THE MEASUREMENT OF BLOOD LOSS AT OPERATION

BY

A. J. S. Gardiner and H. A. F. Dudley

Department of Surgery, University of Aberdeen, and The Royal Infirmary, Aberdeen, Scotland

Large amounts of blood may be lost from the circulation without changes in such indices as blood pressure, pulse rate and skin blanching reflexes. This is true not only in the conscious subject (Barcroft et al., 1944) but also and to a greater extent when the patient is anaesthetized. If physiological trespass in the form of hypotensive techniques, hypothermia or extracorporeal circulation is added, the complexity of the problem of indirect assessment of blood loss by reference to vital signs may defy analysis. It is this difficulty that has long concerned surgeons and anaesthetists interested in the direct measurement of operative blood loss. As the population grows older and operative surgery becomes more involved the need for accurate assessment becomes more clamant. In addition, economy in the use of blood is essential if the growing need is to be met. Finally, accurate measurement and replacement of blood is one key to the understanding of other disorders of the circulation occurring in the intra-operative and postoperative period which have been hidden because of concern for hypovolaemia and pre-occupation with the transfusion bottle.

A distinction should be drawn between retrospective and continuous measurements of blood loss. The former gives information, at a single instant, of events that have taken place over a previous period, whereas the latter provides an up-to-date index. In most situations the degree of elasticity of the body's compensatory mechanisms renders the determination of summated loss at the end of a procedure adequate, but continuous measurement, and its corollary continuous replacement, is of great value, particularly when large losses are taking place.

Standards of accuracy.

A 5 per cent change in blood volume is usually well borne, but one of 10 per cent requires considerable adjustment and if superimposed on pre-existing disease may be of great consequence. Therefore, precisely to adjust transfusion in the face of continuing loss requires an accuracy of determination which is well inside this figure and should be within about 2 per cent of blood volume. For an adult this will represent between 100 and 150 ml, but a similar loss in a neonate corresponds to only 6–8 ml. The inability to make estimates of this degree of accuracy should not, of course, deter the anaesthetist from attempting some objective measure, because anything is better than guesswork. However, firm conclusions about the magnitude of loss should not be drawn without reference to the precision of the technique involved.

Methods.

Four methods which have been modified in a number of ways are available. These, with their advantages and disadvantages, are listed in table I.

Subjective estimation. Visual assessment is difficult and unreliable, and most authorities claim that the surgeon always underestimates the blood loss. Our experience suggests that in the lower loss groups, surgeons and anaesthetists can be quite reliable and they become more so when some objective measure is also available in the operating theatre. However, as the magnitude of loss increases the estimate becomes increasingly unreliable and may err quite wildly on either side of the actual figure.

Blood volume. Much has been written on blood volume determination in assessing loss after trauma or operation (Keith, 1919; Chute, Cleghorn and Lathe, 1945; Grant and Reeve, 1951; Prentice et al., 1954; Clarke, Topley and Flear, 1955; Clarke et al., 1961). One considerable advantage of this technique is that bleeding which occurs after the incision has been closed may be detected. The accuracy of the method varies according to the tracer used and is slightly better with red cell labels such as $^{51}$Cr than with plasma labels such as T-1824 or radio-iodinated human serum albumen. The cost of the tracers themselves is not
<table>
<thead>
<tr>
<th>Group</th>
<th>Actual method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Guesswork</td>
<td>Visual assessment</td>
<td>(i) Inexpensive (ii) Rapid (iii) Continuous</td>
<td>In differentiating between a 500 and 1500 ml loss, i.e. 1 to 3 pints, observers are extremely inaccurate</td>
</tr>
<tr>
<td>Clinical impression</td>
<td>Mental computation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II. Blood volume analysis</td>
<td>(a) Subtractive—subtracting postoperative from pre-operative values</td>
<td>Accurate to 5-6%</td>
<td>(1) A postoperative result (2) Unreliable in certain conditions, e.g. cardiopulmonary failure, or peripheral circulatory failure (3) Time-consuming (4) Haematocrit dependent (5) Expensive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1) Involves servicing and operation of a complex electronic instrument (2) Haematocrit dependent (3) Extremely expensive</td>
</tr>
<tr>
<td></td>
<td>(b) Repeated—using a radio-isotope tracer, the blood volume being calculated by a scintillation-counter computer machine</td>
<td>(1) Fairly rapid (2) Reproducible (3) Accurate 3-5%</td>
<td></td>
</tr>
<tr>
<td>III. Gravimetric</td>
<td>Swab-weighing</td>
<td>Inexpensive</td>
<td>(1) Inaccurate because (a) Loss of weight by evaporation (b) Susceptibility to mathematical errors in addition/subtraction of very many small quantities (c) Fluids other than blood present (d) Loss in drapes not measured (2) Inconvenient because (a) Swabs, gauzes must be standardized (b) Time-consuming</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continuous</td>
<td>(2) Postoperative result (2) Inconvenient because (a) Allowance for dressings, drip-sets and such-like must be made (b) Excessive patient handling (3) Inaccurate because the subtractive result includes (a) Loss of water by respiration (b) Loss of water by perspiration (c) Loss of water by evaporation from wound</td>
</tr>
<tr>
<td></td>
<td>Weighing of patient.</td>
<td>Inexpensive</td>
<td></td>
</tr>
<tr>
<td>IV. Extraction-dilution analysis</td>
<td>(1) Simple method of washing swabs by hand and then measuring the acid haematin found on addition of HCl</td>
<td>Inexpensive</td>
<td>(i) A postoperative result (ii) Incomplete extraction of blood (iii) Acid haematin undergoes change on standing (iv) Standard haemoglobin solutions and curves necessary.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(i) Use of electrolyte containing fluids will invalidate these results (ii) Requires servicing of complex electrical equipment (iii) Extremely expensive</td>
</tr>
<tr>
<td></td>
<td>(2) Washing machine extraction, and use of Wheatstone Bridge principle to measure change in electrical conductivity</td>
<td>Accurate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rapid</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Direct reading</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continuous</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) Washing machine extraction and use of flow-through colorimeter to measure haemoglobin loss continuously</td>
<td>Accurate</td>
<td>(i) Bath must be changed at 500 ml (ii) Not direct reading</td>
</tr>
</tbody>
</table>
THE MEASUREMENT OF BLOOD LOSS AT OPERATION

655

great, but the apparatus is expensive and complicated, particularly if a semi-automatic method which allows repeated determinations is used (Williams and Fine, 1961). On the whole the methods are not suitable for routine application nor do they give a degree of discrimination consistent with the effort expended. Furthermore, they are all haematocrit dependent—that is, conversion from red cell volume or plasma volume to whole blood volume requires knowledge of the ratio between cells and plasma. Inaccuracy of measurement of this and the variations in its value from place to place in the vascular system introduce a random error.

Gravimetric. All weighing methods introduce considerable inaccuracies, although they have the great virtue of cheapness and simplicity. They have the additional advantage of giving a continuous record, marred only by the difficulties of arithmetic, which frequently creep in when a busy nurse is charged with the task. Our own experiments suggest that there are large inherent errors, particularly loss from evaporation which may reach 10 per cent in 15 minutes in a hot theatre. Forsee and Schmidt (1952) indicate that reliance on swab-weighing results in under-replacement of up to 45 per cent. Weighing the patient is equally unreliable (Ausman et al., 1961) and includes in the error insensible losses and the difficult calculations of the weight of excised viscera and dressings.

Extraction-dilution analysis. The fourth group, that of extraction-dilution analysis, needs some definition. Blood can be extracted by various means from the absorptive materials and suction effluent and any constant chemical or physiochemical property used as a yardstick for measurement of its concentration in the resulting solution. The early results (Gatch and Little, 1924; Pilcher and Sheard, 1937; White et al., 1938; White and Buxton, 1942; Coller, Crook and Iob, 1944) which were obtained by measuring some derivative of haemoglobin such as acid haematin were not very accurate because of incomplete recovery, but this method has proved popular until very recently (Dmitriyev, Krinitskiy and Sagaydak, 1960) and may be more extensively used than is usually appreciated. An alternative technique is to exploit the fact that the electrical conductivity of blood is a constant (LeVeen and Rubricius, 1958; Klopstock, LeVeen and Levitan, 1959). Addition of blood to water will produce changes in the electrical conductivity of the mixture which may be measured using a Wheatstone Bridge. Provided other electrolytes are not present this is an extremely accurate method and has the virtue of giving a continuous reading. Unfortunately, the commercial equipment is expensive, and homemade apparatus does not necessarily perform reliably.

The advent of powerful domestic washing machines has made simple the complete extraction of blood from gauzes and by a simple adaptation (Roe, Gardiner and Dudley, 1962) the concentration of blood in the resulting solution can be continuously determined by optical densitometry. This method can give a 1 per cent accuracy, using simple circuitry only, and at minimal expense. Both conductometric and optical techniques have the disadvantage that as the volume of blood added to the system increases, it itself alters the volume of the solvent and thus influences the final concentration. Allowance can be made for this in computation or, alternatively, an arbitrary limit is set, after which the instrument is emptied and a fresh solution added.

POSTOPERATIVE BLOOD LOSS

Repeated blood volume determination is the only method so far available of gaining some measure of postoperative blood loss. This is the case only in closed injuries and operations. Fortunately the increasing use of drainage from operation sites has made some direct measurements possible thus allowing both surgeon and anaesthetist a better assessment of continued bleeding. As with intraoperative determinations this makes for a more accurate analysis of postoperative circulatory disturbances.

In conclusion, as Moore (1959) has said, this is "a well-ploughed field full of pitfalls". Estimates of blood loss can improve operative management and should become much more widespread. Not only do they make for accuracy in surgical care but also they promote a healthy attitude on the part of surgeons to blood loss and conservation.

REFERENCES


