frac{Q_s}{Q_t} = \frac{C_{cO_2} - C_{aO_2}}{C_{cO_2} - C_{\bar{v}O_2}}$$

In order to know the oxygen contents for the intrapulmonary shunt, oxygen saturations were determined photometrically with an OSM1-Radiometer for arterial blood and for mixed venous blood from pulmonary artery. The pulmonary oxygen content was calculated using the alveolar air equation.

Shunt ("Clinical Short-Cut" Method)

For the clinical estimation of intrapulmonary shunt the usual calculation was simplified by arbitrarily setting the C_{v̄O₂} 3.5 ml less than C_{aO₂}.⁷ We also assumed the P_{aO₂} to be proportional to F_{I_{O₂}} as we did when estimating A-aDO₂. The oxygen saturation, which in this case is not directly measured, was obtained from the nomo-

gram for oxygen-haemoglobin dissociation curve (Severinghaus).⁸ One gram of haemoglobin was considered to carry 1.37 ml of oxygen.⁹

The following example will illustrate the calculations of A-aDO₂ and intrapulmonary shunt starting from simple available parameters:

Hb = 9.0 g/dl

P_{aO₂} = 46 mmHg (6.1 kPa)

O₂ sat. = 0.81 (Severinghaus)

P_{aCO₂} = 25 mmHg (3.3 kPa)

F_{I_{O₂}} = 0.60.

"Clinical short cut" estimations are calculated as follows:

(1) Alveolo-Arterial Difference

$$\begin{aligned} A-aDO_2 &= P_{A_{O_2}} - P_{a_{O_2}} \\ &= [P_B - P_{H_2O} - P_{CO_2} - P_{N_2}] - P_{a_{O_2}} \\ &= [760 - 47 - 25 - (713 \times 0.40)] - 46 \\ &= [402.8] - 46 \\ &= 356.8 \text{ mmHg (47.4 kPa)} \end{aligned}$$

(2) Intrapulmonary Shunt

$$Q_s/Q_t = \frac{C_{cO_2} - C_{aO_2}}{C_{cO_2} - C_{\bar{v}O_2}}$$

Keeping in mind that blood O₂ content (C) is obtained from blood Hb content (Hb) and O₂ saturation (So₂)

$$C = (Hb \times 1.37 \times So_2) + (Po_2 \times 0.003)$$

TABLE II
A-aDo₂ VALUES

# pt	A-aDo ₂ "short cut" method		A-aDo ₂ laboratory precise method	
	mmHg	kPa	mmHg	kPa
1	246	32.72	222	29.53
2	90	11.97	70	9.31
3	123	16.36	87	11.57
4	94	12.50	96	12.77
5	346	46.02	313	41.63
6	482	64.11	555	73.82
7	357	47.48	328	43.62
8	112	14.90	86	11.44
9	34	4.52	21	2.79
10	68	9.04	50	6.65
11	89	11.84	105	13.97
12	155	20.62	151	20.08
13	154	20.48	104	13.83
14	170	22.61	124	16.49
15	176	23.41	128	17.02
16	179	23.81	134	17.82
17	120	15.96	95	12.64
18	101	13.43	84	11.17
19	9	1.20	0	0
20	211	28.06	163	21.68

we can calculate capillary (c), arterial (a), and mixed (\bar{v}) blood O₂ contents as follows:

$$Cc_{O_2} = (9 \times 1.37 \times 1.00) + (402.8 \times 0.003) = 13.54 \text{ ml/100 ml (N.B.: capillary } PO_2 = \text{alveolar } PO_2 = 402.8 \text{ mmHg)}$$

$$Ca_{O_2} = (9 \times 1.37 \times 0.81) + (46 \times 0.003) = 10.13 \text{ ml/100 ml}$$

$$C\bar{v}_{O_2} = Ca_{O_2} - 3.5 = 6.63 \text{ ml/100 ml}$$

$$\dot{Q}s/\dot{Q}t = \frac{13.54 - 10.13}{13.54 - 6.63} = 49.4 \text{ per cent.}$$

RESULTS

Table I features the usual clinical laboratory measurements for the twenty patients investigated.

Table II shows both A-aDo₂ values obtained from the "clinical short cut" method and from the more sophisticated one.

Figure 1 shows how closely these two values were correlated ($r = 0.98$, $p < 0.001$).

Table III shows, for a given patient, both pulmonary shunt values obtained from the "clinical short cut" method and from the more sophisticated one. Paired Student t-test gave no statistically significant difference between the values obtained from the "clinical short cut" method and from the more sophisticated one ($p > 0.05$).

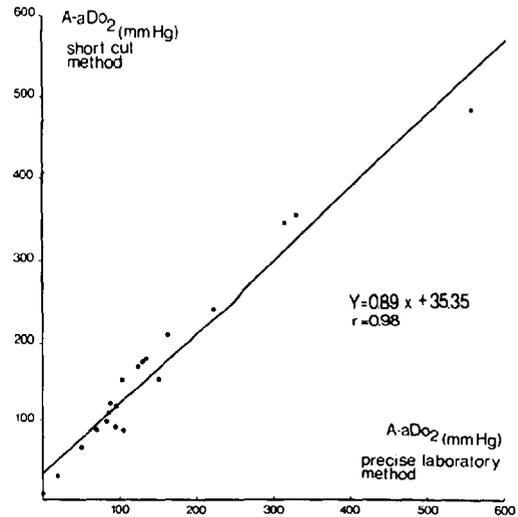


FIGURE 1 Correlation between A-aDo values.

Figure 2 shows how closely these two values were correlated ($r = 0.87$, $p < 0.01$).

DISCUSSION

A-aDo₂ and intrapulmonary shunt estimated with our "short cut" method are in close agreement with values obtained from a more sophisticated method. As a matter of fact, in 90 per cent of the cases the "short cut" method produced a quantitative estimation clinically equivalent to the value obtained by the precise laboratory method.

Furthermore, as we can see in patient #9, the "clinical short cut" method might have a certain advantage over the precise laboratory estimation which requires a degree of collaboration from the patient when he is not on a respirator. This particular patient was semiconscious and uncooperative during the test. This could explain the discrepancy between the shunt values obtained by the two methods. In this instance we would be inclined to accept the "clinical short cut" result as being the true state of this patient.

It thus becomes possible for a clinician having available only arterial gases, haemoglobin and FI_{O_2} to be in a position to use alveoloarterial gradient and intrapulmonary shunt to make a diagnosis, follow the evolution and direct the treatment for his patient.

CONCLUSION

The proposed method of estimation is accurate and simple. The calculations may be done by

TABLE III
Qs/Qt VALUES

# pt	Qs/Qt "short cut" method (per cent)	Qs/Qt laboratory precise method (per cent)
1	31.0	30.6
2	21.7	19.3
3	20.7	9.6
4	19.3	16.3
5	48.2	56.8
6	39.0	47.8
7	49.6	48.5
8	20.1	14.5
9	20.4	0
10	36.1	30.4
11	19.8	19.9
12	22.8	25.0
13	20.2	21.4
14	25.8	30.6
15	25.1	20.7
16	31.1	25.0
17	29.8	13.0
18	20.0	12.4
19	14.6	14.5
20	30.3	24.2

hand or with a pocket calculator (appendix A), without the use of more sophisticated apparatus. A-aDO₂ and intrapulmonary shunt thus become available to any clinician.

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RÉSUMÉ

La présente étude démontre, chez 20 patients, l'application d'une formule simple pour estimer l'A-aDO₂ et le shunt intrapulmonaire. Cette formule utilise les données normalement mesurées chez les patients qui présentent des troubles d'oxygénation. La corrélation entre les valeurs obtenues par la méthode simplifiée et celles découlant d'une méthode à la fois beaucoup plus précise et sophistiquée est statistiquement très valable.

APPENDIX

The following program will run in the programmable calculators TI 58 or TI 59 and will calculate the A-aDO₂ and the intrapulmonary shunt according to the

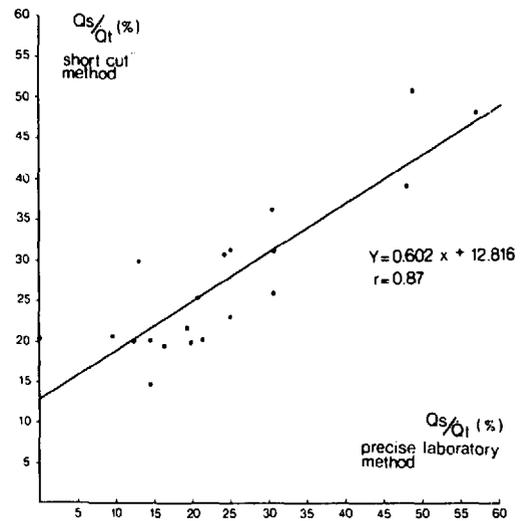


FIGURE 2 Correlation between intrapulmonary shunt values.

approximation given in the article. It can easily be adapted to run in a HP-65 or any other HP programmable calculator.

When the program is inserted into the TI-58 or TI-59 programmable calculator the following steps should be followed:

Enter the P_{O_2} and press on "A"; enter the saturation for this P_{O_2} and press "R/S". We then enter the P_{CO_2} and press "B". When the $F_{I_{O_2}}$ is keyed we press "C" and when Hb is entered we press "D". The order of insertion for the different parameters has no importance but they must all be entered into the calculator.

When all information is furnished to the calculator, pressing "E" will give first the A-a Do_2 in mm Hg and pressing R/S will give the intrapulmonary shunt in percentage.

Summary

Procedure	Enter	Press	Display
1 Enter Program			
2 Measured P_{O_2}	P_{O_2}	A	P_{O_2}
3 Saturation from Severinghaus table (fraction)	S_{O_2}	R/S	S_{O_2}
4 Measured P_{CO_2}	P_{CO_2}	B	P_{CO_2}
5 Inspired O_2 (fraction)	$F_{I_{O_2}}$	C	$F_{I_{O_2}}$
6 Haemoglobin gm per cent	Hb	D	Hb
NB: 2, 3, 4, 5, 6 in any order		E	A-a Do_2
7		R/S	Shunt (%)

Program

LBL	E	RCL	=	(
A	FIX	01	STO	RCL
STO	2	=	09	09
01	7	R/S	RCL	-
R/S	1	1	07	RCL
STO	3	.	x	10
05	-	3	RCL)
R/S	RCL	7	05	÷
LBL	02	x	+	(
B	-	RCL	RCL	RCL
STO	7	04	01	09
02	1	=	x	-
R/S	3	STO	RCL	RCL
LBL	x	07	08	11
C	(+	=)
STO	1	RCL	STO	=
03	-	06	10	x
R/S	RCL	x	-	1
LBL	03	.	3	0
D)	0	.	0
STO	=	0	5	=
04	STO	3	=	R/S
R/S	06	STO	STO	
LBL	-	08	11	