4

PITFALLS IN ASSESSING BLOOD LOSS AND DECISION TO TRANSFER

B. S. Kodkany and R. J. Derman

INTRODUCTION

Pregnancy and childbirth involve health risks, even for women without any pre-existing health problems[1–7]. Obstetric hemorrhage is the single most important cause of maternal death. Of great importance is the inaccurate assessment of blood loss that may result in significant adverse sequelae. Underestimation leads to delayed treatment and overestimation to unnecessary and costly interventions. It is axiomatic that postpartum hemorrhage occurs unpredictably and no parturient is immune from it. Simply stated, postpartum hemorrhage is an equal opportunity killer[8]. Unlike uterine rupture which can precede death by 24 h and antepartum hemorrhage which may lead to death in half that time, postpartum hemorrhage can be lethal in as little as 2 h.

The common definitions of postpartum hemorrhage are described in Chapter 2. Traditionally, blood loss after delivery is visually estimated, with wide variations in accuracy. The importance of accurately measuring vaginal blood loss at delivery was stressed by Williams as early as 1919[9]. The birth attendant grossly makes a quantitative estimate; however, the associated amount of loss is often far greater than appreciated by visual estimation alone[10].

In the past, quantitative methods for estimating vaginal blood loss included direct collection of blood into bedpans or plastic bags; gravimetric methods wherein pads were weighed before and after use and the difference in the weight used to determine the amount of blood lost; determination of changes in blood indices before and after delivery; the acid hematin method, by which blood in the sponges and pads was mixed with a solution that converted hemoglobin to acid hematin or cyanmethemoglobin, which in turn was measured by a colorimeter; plasma volume determinations before and after delivery using radioactive tracer elements; and, finally, measuring blood loss by using ^{51}Cr-tagged erythrocytes.

None of these methods was ever adopted in clinical practice because of their complicated nature or due to the effort, expense and time required to obtain results before beginning interventions. Thus, visual estimation, inaccurate as it may be, continues to be used clinically. Published studies, in which investigators carefully quantified blood loss after delivery, repeatedly indicate that clinical estimates of blood loss are notoriously unreliable, with a tendency to underestimate the incidence of postpartum hemorrhage by 30–50%[1]. As a result, numerous authorities have advocated a more objective approach to the diagnosis of postpartum hemorrhage. Although many studies address this issue, accurate measurement of blood loss by an ideal method remains a gray area.

NORMAL BLOOD LOSS DURING DELIVERY

Investigators report a range of average blood loss during vaginal delivery. For example, at the low end it has been reported as 343 ml in 1000 consecutive term vaginal deliveries, 339 ml and 490 ml, respectively, in two separate studies of 100 and 123 patients using the acid hematin spectrophotometric method, and a 450-ml average blood loss in 123 deliveries using chromium-labeled red blood cells[10–13]. Despite such variations, it is now generally accepted that the average blood loss during delivery is between 400 and 500 ml, whereas most Cesarean births loose about 1000 ml[14]. Unfortunately, these values are reflective of hospital-based data, primarily among women in the developed world.

PHYSIOLOGICAL ADAPTATIONS IN PREGNANCY

Antepartum adaptations for physiologic blood loss at delivery include a 42% increase in plasma volume and a 24% increase in red blood cell volume by the third trimester[15]. Women who develop pre-eclampsia either experience little or no expansion over non-pregnant levels or lose during the third trimester what gain had been accrued early in gestation[16]. In severe pre-eclampsia, the blood volume frequently fails to expand and is similar to that in a non-pregnant woman[17]. Hemoconcentration is a hallmark of eclampsia with increased sensitivity to even normal blood loss at delivery[18]. Women so afflicted are relatively less prepared to withstand blood loss and may develop life-threatening hypovolemia with smaller amounts of hemorrhage[16].

Progressively complicated deliveries are accompanied by greater degrees of blood loss: vaginal delivery (500 ml), Cesarean section (1000 ml), repeat Cesarean section plus hysterectomy (1500 ml), and emergency hysterectomy (3500 ml)[19–21].

Some of the factors leading to increased blood loss in the third stage of labor are as follows[22–24]:

(1) Mean vaginal blood loss is higher in multiparae than in primiparae;

(2) In primiparae, forceps delivery is associated with greater blood loss than spontaneous delivery; this is related to the episiotomies and other injuries to the genital tract;

(3) Patients with an episiotomy and a laceration lose significantly more blood than those without such insult. Episiotomies contribute 154 ml to the average blood loss[25]. However, forceps delivery does not appear to contribute to blood loss *per se*; any excess bleeding in this instance is due to the episiotomy that is almost always required.

DIAGNOSIS OF POSTPARTUM HEMORRHAGE

Over the years, different methods have been used for estimation of blood loss; these can be classified as clinical or quantitative methods and are delineated below.

Clinical methods

Clinical estimation remains the primary means to diagnose the extent of bleeding and to direct interventional therapy in obstetric practice. Examples include internal hemorrhage due to ruptured tubal pregnancy, ruptured uterus, and the concealed variety of abruptio placentae. The classification of hemorrhage can be based on a graded physiological response to the loss of circulating blood volume (Table 1)[26,27]. This scheme has worked well in the initial management of trauma patients. Knowing that the blood volume of a pregnant woman is 8.5–9% of her weight, one is able to quickly approximate blood loss based on changes in pulse,

Table 1 Classes of hemorrhage

	Class I	*Class II*	*Class III*	*Class IV*
% Blood loss	15	20–25	30–35	40
Pulse (beats/min)	normal	100	120	140
Systolic blood pressure (mmHg)	normal	normal	70–80	60
Mean arterial pressure (mmHg)	80–90	80–90	50–70	50
Tissue perfusion	postural hypotension	peripheral vasoconstriction	pallor, restlessness, oliguria	collapse, anuria, air hunger

systolic blood pressure and mean arterial pressure. Thus, the failure to respond to the initial administration of 3000 ml of crystalloid would suggest a Class II hemorrhage with loss greater than 20–30% of the total blood volume or acute ongoing bleeding[26,27]. A systolic blood pressure below 100 mmHg and a pulse rate above 100 beats/min are late signs of depleted blood volume and indicate commencing failure of compensatory mechanisms[28], whereas acute blood loss might not be reflected by a decrease in hematocrit or hemoglobin level for 4 h or more[26,27]. The importance of diagnosis at a Class I stage cannot be too strongly emphasized as women can progress into Class II rapidly. At level III, unless intervention is rapid and appropriate, women may progress to irreversible shock.

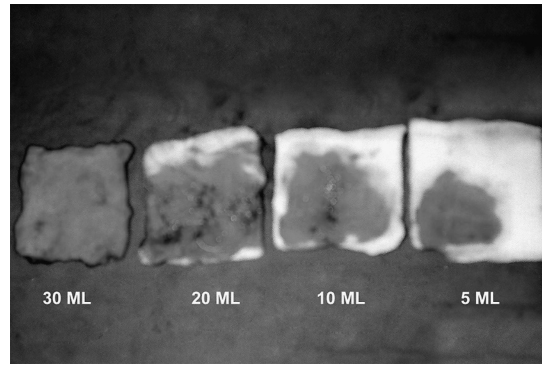

Figure 1 Soakage characteristics of 10 × 10 cm pads

Figure 2 Blood drained into a fixed collecting container

Quantitative methods

Visual assessment

The standard method of observation used for the measurement of blood loss is relatively straightforward and requires no expenditure[8]. Despite its inaccuracy and variation from one care-giver to the next, birth attendants correlate it with clinical signs. A review of the records of 32 799 deliveries at a large municipal hospital during the decade of 1963–1972 found an incidence of postpartum hemorrhage of 4.7/1000 live births or 0.47%. This was extremely low compared to stated rates in the literature, and the author concluded that many cases of postpartum hemorrhage were not recorded due to underestimation of blood loss[29].

The accuracy of this method can be improved by standardization and training. The observer needs to be trained in determining the blood loss using a single collecting container and fixed-sized gauze pads of size 10 × 10 cm. Simulated scenarios with known measured blood volume need to be created and calibrated visually (see Figure 1).

Another method of calculation is by allowing blood to drain into a fixed collecting container (Figure 2) for estimation at the end of 1 h. Blood losses on the delivery table, garments and floor should also be assessed. At the end of 1 h, the total amount of blood lost is estimated by totaling up the blood in the container, in the sponges and secondary blood spillage on the delivery table, garments and floor. How often such calculation is utilized is unknown, but failure to do so undoubtedly contributes to underestimation.

Direct collection of blood into bedpan or plastic bags

This approach was used in the World Health Organization (WHO) multicenter, randomized trial of misoprostol in the management of the third stage of labor[30]. In this trial, blood loss was measured from the time of delivery until the mother was transferred to postnatal care. Immediately after the cord was clamped and cut, the blood collection was started by passing a flat bedpan under the buttocks of a woman delivering in a bed or putting in place an unsoiled sheet for a woman delivering on a delivery table.

Blood collection and measurement continued until the third stage of the labor was completed and the woman was transferred to the postnatal ward. This period was generally up to 1 h postpartum. At that time, the collected blood was poured into a standard measuring jar provided by WHO and its volume measured. To simplify the procedure for measurement of blood loss, any available small gauze swabs soaked with blood were put into the measuring jar and included in the measurement together with the blood and clots. A validity study was performed before the trial to assess the effect of adding the gauze swabs on the estimation of blood loss and was found to result in an approximately 10% increase in the blood loss measurement.

Gravimetric method

This method involves weighing sponges before and after use. The difference in weight provides a rough estimate of blood loss.

Determination of changes in hematocrit and hemoglobin

The changes in values before and after delivery of the hematocrit and hemoglobin levels provide quantitative measurements of blood loss, as depicted in Figure 3.

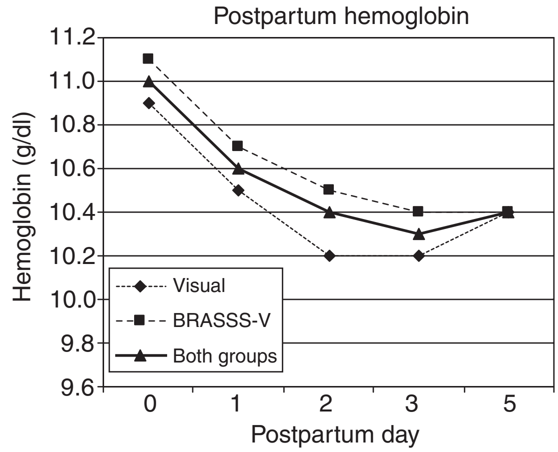

Figure 3 Postpartum hemoglobin changes

Acid hematin method

This method is based on collected blood being mixed with a standardized solution which converts hemoglobin to acid hematin or cyan-methemoglobin. This in turn can be measured by a spectrophotometer or colorimeter. Spectrophotometric analysis can be performed by the methods described below[9,31]:

(1) *Preparation of standard* Two milliliters of peripheral blood are collected pre-delivery. The blood standard is prepared with 0.1 ml of the patient's peripheral blood in 9.9 ml of 5% sodium hydroxide solution. The optical density (OD) is read at 550 nm after 30 min;

(2) *Preparation of sample* The collected sample is added to 2 liters of 5% sodium hydroxide and let stand for 15 min. One ml of the filtrate is diluted 10 times in 5% sodium hydroxide and left to stand for another 15 min. The optical density (OD) is read with a spectrophotometer at 550 nm at 30 min after the addition of sodium hydroxide to the sample;

(3) *Calculations*

$$\frac{\text{OD sample} \times 2000 \times 10\,\text{ml}}{\text{OD blood standard} \times 100} = \text{Blood volume loss}$$

Plasma volume changes

The plasma volume can be determined before and after delivery using radioactive tracer elements.

Measurement of tagged erythrocytes

Blood loss can be measured by using ^{51}Cr-tagged erythrocytes[13].

Failures of each method

Visual assessment

The major advantage of this method is that it is a real-time assessment and enables the birth attendant to correlate findings, on an individualized basis, with the clinical presentation. However, significant differences between clinical estimates and actual measurements have been consistently demonstrated in several studies[28]. The most common error is underestimation of blood lost, with an average error of 46% when estimates at the time of delivery are compared with more precise measurements. As might be expected, observers tend to give median or average estimate of blood loss. When losses were large, they were most often underestimated and, when the losses were less than average, they tended to be overestimated[11].

Standardized visual estimation

In an attempt to rectify this error, the use of a standardized visual estimation can be employed as a simple method to be routinely practiced in low-resource setting, albeit based on training the providers and standardization of the pads (size and quality) used during delivery. The accuracy of estimated blood loss is not dependent upon age or the clinical experience of the provider[32–35]. Teaching this tool significantly reduced the error in blood loss estimation for inexperienced as well as experienced clinicians. Of particular clinical importance is a reduction in underestimation of blood loss in the face of greater degrees of measured blood loss; this has the strongest potential to reduce hemorrhage-related morbidity and mortality[36].

Collection in pan or plastic bags

The errors in estimating blood loss arise from failure to collect or note all the blood in stained linen, incomplete extraction from the collection device, ignoring maternal blood within the placenta (approximately 153 ml), confusion related to the mixing of blood contaminated with amniotic fluid and urine, and technical inaccuracies associated with transfer of the collection to a measuring device.

Gravimetric methods

The gravimetric method requires the weighing of materials such as soaked pads on a scale and subtracting the known weights of these materials to determine the blood loss[37]. Inaccuracies can arise at several steps in this procedure, including lack of international standardization of size and weight of gauze, sponges and pads.

Use of blood indices and spectrophotometric measurement of hemoglobin

The first study reporting on measurement of blood loss during surgical procedures employed the colorimetric technique, which required that hemoglobin be washed from surgical materials in a blender and measured in a colorimeter[38]. Clearly, this is impractical in obstetric practice. Routine hematocrit determination, on the other hand, is possible if the equipment is available. However, routine postpartum hematocrits are unnecessary in clinically stable patients with an estimated blood loss of less than 500 ml. After delivery associated with an average blood loss, the hematocrit drops moderately for 3–4 days, followed by an increase. The peak drop may be appreciated on day 2 or day 3 postpartum[39]. By days 5–7, the postpartum hematocrit will be similar to the prelabor hematocrit[15]. Should the postpartum hematocrit be lower than the prelabor hematocrit, the blood loss may have been larger than appreciated[40].

Plasma volume changes and measurement of tagged erythrocytes

Blood volume estimation using dye-dilution or radioisotope dilution techniques is more difficult and requires special equipment and serial measurements[41,42]. Measurement of erythrocytes appears to be more consistent than estimates of plasma volume secondary to physiological hemodilution causing a fluid overload of approximately 1080–1680 ml in pregnancy[14]. Significant cardiovascular changes occur immediately postpartum. The cardiac output remains elevated for 24 h, blood pressure declines initially and then stabilizes on postpartum day 2. Maternal physiological changes of hemodilution lead to reduced hemoglobin and hematocrit values, reflecting the importance of timing of the measurement[43]. In the majority of patients[44], no single timed hemoglobin or hematocrit determination in the first 24 h postpartum will detect the peak.

BRASSS-V DRAPE: BLOOD LOSS COLLECTION TOOL

A randomized, placebo-controlled trial to test the use of oral misoprostol was conducted to reduce the incidence of acute postpartum hemorrhage and hence maternal morbidity and mortality in women delivering in rural villages (away from major hospitals) within Belgaum District, Karnataka, India. The intervention was delivered by local health-care workers. A critical component of this trial was the development of a specially designed low-cost 'calibrated plastic blood collection drape' that would objectively measure the amount of blood collected in the immediate postpartum period. The BRASSS-V drape was developed by the NICHD-funded Global Network UMKC/JNMC/UIC collaborative team to specifically estimate postpartum blood loss[45,46]. (The name 'BRASSS-V' was coined by adding the first letter of the names of the seven collaborators who developed the drape.) The drape has a calibrated and funneled collecting pouch, incorporated within a plastic sheet that is placed under the buttocks of the patient immediately after the delivery of the baby. The upper end of the sheet has a belt, which is loosely tied around the woman's abdomen to optimize blood collection, particularly for deliveries performed on the floor or on a flat surface at homes or in rural primitive health posts. This simple tool not only has the potential for a more accurate detection of postpartum blood loss, but we hypothesize that this approach will lead to earlier interventions, with an ultimate goal of decreasing maternal morbidity and mortality due to postpartum hemorrhage. Since most developing countries use some form of under-buttock sheet, either at home, in the health center or in hospitals, drape substitution is acceptable and relatively simple. The BRASSS-V calibrated drape used for objective estimation of blood loss is shown in Figures 4 and 5.

Results of three studies conducted at JNMC, Belgaum, Karnataka, India[4,7] strongly suggest that the BRASSS-V drape is an accurate and practical tool to measure blood loss occurring in the third stage of labor. While, among women with little blood loss, the ranges of blood loss were similar in both visual and drape assessment, the actual visual assessment amount was considerably less compared with the calibrated drape values (Table 2 and Figure 6). This observation further underscores the inaccuracy of the visual estimation method as described in the literature, whereas differences between the drape and spectrophotometry values were found to be 37.15 ml, with the drape having the higher value (an average error of 16.1%). The drape measured blood loss equally and as

Figure 4 BRASSS-V blood collection drape with calibrated receptacle

Figure 5 Collection of blood using BRASSS-V blood collection drape with calibrated receptacle

Table 2 Distribution of blood loss

	Blood loss (ml)		
	Visual (n = 61)	*Drape* (n = 62)	*All cases* (n = 123)
Mean ± standard deviation	203.11 ± 147.49	302.82 ± 173.28	253.37 ± 168.86
Range	50–950	50–975	50–975

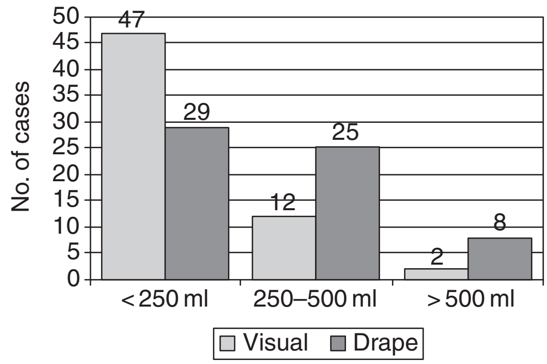

Figure 6 Number of cases detected for specific blood loss (p < 0.01). The calibrated drape more accurately determined true blood loss when ≥ 250 ml and more accurately estimated overall levels

Table 3 Comparison between drape-measured and spectrometrically analyzed blood loss

	Blood loss (ml)	
	Drape-measured	*Spectrometry*
Mean ± standard deviation	225 ± 96.10	187.84 ± 61.79
Range	100–350	93.19–285.98

efficiently as gold-standard spectrophotometry (Pearson's correlation coefficient of 0.928; p = 0.01, Table 3).

Use of the drape diagnosed postpartum hemorrhage four times as often as the visual estimate. A larger validation study is presently underway at the University of Missouri at Kansas City School of Medicine. In addition, the drape is being tested in a number of international settings including Tibet, Vietnam, Egypt, Ecuador, Brazil and Argentina. Based on the Indian experience, it appears to have great potential for training delivery attendants to determine postpartum blood loss in an accurate and timely manner. The drape, apart from being an objective tool for measurement of postpartum blood loss, also provided a hygienic delivery surface while permitting early management and referral. Residents and nurses in hospital settings and the nurse midwives who used the BRASSS-V drape during home delivery all found it to be a very useful tool to measure blood loss after delivery and for early diagnosis of postpartum hemorrhage; it also led to earlier transfer from rural areas to the higher facility. The women who delivered at home and their family members also appreciated the usefulness of the drape for easy disposal of body fluids after birth[45].

A similar approach has been used in another recently reported study[48]. A plastic collecting bag put under the pelvis of the mother just after delivery can serve as a quantitative and objective method of measuring blood loss. The study goal was to assess sensitivity, specificity, positive predictive value and negative predictive value, including correlation between the bag's volume and hemoglobin and hematocrit variation. The authors conclude that the collecting pelvis bag is a rapid and precise procedure with which to diagnose postpartum hemorrhage in the delivery room. It also enables a visual and quantitative non-subjective estimation of blood loss. Because of its simplicity and very low cost, the pelvis collecting bag may have applicability as a routine preventive measure.

Accurate measurement of blood loss at delivery as a means of early detection of postpartum hemorrhage is necessary for several reasons, not the least of which is the fact that oxytocic agents, while an important component for addressing the third stage of labor, do not address many factors related to postpartum

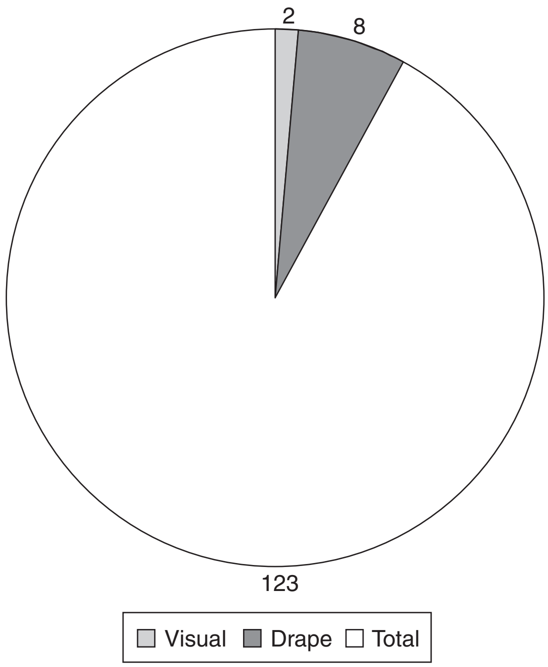

Figure 7 Number of cases of postpartum hemorrhage (PPH) detected for specific blood loss ($p < 0.01$). The calibrated drape diagnosed PPH at a rate four times that of the visual estimate method

hemorrhage in resource-poor areas. Trauma of the birth canal during delivery and retained placental fragments are important causes of postpartum hemorrhage and may occur more often than previously reported. Visual assessment of blood loss in the presence of a contracted uterus may diagnose traumatic postpartum hemorrhage late and therefore result in delayed referrals. In India and many other developing nations, at least half of all births take place in rural areas. Most of these deliveries are conducted by indigenous health-care providers such as dais (traditional birth attendants) or auxiliary nurse midwives having varying levels of training. Blood loss appears to be commonly underestimated, as visual assessment is the only means available to the birth attendant to make this diagnosis. The clinical symptoms of blood loss (low blood pressure, fast pulse, pallor and sweating, signs of hypovolemia and impending shock) are often the primary indicators for intervention. However, relying on the onset of such symptoms may lead to delayed intervention, resulting in increased rates of morbidity and mortality. As other quantitative methods employed have both practical and technical limitations, the employment of simple tools, such as the BRASSS-V under-buttock blood collection drape with a calibrated receptacle, can be effectively employed for objectively assessing the blood loss. It is likely to be of great utility to the midwife/birth attendant and thus help to ensure more timely and accurate patient management. Having identified excessive blood loss, corrective measures can be taken at the earliest time, thus improving outcomes associated with postpartum hemorrhage.

ACKNOWLEDGEMENTS

Our sincere thanks to Dr Shivaprasad S. Goudar, Professor of Physiology & Research, Coordinator Global Network for Women's and Children's Health Research Site 8, and Dr Kamal Patil, Associate Professor of Obstetrics & Gynecology, JNMC for invaluable assistance in the preparation of this manuscript. We also acknowledge the contribution of Dr Kuldeep Wagh and Dr B. V. Laxmi, residents in the Department of Obstetrics & Gynecology, JNMC for participating in the validation study and to Dr A. Patel for her contributions to the design of the BRASSS-V drape.

References

1. Starr A. *The Safe Motherhood Agenda: Priorities for the Next Decade*. New York: Inter-agency Group for Safe Motherhood, Family Care International, 1997
2. *Reduction of maternal mortality*. A joint WHO/UNFPA/UNICEF/World Bank Statement. 1999http://www.who.int/reproductive-health/publications/reduction_of_maternal_mortality/reduction_of_maternal_mortality_contents.htm
3. Abou Zahr C. Antepartum and postpartum hemorrhage. In Murray CJL, Lopez AD, eds. *Health Dimensions of Sex and Reproduction*. Boston: Harvard University Press, 1998
4. Berg CJ, Atrash HK, Koonin LM, Tucker M. Pregnancy-related mortality in United States, 1987–1990. *Obstet Gynecol* 1996;88:161–7
5. Hogberg U, Innala E, Sandstorm A. Maternal mortality in Sweden, 1980–1988. *Obstet Gynecol* 1994;84:240–4

6. Razum O, Jahn A, Blettner M, Reitmaier P. Trends in maternal mortality ratio among women of German and non-German nationality in west Germany, 1980–1996. *Int J Epidemiol* 1999;28:919–24
7. Dildy GA. *Postpartum Hemorrhage*. Washington, DC: American College of Obstetricians and Gynecologists, 1998
8. Maine D. *Safe Motherhood Programs: Options and Issues*. Columbia University: Center for Population & Family Health, 1993:42
9. Williams JW. The tolerance of freshly delivered women to excessive loss of blood. *Am J Obstet Gynecol* 1919;90:1
10. Duthie SJ, Ven D, Yung GL, Guang DZ, Chan SY, Ma HK. Discrepancy between laboratory determination and visual estimation of blood loss during normal delivery. *Eur J Obstet Gynecol Reprod Biol* 1990;38:119–24
11. Newton M, Mosey IM, Egli GE, Gifford WB, Hull CT. Blood loss during and immediately after delivery. *Obstet Gynecol* 1961;17:9–18
12. Newton M. Postpartum hemorrhage. *Am J Obstet Gynecol* 1966;94:711–16
13. Gahres EE, Albert SN, Dodek SM. Intrapartum blood loss measured with Cr51-tagged erythrocytes. *Obstet Gynecol* 1962;19:455–62
14. Nelson GH, Ashford CB, Williamson R. Method for calculating blood loss at vaginal delivery. *South Med J* 1981;74:550–2
15. Chesley LC. Plasma and red cell volumes during pregnancy. *Am J Obstet Gynecol* 1972; 112:440–50
16. Knuppel RA, Hatangadi SB. Acute hypertension related to hemorrhage in obstetric patients. *Obstet Gynecol Clin N Am* 1995;22: 111–29
17. Gabbe SG, Niebyl JR, Simpson JL, eds. *Obstetrics: Normal and Problem Pregnancies, 4th edn*. Churchill Livingstone, 2001
18. Cunningham FG, Gilstrap LC, Gant NF, *et al*., eds. *Williams Obstetrics*, 21st edn. McGraw-Hill, 2001
19. Pritchard JA, Baldwin RM, Dickey JC, *et al*. Blood volume changes in pregnancy and the puerperium. II. Red blood cell loss and change in apparent blood volume during and following vaginal delivery, cesarean section, and cesarean section plus total hysterectomy. *Am J Obstet Gynecol* 1962;84:1272–82
20. Clark SL, Yeh SY, Phelan JP, *et al*. Emergency hysterectomy for obstetric hemorrhage. *Obstet Gynecol* 1984;64:376–80
21. Waters EG. Surgical management of postpartum hemorrhage with particular reference to ligation of uterine arteries. *Am J Obstet Gynecol* 1952;64: 1143–8
22. Combs CA, Murphy EL, Laros RK Jr. Factors associated with hemorrhage in cesarean deliveries. *Obstet Gynecol* 1991;77:77–82
23. Calkins LA. Factors governing blood loss in the third stage of labor. *Am J Obstet Gynecol* 1929; 17:578
24. Hill JA, Fadel HE, Nelson MC, Nelson RM, Nelson GH. Blood loss at vaginal delivery. *South Med J* 1986;79:188–92
25. Qubil LD, Saski A. Episiotomy blood loss. *Am J Obstet Gynecol* 1947;54:51
26. Spoerel WE, Heagy FC. The use of blood volume determination for the evaluation of blood loss during operation. *Can J Surg* 1962;5:25–32
27. Arulkumaran S, Symonds IB, Fowlie A. Massive obstetric hemorrhage. In *Oxford Handbook of Obstetrics & Gynaecology*. Oxford: Oxford University Press, 2003:399
28. Brant HA. Precise estimation of postpartum haemorrhage: difficulties and importance. *Br Med J* 1967;1:398–400
29. Hester JD. Postpartum hemorrhage, and re-evaluation of uterine packing. *Obstet Gynecol* 1975;45:501–4
30. Gulmezoglu AM, Villar J, Ngoc NT, *et al*. WHO Multicentre randomized trial of misoprostol in the management of the third stage of labour. *Lancet* 2001;358:689–95
31. Chua S, Ho LM, Vanaja K, Nordstrom L, Roy AC, Arulkumaran S. Validation of a laboratory method of measuring postpartum blood loss. *Gynecol Obstet Invest* 1998;46:31–3
32. Dildy GA, Paine AR, George NC, Velasco C. Estimating blood loss: can teaching significantly improve visual estimation? *Obstet Gynecol* 2004; 104:601–6
33. Grant JM. Treating postpartum haemorrhage. *Br J Obstet Gynaecol* 1997;104:vii
34. Patton K, Funk DL, McErlean M, Bartfield JM. Accuracy of estimation of external blood loss by EMS personnel. *J Trauma* 2001;50:13–20
35. Meiser A, Casagranda O, Skipka G, Laubenthal H. Quantification of blood loss. How precise is visual estimation and what does its accuracy depend on? *Anaesthesist* 2001;50:13–20
36. Luegenbiehl DL, Debra L. Improving visual estimation of blood volume on peripads. *MCN Am J Matern Child Nurs* 1997;22:294–8
37. Buchman MI. Blood loss during gynecological operations. *Am J Obstet Gynecol* 1953;65:53–64
38. Gatch WD, Little WD. Amount of blood lost during some of the more common operations. *JAMA* 1924;83:1075–6

39. Maruta S. The observation of the maternal haemodynamics during labour and cesarean section. *Nippon Sanka Fujionka Gakkai Zasshi* 1982;34:776–84
40. Pritchard JA, Baldwin RM, Dickey JC, Wiggins KM. Blood volume changes in pregnancy and the puerperium. *Am J Obstet Gynecol* 1962;84:1271
41. Quinlivan WLG, Brock JA, Sullivan H. Blood volume changes and blood loss associated with labor. Correlation of changes in blood volume measured by ^{131}I-albumin and Evans blue dye, with measured blood loss. *Am J Obstet Gynecol* 1970;6:843–9
42. Ueland K. Maternal cardiovascular dynamics. VII. Intra-partum blood volume changes. *Am J Obstet Gynecol* 1976;126:671–7
43. Robson SC, Boys RJ, Hunter S, Dunlop W. Maternal hemodynamics after normal delivery and delivery complicated by postpartum hemorrhage. *Obstet Gynecol* 1989;74:234–9
44. Nelson GH. Consideration of blood loss at delivery as a percentage of estimated blood volume. *Am J Obstet Gynecol* 1980;138:1117
45. Kodkany BS, Derman RJ, Goudar SS, *et al*. Initiating a novel therapy in preventing postpartum hemorrhage in rural India: a joint collaboration between the United States and India. *Int J Fertil Women Med* 2004;49:91–6
46. Geller SE, Patel A, Naik VA, *et al*. Conducting international collaborative research in developing nations. *Int J Gynaecol Obstet* 2004;87:267–71
47. Patel A, Goudar SS, Geller SE, *et al*. Drape estimation versus visual assessment for estimating postpartum hemorrhage. *Int J Gynaecol Obstet* 2006;93:220–4
48. Tourne G, Collet F, Lasnier P, Seffert P. Usefulness of a collecting bag for the diagnosis of post-partum hemorrhage. *J Gynecol Obstet Biol Reprod (Paris)* 2004;33:229–34