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Errors in Intraoperative Hematocrit Determination

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Arterial lines for direct pressure monitoring are frequently used to sample blood for various other laboratory studies. Blood-gas analysis and serial hematocrit determinations are often done when patients are losing considerable amounts of blood. Intentional hemodilution and the potential danger of every transfusion make accurate hematocrits a necessity. This study investigates one source of error, hemodilution by flush solutions in arterial lines.

METHODS

Six patients undergoing surgical procedures were studied. Each patient had a 20-gauge radial-artery catheter† connected to a pressure transducer and a three-way stopcock‡ by a transmission line filled with heparin flush solution. After the line and catheter had been flushed, a syringe was attached to the the stopcock and fluid withdrawn until blood-tinged fluid appeared in the syringe. Two hematocrit samples were taken from the stopcock in capillary tubes (sample volume approximately 0.05 ml each). At this point 0.4 ml more solution was withdrawn and another two hematocrit samples were taken. This procedure was repeated until a total 10 ml had been withdrawn. Ten ml more were withdrawn and final hematocrit samples were taken. This technique provided sample points every 0.5 ml from the first appearance of blood at the end of the transmission line until 10 ml more had been withdrawn. This procedure was repeated with each of four different transmission lines for each of the six patients. The samples obtained after a total of 20 ml had been withdrawn were assumed to be the patient's actual hematocrit, and verified by a simultaneous venous hematocrit. The transmission lines used and pertinent physical data are shown in table 1.

TABLE 1. Arterial Pressure Transmission Lines Used and Their Dimensions*

	Length, cm (Inches)	Internal Diameter, cm	Volume, ml
Cutter†			
Transmission set (single length)	92 (36)	0.12	1.0
Transmission set (double length)	184 (72)	0.12	2.0
Cobe‡			
Pressure line	92 (36)	0.17	2.2
Pharmaseal§			
Extension tube	84 (33)	0.24	3.8

* Internal diameter was calculated from measured length and volume.

† Cutter Laboratories, Inc., Berkeley, California 04710.

‡ Cobe Laboratories, Inc., Denver, Colorado 80215.

§ Pharmaseal, Inc., Toa Alta, Puerto Rico 00758.

RESULTS

On the average, withdrawing a volume equivalent to 80 to 90 per cent of the volume

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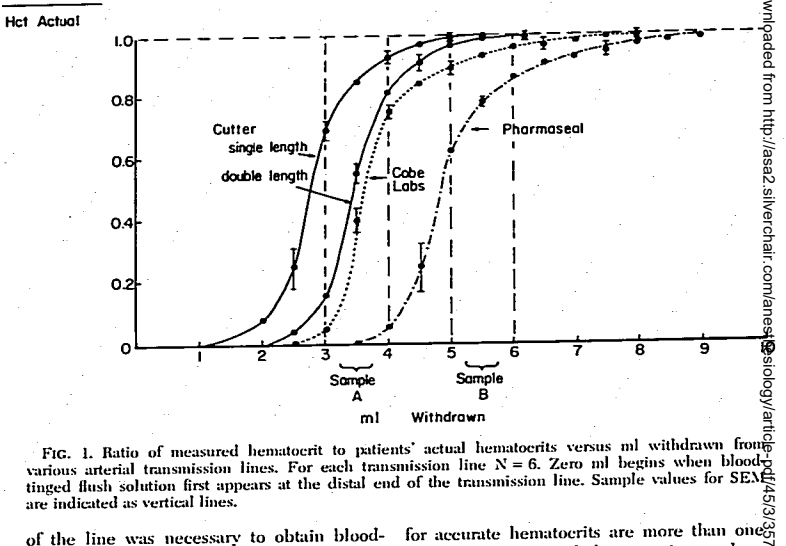

FIG. 1. Ratio of measured hematocrit to patients' actual hematocrits versus ml withdrawn from various arterial transmission lines. For each transmission line N = 6. Zero ml begins when blood-tinged flush solution first appears at the distal end of the transmission line. Sample values for SEM are indicated as vertical lines.

of the line was necessary to obtain blood-tinged fluid. Figure 1 plots the fraction of measured to final hematocrit versus the number of ml withdrawn after the appearance of blood at the end of the transmission line. Table 2 shows the total volumes necessary to withdraw to obtain hematocrit values that will reliably be 95 per cent of the actual values.

DISCUSSION

The results are not surprising save for two features. First, the volumes to be evacuated for accurate hematocrits are more than one might predict. Second, the errors incurred are larger and more significant than would at first seem apparent. Two examples may serve to illustrate the point. In each instance, assume a patient losing blood, which is being replaced with non-erythrocyte-containing volume expanders. Each patient's blood volume has been maintained, but both have been hemodiluted to a hematocrit of 37 volumes per cent. Samples for hematocrit determination are obtained by aspirating the flush solution from the arterial line until blood-tinged fluid appears in the aspirating syringe. In the first case, 3 ml more are withdrawn and discarded, and a 1-ml sample is then taken for hematocrit determination (sample A in fig. 1). In the second case the same procedure is followed except that 5 ml are discarded before the 1-ml hematocrit sample is withdrawn (sample B in fig. 1). Table 3 shows the hematocrit values obtained from the above sampling techniques for each of the arterial lines under consideration. These values are calculated from the data in figure 1. Assume you had determined, based upon other pertinent factors, to administer a blood trans-

TABLE 2. Total Volume* to be Aspirated from Line Filled with Heparin Flush Solution before Hematocrit Sampling will be Accurate

	Total Volume, (ml) for Accurate Hematocrit
Cutter	
Single length	5.4
Double length	6.7
Cobe	8.0
Pharmaseal	10.7

* Including initial flush solution.

fusion to this patient if the hematocrit were 35 volumes per cent or lower. The figures in table 3 show that, in all probability, in six of the eight instances the patient would receive an unnecessary blood transfusion as a result of sampling error.

Although hematocrit values are seldom the sole consideration for blood transfusions, inaccurate low hematocrits may lead to needless transfusions. The sampling technique used in this study certainly does not exactly duplicate that which might be used in clinical practice. The actual numerical results presented cannot, therefore, be directly translated into routine clinical guides. The intent is to illustrate the source and potential magnitude of error. Our general observation is that one can be assured of accurate results only after six times the deadspace volume has been withdrawn. Obviously this problem can be greatly reduced if one can sample directly from the arterial catheter, but this is not always possible. Further, it should be clear that any other quantitative determinations on blood so sampled are subject to the same source of potential error.

TABLE 3. Values for the Two Sampling Techniques Calculated from the Data in Figure 1*

Arterial Lines Used	Measured Hematocrit (Vol Per Cent ± SEM) (Actual Hematocrit = 37 Vol Per Cent)	
	Sample A	Sample B
Cutter		
Single length	31 ± 1.7	37 ± 1.2
Double length	29 ± 3.1	36 ± 2.0
Cobe	15 ± 5.0	34 ± 3.3
Pharmaseal	6 ± 8.2	29 ± 4.5

* Patient's actual hematocrit is 37 volumes per cent. See text and figure 1 for explanation.

Scavenging System for the Harvey Blood Oxygenator

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Because of the current interest in scavenging waste anesthetic gases, we recently began analyzing, by gas chromatography, air in our operating rooms. We discovered that during cardiopulmonary bypass, with 0.5 per cent halothane delivered to the blood oxygenator, the halothane levels in the operating room were as great as 2.59 parts per million (ppm). This level is five times the recommended maximum of 0.5 ppm, which can be achieved by using presently available scavenging apparatus designed for the circle anesthesia system.[1] A recent clinical report[2] describes a device for removing waste anesthetic gases from the Bentley Temptrol extracorporeal oxygenator. We describe a system that effectively scavenges the adult and pediatric models of the Harvey oxygenator.

The Harvey blood oxygenator emits spent gases through a circumferential series of openings around the top of the oxygenator. To scavenge this exhaust we designed a cylindrical hood that fits loosely over the oxygenator and extends two-thirds of the way down its side (fig. 1). Attaching the hood to the oxygenator creates an interspace in which exhaust gases will circulate upward as a vacuum is created at the suction port on the top of the hood. The enclosed hood top has a groove extending to its center, which facilitates attachment of the oxygenator to its spring-loaded mounting. In addition, two holes on the top of the hood allow access to injection ports on the oxygenator. These openings in the hood rest snugly against the top of the oxygenator to minimize waste gas leakage. The cylindrical hood is open at the bottom and has a radius approximately one centimeter

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