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Severe Acute Maternal Morbidity and Postpartum Hemorrhage

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INTRODUCTION

For every woman who dies of postpartum hemorrhage (PPH), many more suffer short- and long-term consequences even when well managed. During the 1990s, the concept of severe adverse maternal morbidity (SAMM) emerged in response to the need for a more sensitive marker of quality of maternity care than maternal death[1,2]. This concept and the accompanying acronym have the advantage of drawing attention to surviving women's health and are applicable in both resource rich and poor countries. As such, SAMM has had increased interest worldwide over the past 5 years, especially in lower income settings such as Brazil[3], Indonesia[4] and several African countries[5,6]; at the same time, it is highlighted in a WHO report aiming to quantify the global problem[7].

The UK is one of the few countries in which every maternal death has been investigated by the Confidential Enquiry into Maternal Death (CEMD) for six decades. In most other developed countries, death from PPH has become too rare for adequate and contemporaneous surveillance of local services. For example, the annual number of maternal deaths from hemorrhage fell from 40 to three in the UK over the past 50 years[8], and only 14 deaths were attributed to hemorrhage in the 2003–2005 CEMD triennium. In the 2006–2008 period which recorded nine deaths, only five were attributable to PPH. Currently, the overall maternal mortality rate in the UK is around 11/100,000 maternities with 0.39 deaths/100,000 attributable to hemorrhage, the lowest since the CEMD began in 1952[9]. Obstetric hemorrhage currently represents the sixth leading cause of direct maternal deaths in the UK. Despite a rising cesarean section rate, the actual number of deaths from hemorrhage and genital tract trauma (including ruptured uterus) has declined slightly (although not statistically so) or is static. Lower death rates may be due to recommendations made in previous reports.

Within the UK, in 2003 Scotland established a national prospective audit of severe morbidity in parallel to the CEMD. The total SAMM rate varied with time, ranging from 4.5/1000 births in 2003 to 6.2/1000 in 2006, with the rate being 5.88/1000 for 2006–2008[10]. This fluctuation is largely due to changes in the rates of major obstetric hemorrhage (MOH, defined as blood loss of more than 2.5 liters), which initially peaked in 2006 (4.9/1000 live births) and has been declining steadily since to 4.3/1000 births. The Scottish authors characterize many cases of severe morbidity as 'great saves' rather than 'near-misses'. Although the audit's threshold for MOH is higher than most other studies, this survey provides a means to monitor trends and is more likely to reflect the burden of severe disease than the extreme 'tip of the iceberg' represented by death.

WHAT IS SEVERE ADVERSE MATERNAL MORBIDITY AS OPPOSED TO A NEAR-MISS?

The term near-miss was previously used to characterize a case where a woman had a near brush with death; in other words, she would have died were good fortune and medical care not on her side. This characterization was also used for women with severe organ dysfunction or organ failure who survived[11,12] whereby, with intensive medical intervention, a maternal death was avoided and a survival ensued[13]. The term SAMM was later introduced to refer to the *morbidity* a woman *actually suffers*, rather than focusing on the fact that she *nearly died* (which may still be more important from a risk management point of view). Recently, the WHO working group on Maternal Mortality and Morbidity recommended a return to the near-miss terminology, referring to the fact that the woman 'nearly died but survived'[7]. Our review for this chapter shows that the two terms, SAMM and near-miss, are currently being used interchangeably in the literature.

Three different definitions for SAMM have been proposed by various authors[7]:

- A severe life-threatening obstetric complication necessitating an urgent medical intervention to prevent the likely death of the mother[14]
- Any pregnant or recently delivered woman, in whom immediate survival is threatened and who survives by chance or due to the hospital care she received[15]
- A very ill woman who would have died had it not been that luck and good care was on her side[11].

Attempting to unify these differences, WHO defines a maternal near-miss as: *a woman who nearly died but survived a complication that occurred during childbirth or within 42 days of termination of pregnancy*[7]. This simplifies the concept and attaches a useful time-frame. However, it excludes complications in pregnancy that do not lead to delivery (such as septicemia, pulmonary embolus or cardiac arrest); moreover, it does not generate a universal system for case identification which would facilitate cross-country comparisons.

The three definitions cited above clearly are similar and illustrate the concept of a continuum of worsening morbidity in the pregnant population, culminating in maternal death. The disease pyramid illustrates this concept (Figure 1) by which the base represents the general pregnant population, and the 'tip of the iceberg' is maternal death with a spectrum of morbidity between[11,12,16]. A clinical insult may be followed by a systemic response and subsequent organ dysfunction, which leads to organ failure and eventual death[2,11]. The figure shows the severity continuum of morbidity as well as factors that move women up and down the pyramid. For example, a faulty ambulance or wrongly cross-matched blood might lead to an anemic woman dying of hemorrhage unnecessarily. If the same patient had been provided iron supplementation antenatally, was well managed and treated promptly, there may be no residual morbidity. On the other hand, pathologies such as placenta previa and uterine rupture would drive women up towards the tip of the pyramid. Interventions such as uterotonics might stop bleeding at an early stage, whereas interventions such as obstetric hysterectomy may be used near the top.

Despite the different definitions of MOH, studies have used three main approaches for case identification (outlined in Table 1). Each approach has advantages and disadvantages:

(1) Specific disease entities (e.g. eclampsia, PPH) allow relatively easy retrospective data collection from case notes or registers. Quality of care and complication rates can be determined for the specific disease and set against standards of care. However, it is difficult to use this for ongoing audits. There may be poor documentation in the worst cases and morbidity criteria may have too low a threshold to be considered a near-miss.

(2) Intervention-based criteria are easily measured and agreed, do not rely on medical diagnosis and coding, but are affected by local units' different facilities, policies, customs and practices, as well as thresholds for transfer (e.g. use and availability of high dependency/intensive-care beds or interventional radiology).

(3) The main advantage of an organ system dysfunction approach is that it allows mortality and morbidity surveys to run in parallel, thus enabling calculations of morbidity : mortality ratios for various disease processes. The Scottish Morbidity Survey is an example, and its findings have been reported in parallel to the CEMD. Trends in diseases can be established. This approach also focuses on diseases which should not cause death if appropriately managed (e.g. PPH). However, cases can only reliably be identified prospectively and depend on investigative test availability.

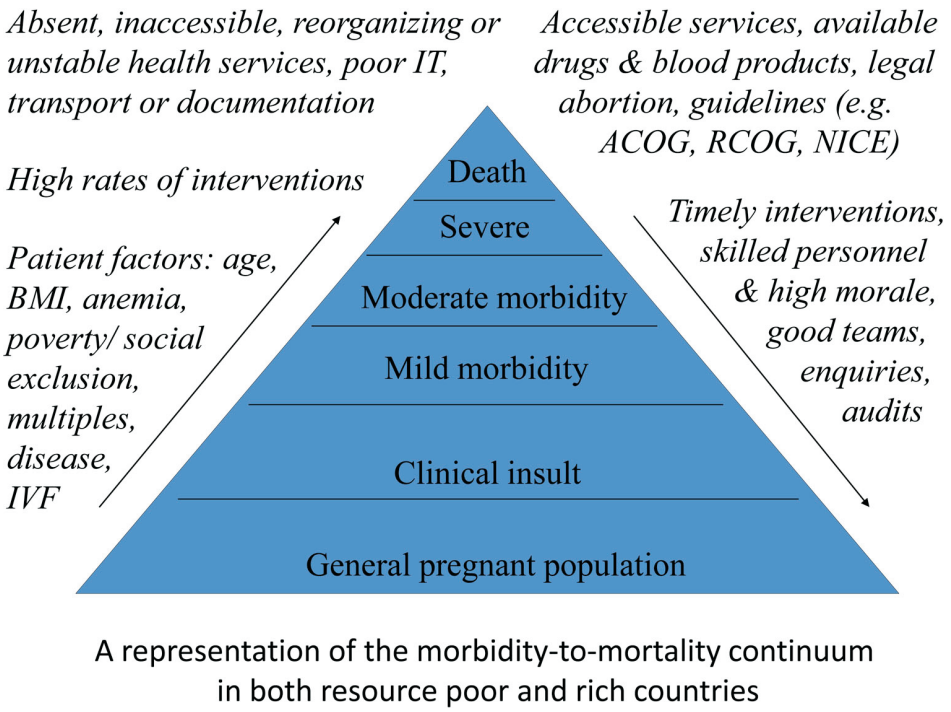

Figure 1 A representation of the morbidity–mortality continuum. ACOG, American College of Obstetricians and Gynecologists; BMI, body mass index; IVF, *in vitro* fertilization; NICE, National Institute for Health and Clinical Excellence; RCOG, Royal College of Obstetricians and Gynaecologists[2,24]

Table 1 Different methodological approaches to the identification of cases of SAMM

Criteria for identification of near-miss	*Case definition*	*Study*
Related to specific disease	Starting point is a specific disease and morbidity is defined for each. For example, pre-eclampsia might be the disease with severe morbidity identified by its complications (i.e. renal failure, pulmonary edema, eclampsia, etc.) Can be prospective or retrospective	Waterstone *et al.*, 2001[17] Scottish survey, 2003 ongoing[18,19] LEMMoN, 2008[20] UKOSS, 2005 ongoing[21]
Intervention based	Marker for near-miss is an identifiable event or procedure (e.g. admission to ITU, large blood transfusion or emergency hysterectomy) to save the mother's life Usually retrospective studies	Bewley & Creighton, 1997[13] Killpatrick & Matthay, 2002[22] LEMMoN, 2008[20] UKOSS, 2003 ongoing[21] Obstetric hysterectomy studies[23,24]
Based on organ-system dysfunction	System is based on the concept of the pyramid of disease from good health to death. A clinical insult is followed by a systemic response syndrome, then organ dysfunction, organ failure and death. Near-miss cases are the women with organ dysfunction or failure who survive. Markers for dysfunction for each organ system are specified and criteria for defining a near-miss are given (e.g. cardiovascular shock from hemorrhage) Usually prospective studies	Mantel *et al.*, 1998[11] Pattinson *et al.*, 2003[12] Waterstone *et al.*, 2001[17] Scottish survey, 2003 ongoing[19]
Rare event	A rare event allows large, even national, population estimates. UKOSS, for example, has studied risk factors (e.g. BMI >50), specific diseases (e.g. swine flu, amniotic fluid embolism), complications of obstetric morbidity (e.g. acute fatty liver) or treatment (e.g. extraordinary interventions for massive hemorrhage – hysterectomy, factor VII, intrauterine balloon, brace suture). The disadvantage is the inability to examine common severe morbidities	BEST study, 1995 (eclampsia)[25] Waterstone *et al.*, 2001 (uterine rupture as rare event)[17] UKOSS, 2005 ongoing[21] Obstetric hysterectomy studies[23,24]

BMI, body mass index; UKOSS, UK Obstetric Surveillance System

Rates may be biased if ascertainment problems are present. A diligent unit may report more cases via the organ-system approach, and careful recording could translate into a disproportionately higher rate of SAMM[12]. On the other hand, a poor-quality unit that does not recognize and treat hemorrhage promptly may have more severe sequelae as the natural history progresses. Thus the true incidence of SAMM may be underestimated.

HOW COMMON IS ALL-CAUSE SEVERE ADVERSE MATERNAL MORBIDITY?

Because quantification is problematic, with no international definition and haphazard recording, wide variations are present in incidence estimates (summarized in Table 2).

High income countries

A recent review including studies from Europe, Canada and USA suggested the incidence of SAMM to approximate to 0.5–1% of all deliveries in high income countries (3.3–12/1000)[35]. The rates/1000 births ranged from 3.3 in France, through 3.8 in Scotland, 4.6 in Canada, 7.2 in The Netherlands, 10.9 in South Africa to 12.0 in England.

Low income countries

A 2009 review grouped low income countries into those of Africa, Latin America and Asia[36], and included landmark audits of severe morbidity in South Africa[11,37]. Thirty-seven studies from 24 countries were examined, ranging from small audits of near-miss morbidity[5,11,37,38] in general and teaching hospitals, to large population based surveys[37,39,40] or surveys of need for life-saving surgery (Tanzania, Guinea, Indonesia)[36]. Comparisons are difficult, however, because all women do not give birth in health facilities and standards vary widely (e.g. availability of ITU beds). African studies exemplified these wide variations. The rate of severe morbidity across several West African states was calculated as 59.8/1000 deliveries (almost 6%)[39], whilst contemporaneous studies in South Africa yielded rates of 1%[11,37], falling to 0.5% in 2004[41], a rate which is similar to that in high income countries.

In low income settings, major surgical interventions such as cesarean section or hysterectomy are likely to be accurately recorded and may be useful markers of severe morbidity. One way to quantify the need for life-saving surgery is by cesarean section for absolute maternal indications (severe antepartum hemorrhage due to placenta previa, major cephalopelvic disproportion, transverse lie or brow presentation). In settings without ITU facilities, a combination of life-saving surgery and organ dysfunction approaches are likely to work best, as evidenced by studies in Brazil[3] and Indonesia[36]. Using transfused blood has limitations as thresholds for transfusion vary, blood may not be available in low income settings or women may refuse transfusion (e.g. Jehovah's Witnesses).

RELATIONSHIP OF SEVERE ADVERSE MATERNAL MORBIDITY TO MORTALITY

Two methods generally are used to address the relationship between severe morbidity and mortality.

Table 2 SAMM studies showing incidence and proportion related to hemorrhage

Study, country and year of publication	*Incidence of SAMM per 1000 deliveries (all causes)*	*Incidence of hemorrhage/ 1000 deliveries* (% of total SAMM)	*Incidence of hypertension* (% of total)	*Incidence of severe sepsis* (% of total)	*Additional comments*
Stones *et al.*[1] UK 1991	8.8	3.23 (36.8%)	2.77 (31.5%)	Not available	SAMM defined as 'potentially life-threatening episodes'. Incidence for total (all) morbidity 267/1000. Incidence of all sepsis 30.5/1000 (severe sepsis not separated). Hemorrhage includes antepartum and PPH if over 2000 ml. One case of secondary PPH due to sepsis
Bouvier-Colle *et al.*[26] France 1996	3.1	0.62 (20%)	0.81 (26.2%)	0.14 (4.36%)	Third highest cause of morbidity is embolic events at 0.38/1000. Hemorrhage includes uterine rupture. Hypertensive disease includes cerebral hemorrhage
Bewley & Creighton[13] UK 1997	4.97	2.3 (46.7%)	1.98 (40%)	0.49 (10%)	SAMM = ITU admission. Total 30 cases of SAMM. 14 cases classed as hemorrhage (blood loss >2000 ml but a further 2 cases DIC/HELLP so proportion due to hemorrhage could be >50%)
Baskett & Sternadel[27] USA 1998	0.72	0.16 (22%)	0.18 (25%)	0.1 (14.5%)	SAMM = ITU admission
Mantel *et al.*[11] South Africa 1998	10.9	6.1 (55.8%)	2.82 (25.8%)	2.16 (19.7%)	Sepsis incorporates septic abortion, chorioamnionitis and puerperal sepsis. Hemorrhage incorporates antepartum and PPH and emergency hysterectomy; PPH alone is 1.8/1000
Prual *et al.*[15] West Africa 2000	50.8	29.6 (49.5%)	6.15 (10.3%)	0.9 (1.5%)	Obstructed labor is significant cause for severe morbidity (20.5/1000 of which 1.2/1000 uterine rupture)
Waterstone *et al.*[17] UK 2001	12.0	6.7 (55.7%)	4.6 (38%)	0.35 (2.89%)	Clinically based definitions, not including management processes. Estimated blood loss >1500 ml picked up 55% of cases of SAMM due to hemorrhage
Brace *et al.*[18] Scotland 2004	3.8	1.9 (50%)	1.15 (30%)	0.09 (3%)	Septic shock is the only category for sepsis. Number of SAMM due to hypertensive disease derived by adding the number of cases with eclampsia, renal dysfunction and pulmonary edema. Only one-third of patients with SAMM were admitted to ITU
Zhang[28] MOMS-B Europe 2005	9.48	4.6 (48.8%)	4.33 (45.7%)	0.8 (8.2%)	Multinational study, rates differing widely between countries. Range of SAMM 6–14.7%. Highest rates in Finland, Belgium, UK and lowest rates in Italy, Ireland, France
Minkauskiene *et al.*[29] Lithuania 2006	7.91	2.83 (35.8%)	4.47 (56.6%)	0.3 (3.8%)	13,399 deliveries, 106 cases SAMM, 1 death 60 cases hypertension (57 severe PET, 3 eclampsia), 38 severe hemorrhage, 4 cases severe sepsis, 3 cases uterine rupture

Zwart *et al.*[20] LeMMoN Netherlands 2008	7.1	4.5 (63% of total, 47% of ITU admissions)	0.62 (eclampsia 8.7% of total)	0.23 (3.3% of total, 10% were due to group A streptococcus)	5 categories for SAMM (ITU admission, uterine rupture, needing cesarean/hysterectomy or laparotomy, eclampsia/HELLP, major hemorrhage needing transfusion or hysterectomy and group of others e.g. sepsis, pre-eclampsia). 27% of MOH admitted to ITU. MOH counted as separate group but also a surgery group (some for rupture or hysterectomy, i.e. implies hemorrhage, so rate of MOH may be underestimate)
UKOSS[19,30] UK 2005–2011		0.41 peripartum hysterectomy 0.26 2nd line treatment	0.27 (in 2005)	Not surveyed	National surveillance of rare disorders in pregnancy – system reporting from all consultant-led maternity units in the UK. Different morbidities studied at different times and surveillance is not continuous for all causes. Second-line treatments for MOH are compression sutures, pelvic vessel ligation, embolization or factor VII
Ronsmans *et al.*[4] Indonesia 2009	141.6	125 (30% of life-saving surgery for placenta previa; 34% of total)	19.3 eclampsia (11.2%)	2.32 (1.35%)	Study in 2 rural and 2 urban areas in West Java; higher incidence of morbidity in urban than rural areas but mortality higher in rural areas. Distinction made between near-miss and life-saving surgery (e.g. labor dystocia is a common cause for life-saving surgery but not for near-miss). Organ dysfunction/management-based criteria (ITU, surgery)/clinical diagnosis. Mortality 42.1/1000 live births
Souza *et al.*[31] Brazil 2010	21.1	18.4%	0.6%	1%	Near-miss from health records in 5 regions of Brazil over a 5-year period. Questionnaire design, self-reported morbidity. Categories are eclampsia, hysterectomy, transfusion and ITU admission. Validated questionnaire sent to women identified through population database; women more likely to recall procedures than signs and symptoms. Mortality ratio 0.75/1000 live births. Only proportions given without numbers as weighting used
Lawton *et al.*[32] New Zealand 2010	4	12 (41.4%)	8 (27.6%)	5 septicemia (17.2%)	SAMM = ITU admission. Study during 2005–07 during pregnancy or within 42 days of delivery. Total 29 cases in tertiary center using organ-system dysfunction. 25 postpartum cases, 9 hysterectomies. Hypertension includes high blood pressure and HELLP cases but there are also some CVAs counted separately. Same criteria as Bewley & Creighton[13], cases could have more than one morbidity
Almerie *et al.*[33] Syria 2010	32.9	11 (34.4%)	17 (52%)	0.9 (2.8%)	Retrospective review of near-miss and maternal mortality in a tertiary hospital in Damascus 2006–2007. 28,025 deliveries, 15 deaths, 901 near-miss cases. MMR = 54.8/100,000 live births, mortality index 1.7%. Most cases referred in critical conditions from other facilities (traditional birth attendants, homes, private practices, primary and secondary care units). 26% of near-miss cases admitted to ITU. Hemorrhage accounted for 60% of mortality cases. Rates are given per 1000 live births rather than deliveries. Sepsis and dystocia are uncommon causes of near-miss but high mortality indices (7.4% and 2.9%, respectively)
Lennox[10] Scotland 2011	5.88	4.51 (76.8%)	0.28 (4.7%)	0.11 (1.85%)	174,430 births in Scotland. Major PPH >2500 ml Mortality: morbidity ratio 1:79. 46.9% of all cases of MOH due to atony. Hypertensive morbidity is eclampsia only. Sepsis = septic shock. Proportions may be slightly different if encompass ICU admission, pulmonary edema, renal or liver dysfunction or CVA
Mutihir & Utoo[34] Nigeria 2011	0.27	9.6 (35.4%)	6.8 (24.8%)	4.5 (16.7%)	3 year prospective observational study at a university hospital. 9056 deliveries, 246 SAMM (2.72%). Junior staff supervized almost half of deliveries (43.5%) and this correlated with the degree of morbidity

CVA, cerebrovascular accident; DIC, disseminated intravascular coagulation; HELLP, hemolysis, elevated liver enzymes, low platelets; ICU, intensive care unit; ITU, intensive therapy unit; MOH, massive obstetric hemorrhage (1500 ml in some studies, 2500 ml in others); PET, pre-eclampsia; PPH, postpartum hemorrhage; SAMM, severe adverse maternal morbidity

These are the *mortality-to-morbidity ratio* and the *mortality index*. The mortality-to-morbidity ratio simply describes the number of severe morbidity cases for each maternal death[2,17]. The mortality index, on the other hand, is defined as the number of maternal deaths divided by the sum of women with SAMM and maternal deaths, and is expressed as a percentage[12,37]. Both can be expressed as totals (all-cause) or by condition. Both reflect the fatality of a condition and identify those conditions that are more or less amenable to intervention. Recently WHO have introduced a new set of definitions (see text box below).

In general, the risk of mortality depends on (1) the prior health of the mother, (2) the severity of the particular condition, (3) access to skilled help, and (4) the availability and quality of medical intervention. PPH is the morbidity *par excellence* for assessing these parameters. It is common and has a high morbidity-to-mortality ratio (or low mortality index)[2,12,17,37]. In developed countries, at least, this is because the condition is amenable to treatment. More women's lives can be, and indeed are being, saved daily by the provision of adequate maternity services worldwide. As hemorrhage is largely treatable (and often avoidable), and *because all parturients are at risk*, it is tragic that so many women still die unnecessarily worldwide. The United Nations discusses women's and children's health in terms of fundamental human rights[43]. Progress towards Millennium Development Goal 5 (MDG 5, a 75% reduction in maternal mortality 1990–2015) has been disappointing[44] as only 23/181 (13%) countries analysed are on track to achieve the target[45].

What are the main causes of SAMM?

Most cases of SAMM fall into three major categories of causation:

- Hemorrhage
- Hypertensive diseases of pregnancy (including eclampsia and HELLP syndrome)
- Sepsis.

The incidence of these conditions in European countries appears similar despite the use of different definitions. Regardless of geographical factors, hemorrhage is the largest contributor, accounting for between 20%[26] and 50%[11,18,39] of cases. Hypertensive disease and its consequences account for 10%[39] to 45%[28], whereas morbidity secondary to sepsis is much lower, at 1.5%[39] to 20%[11]. Rarer causes of SAMM include thromboembolic disease and psychiatric illness[46,47].

NEW WHO TERMINOLOGY

WHO has recently published a document aimed at providing a universal framework for defining and counting severe morbidity. The near-miss definition is the same as was used in 2009[7]. New terms which are outlined below have been introduced, with the aim of unifying the near-miss and severe morbidity concepts, whilst recognizing the morbidity ortality continuum as described in Figure 1.

Women with life-threatening conditions (WLTC) = maternal near-misses (MNM) + maternal deaths (MD)

Severe maternal outcome ratio (SMOR) = WLTC (MNM + MD) per 1000 live births; this gives an estimate of the amount of care and facilities that may be needed in an area or facility

MNM ratio (MNMR) = number of near-miss cases per 1000 live births; can also be used to estimate the amount of care or resources needed

Maternal near-miss mortality ratio (MNM : MD) is the ratio of near misses to deaths as MNMR previously described. Higher ratios would indicated better care as more lives are being saved

Whilst the concepts of SMOR and MNMR are useful from a resource planning perspective, comparisons between high and low resource settings remain difficult to make. For example, for PPH the operational definition for severe morbidity is blood loss more than 1000 ml and standard of care implies that all women receive 10 IU Syntocinon for third stage. In a low-resource setting, a woman with a borderline starting hemoglobin in a facility lacking drugs to manage the third stage and no access to transfusion will create a case of severe morbidity at 1 liter blood loss. Conversely, in a developed country the standard of care would be met simply by the routine use of Syntocinon; a woman with a normal hemoglobin can lose 1000 ml without any significant morbidity. Comparisons based on volume loss alone may encourage complacency in such settings where the minimum intervention set by WHO is already routine and the severe morbidity occurs at bigger volumes of blood loss, increased interventions, ITU care, etc.

The same working party encourages the development of ongoing audit of severe morbidity cases in all health facilities, at local and district level. The aim is mainly for resource planning but also to enable comparisons regarding quality of care. The appendices and checklists provide useful practical tools for implementing an international audit strategy for severe maternal morbidity. They estimate the global prevalence to be around 7.5 per 1000 deliveries, but as shown in Table 2, the worldwide prevalence is more widely spread. Ongoing audit using this universal tool at local and national level would provide valuable information about quality of care and resource planning in different settings, but does not make comparisons across resource brackets (high and low) any easier[42].

WHAT IS THE INCIDENCE OF SEVERE ADVERSE MATERNAL MORBIDITY ATTRIBUTABLE TO HEMORRHAGE?

Hemorrhage illustrates the difficulties faced with defining near-miss or severe morbidity. All women experience some blood loss at delivery. The amount is difficult to measure, and often mixed with amniotic fluid. Hemorrhage is a clinical insult that strikes the general pregnant population, both low and high risk. Whether due to atony, retained placenta or genital tract lacerations it has the potential to cause morbidity ranging from mild to severe or even death (Figure 1). In addition, specific bleeding causes rapidly endanger women (e.g. ruptured ectopic, ruptured or inverted uterus, massive abruption or morbid placental adherence).

Table 2 summarizes some of the landmark studies that have attempted to quantify this problem in developed countries over the past 15 years. Wide variations are present in study settings, definitions and main causes. Some studies use admission to ICU[22,48], others define the actual conditions responsible for the morbidity[11,12], and still others list both[13]. The wide variation in case definition might explain the extreme range of incidence of SAMM (4% in UK to 53% in Hong Kong for studies using retrospective ITU admission to define SAMM; 1–6% incidence in prospective multicenter studies). Regardless of such differences, most studies concluded that up to half of the cases of SAMM were related to hemorrhage, and this continues to be the case in recent investigations (Table 2).

World Health Organization has set some maternal near-miss criteria[7] which aim to incorporate life-threatening clinical signs (e.g. cyanosis, shock, increased respiratory rate) and investigational results (e.g. oxygen saturation, pH, lactate) as well as life-saving interventions (e.g. hysterectomy, transfusion) into an algorithm that ensures severe cases are not missed. Worldwide adoption of this definition would identify all the cases of SAMM regardless of inciting condition but would not facilitate international comparisons between disease processes. This is because different pathologies can lead to the same clinical sign (e.g. raised respiratory rate in shock from hemorrhage as well as pulmonary embolus). A pragmatic proforma for case identification relating to SAMM secondary to hemorrhage would include all aspects shown in Table 3[42].

RISK FACTORS FOR SEVERE ADVERSE MATERNAL MORBIDITY DUE TO HEMORRHAGE

Although it is challenging to define the size of the problem (i.e. the incidence of SAMM as a result of hemorrhage), Table 4 summarizes risk factors identified over the past 10 years that increase the risk of severe hemorrhage.

Some risk factors, such as previous PPH or manual removal of placenta, are intuitive and universal. Induction of labor appears to increase the risk of PPH regardless of the indication[17]. This may relate to an increased duration of labor or risk of sepsis. Anemia is likely to be more prevalent in low income countries as well as in recent immigrants and 'socially excluded' women in high income countries as a reflection of

Table 3 A pragmatic proforma for case identification relating to SAMM secondary to hemorrhage would include all these aspects

Category	*Parameters*	*Advantage*	*Disadvantage if used alone*
Actual blood loss	EBL >1500–2000 ml (or more)	Measured and measurable	Accurate quantification notoriously difficult
Clinical symptoms	Dizziness, faintness Agitation, thirst, collapse Cardiac arrest	Easy to measure Cheap Applicable in low resource settings	Tolerance depends on mother's size, pre-existing total blood volume and pre-delivery hemoglobin Antenatal anemia will cause morbidity out of proportion to actual blood loss
Clinical signs	Pulse >100 or Systolic BP <80 mmHg Respiratory rate Peripartum fall in hemoglobin		May be non-specific to hemorrhage; thus aids recognition but difficult to audit management if used alone
Blood product replacement	Packed red cells >4 or >5 units Use of FFP/clotting factors	Measurable	Product availability Changing guidelines re: ratios of transfusing blood and FFP Jehovah's Witnesses and others who refuse blood
Specific life-threatening conditions	Abruption Uterine rupture Morbid placental adherence Placenta previa Infection	Diagnosis is fixed once made Comparisons of rates can be made	Varying degrees of severity Can have several causes Management and thus degree of morbidity dependent on local resources
Interventions which imply severe hemorrhage	Balloon tamponade Compression sutures Hysterectomy Interventional radiology Use of factor VII	Measurable Easy to identify cases both retrospectively and prospectively	Availability dependent on setting and expertise of personnel Timeliness of intervention decreases severity of morbidity so use itself does not demonstrate standard of care
ITU/HDU admission	Ventilatory support Requirement for inotropes	Auditable Easy case identification	Availability depends on clinical setting

BP, blood pressure; EBL, estimated blood loss; FFP, fresh frozen plasma; HDU, high dependency unit; ITU, intensive therapy unit

Table 4 Risk factors for major obstetric hemorrhage

Risk factor	*Odds ratios for SAMM (95% CI)*	*Study/Country/Year*
Age >35 years	1.41 (1.03–1.95)	Waterstone *et al.*/UK/2001[17]
	1.2 (1.1–1.3)/ (1.4 if >40)	Zwart *et al.*/Netherlands/2008[20]
	1.02 (0.96–1.09)	Ford *et al.*/Australia/2007[55]
	1.14 (1.03–1.21)	Al-Zirqi *et al.*/Norway/2008[56]
Hypertension at booking	1.18 (1.06–1.31)	Waterstone *et al.*/UK/2001[17]
	1.33 (1.07–1.66)	Ford *et al.*/Australia/2007[55]
Ethnic minority	1.82 (1.09–3.03)	Waterstone *et al.*/UK/2001[17]
	1.3 (1.2–1.5) non-Western immigrants	Zwart *et al.*/Netherlands/2008[20]
	1.16 (1.1–1.22)	Ford *et al.*/Australia/2007[55]
	1.77 (1.48–2.12)	Al-Zirqi *et al.*/Norway/2008 (SE Asian ethnicity)[56]
Social exclusion	2.91 (1.76–4.82)	Waterstone *et al.*/UK/2001[17]
	2.18 (1.15–4.10)	Souza *et al.*/Brazil/2007[3]
BMI >30	1.5 (1.3–1.7)	Zwart *et al.*/Netherlands/2008[20]
Previous PPH	2.74 (1.69–4.44)	Waterstone *et al.*/UK/2001[17]
Multiple pregnancy	2.29 (1.2–4.37)	Waterstone *et al.*/UK/2001[17]
	4.9 (4.3–5.7)	Zwart *et al.*/Netherlands/2008[20]
	2.34 (2.02–2.7)	Al-Zirqi *et al.*/Norway/2008[56]
Anemia	5.98 (2.28–15.65)	Waterstone *et al.*/UK/2001[17]
	2.2 (1.63–3.15)	Al-Zirqi *et al.*/Norway/2008[56]
Oxytocin augmentation	1.61 (1.2–2.15)	Waterstone *et al.*/UK/2001[17]
IOL	2.45 (1.68–3.57)	Waterstone *et al.*/UK/2001[17]
	3.1 (2.8–3.4)	Zwart *et al.*/Netherlands/2008[20]
	1.5–2.42 (spontaneous vs. instrumental)	Ford *et al.*/Australia/2007[55]
	1.6 (1.46–1.75)	Al-Zirqi *et al.*/Norway/2008[56]
Manual removal of placenta	13.12 (7.72–22.30)	Waterstone *et al.*/UK/2001[17]
Emergency CS	3.09 (2.29–4.17)	Waterstone *et al.*/UK/2001[17]
	5.2 (4.8–5.6) all CSs	Zwart *et al.*/Netherlands/2008[20]
	0.81 (0.7–0.92) CS in spontaneous labor	Ford *et al.*/Australia/2007[55]
	3.61 (3.28–3.95)	Al-Zirqi *et al.*/Norway/2008[56]
Instrumental delivery	1.6 (1.4–1.71)	Zwart *et al.*/Netherlands/2008[20]
	1.87 (1.4–2.42)	Al-Zirqi *et al.*/Norway/2008[56]
	1.25 (1.1–1.42)	Ford *et al.*/Australia/2007[55]
Birth weight >4.5kg	1.93 (1.71–2.17)	Al-Zirqi *et al.*/Norway/2008[56]
	2.55 (2.15–3.03)	Ford *et al.*/Australia/2007[55]

BMI, body mass index; CS, cesarean section; IOL, induction of labor

poorer nutrition. Waterstone *et al.*[47] defined social exclusion as a composite measure of a woman's social deprivation beyond the traditional use of her marital or partner's employment status or postcode deprivation score. The definition included concealed pregnancy, age less than 16 years, poor housing, 'on income support' (state welfare benefit) written in the notes, previous minor or child in local authority or state care (currently or in the past), in trouble with the law (currently or previously), living alone, unbooked, unwanted pregnancy, currently or previously in foster care, care order being considered on potential child, social worker involved or drug or alcohol dependency. Other studies in countries such as the USA[49], Brazil[3] and Uganda[50] have found a similar trend. Kaye *et al.*[50] defined women of 'low status' by a composite of poor education, poverty, low antenatal care attendance, low contraceptive-ever use and little power to make decisions regarding access to health care. Souza *et al.*[31] referred mainly to the woman's educational achievement, with women educated to high school level having a lower risk of severe morbidity.

IS THE PREVALENCE OF SEVERE ADVERSE MATERNAL MORBIDITY SECONDARY TO HEMORRHAGE RISING?

Health services need to monitor trends of various diseases as well as the actual morbidity suffered or deaths caused. It is plausible that disease burden can be rising or falling at the same time as outcomes are improving which would have implications for service provision. There are only a few register-based studies that track rates of SAMM; these are located in Canada[51], Finland[52] and USA[53].

In 2009 an international group explored trends in PPH in several high-resource countries (Australia, Belgium, Canada, France, UK and USA)[54]. Looking at risk factors for SAMM secondary to hemorrhage (Table 4), it is not surprising that rates of severe PPH are increasing as childbearing women are older and more obese, with more multiple pregnancies and cesareans in high income countries. Maternal mortality rates, however, were largely static in these same settings. However, markers of severe hemorrhage (uterine rupture, hysterectomy) were increased[35]. Knight *et al.*[54] compared data in several high income countries (Australia, Belgium, Canada, France, UK and USA) from the early 1990s with those of early 21st century and found that rates of hysterectomy for atonic PPH increased from 24/100,000 deliveries in 1991 to 41.7/100,000 deliveries in 2004.

Canada

The rate of SAMM appears similar between the early and late 1990s (4.4/1000 births in 1991–1993 vs. 4.25/1000 births 1998–2000)[35]. However, Sheehan's syndrome increased 4-fold in Canada over the same 10 years, suggesting that the severity of PPH had increased. Also, the rate of peripartum hysterectomy increased by 73% from 24/100,000 births in 1991 to 41.7/100,000 births in 2004[54]. Another retrospective Canadian cohort study[57] looked at all hospital deliveries between 1991 and 2004, identifying a 34% increase in atonic PPH from 29.4/1000 deliveries in 1991 to 39.5/1000 in 2004. The authors could not find a satisfactory explanation for the increased rate.

Finland

The overall rate of severe morbidity increased from 5.9/1000 births in 1997 to 7.6/1000 births in 1999–2002[35].

Scotland

An ongoing prospective audit since 2003 uses the organ-system definitions generated by Mantel *et al.*[11]. The Scottish survey uses a cut-off of 2500 ml or more for defining MOH, which is higher than most other studies, probably for pragmatic reasons and ease of data collection. The mortality : morbidity ratio has improved from 1 : 56 in 2003 to 1 : 79 in 2008; this change reflects an increase in the rate of MOH but no rise in deaths. Over half of the cases of MOH were associated with cesarean section (55.2% for all cesarean sections, 44.3% emergency cesarean sections), of which 20% were deemed of an emergency nature and performed in the second stage. In the same national audits, the rate of peripartum hysterectomy showed a steady decline between 2003 and 2008, as other conservative surgical techniques such as brace sutures and balloon tamponade were increasingly used[10].

Australia

A population-based survey of 752,374 women delivering between 1994 and 2002 in New South Wales, the most populous region in Australia, noted an increased rate of total PPH (defined as 500 ml at vaginal delivery and 750 ml at cesarean section) from 4.7 to 6.0/1000 births. This rate appeared to increase more after vaginal delivery. The authors postulated this may be due to use of Syntocinon rather than Syntometrine for third stage management. It is, however, concerning that PPH increased despite a slight reduction in the delivery rate[55].

USA

Overall morbidity increased from 4.5/1000 deliveries during 1991–1994 to 5.9/1000 in 1999–2003[35]. Another study[58] showed an increase in severe obstetric complications from 0.64% in 1998–1999 to 0.81% in 2004–2005. Amongst causes of severe morbidity there was a 24% increase in cases of shock and 92% increase in transfusion rates. These increases are partly explained by a rising cesarean delivery rate, although adjustment for mode of delivery rendered differences statistically insignificant.

Ireland

A population study based on 649,000 deliveries has found a three-fold increase in PPH rate within a decade in the Republic of Ireland from 1.5% in 1999 to 4.1% in 2009[59]. This trend was observed for both vaginal and cesarean deliveries and was not wholly explicable by demographic changes (i.e. advancing maternal age or multiple birth), or by increased cesarean section rates[59]. The increase was largely related to increased atonic PPH rates, unlike the Australian data[55] where the highest rate was among cesarean section deliveries.

SPECIFIC CAUSES OF SEVERE ADVERSE MATERNAL MORBIDITY RELATED TO HEMORRHAGE

Uterine rupture

Although this diagnosis can be one surrogate measure for SAMM due to hemorrhage, studies report it differently. For example, it has been combined with data for obstructed labor in South Africa[39], and analysed as a cause of hemorrhage in a French study[26]. Waterstone *et al.*[17] in the UK considered uterine rupture as a separate entity, which is a more accurate means of using these data unless there is clear evidence of the blood loss associated with each case. These authors found a rate of 1 : 4000 deliveries (0.025%). Studies in high income countries suggest low rates of uterine rupture causing SAMM which range from 0.002%[60] through 0.017%[21] to 0.06%[20].

A systematic review of the literature published in 2005 examined 83 studies concerning uterine rupture between 1990 and 2005[61]. Prevalence was higher in developing than developed countries. In all countries, rupture affected 1% of women with previous cesarean section. This same trend was found by the UK Obstetric Surveillance Survey (UKOSS) study undertaken in 2010, where 86% of ruptures occurred in women with a previous cesarean section. The 2005 review found variable rates of rupture across the world, especially when studies were conducted in developing countries; in these settings women may die unattended out of hospital, and studies were less likely to distinguish women with scarred and unscarred uteri. Rates of rupture were lowest in developed countries and in women without a uterine scar (0.006%, rising to 1% in women with scarred uteri). In contrast, in the least developed countries rates of rupture could be as high as 25% (one study of 945 women in Ethiopia in the 1990s) and mostly associated with obstructed labor; 75% of cases of uterine rupture in Africa and Asia were found to occur in unscarred uteri. In low-resource settings rupture is associated with a high maternal mortality which ranges from 1 to 13% and a very high perinatal mortality (74–92%)[61]. The WHO review suggests that reducing rupture rates in these populations would require a focus on reducing unwanted pregnancies, especially in women of high parity, accessibility of services and cesarean sections for obstructed labor and adequate guidelines for safe use of misoprostol as an induction agent[61].

Data from Australia and Northern Europe also suggest that rupture is a rare event in developed countries, but the rate is increased by induction of labor[20,56].

Peripartum hysterectomy

Obstetric hysterectomy provides another means of examining SAMM associated with PPH and has the advantage of being more clearly defined, and rare enough for data to be easily collected. The threshold for performing hysterectomy clearly varies with the operator, unit and individual case, but evidence suggests that early hysterectomy decreases both

morbidity[62] and mortality[63]. The several studies that have examined the incidence of peripartum hysterectomy as a marker of SAMM from hemorrhage are listed in Table 5. Population studies between 1986 and 2005 yielded rates of 0.3–1.55 hysterectomies/1000 deliveries[23]. More recent rates of 0.33 and 0.77/1000 deliveries have been reported in The Netherlands[20] and the US[64]. The largest population study from the UK showed an incidence of 0.41/1000 deliveries[30].

Table 5 also shows that the main causes of bleeding leading to hysterectomy are atony (30–50%) and adherent placenta (38–40%). Recently, more conservative treatment modalities for PPH have been introduced, but the hysterectomy studies show that even these can fail to arrest bleeding. Failed brace sutures were found in 25% of cases in the UK[30], whilst a Dutch study showed that 9.7% and 13% of cases of hysterectomy followed intrauterine balloon tamponade and uterine artery embolization, respectively[20]. It is difficult to draw meaningful conclusions regarding failed conservative measures as there are no standardized guidelines for use before proceeding to hysterectomy nor are there established guidelines for the timely use of either the brace suture or the balloon. For example, if bleeding has proceeded for a long time prior to institution of therapy, the likelihood that it is accompanied by some degree of coagulopathy (disseminated, dilutional or both) is high (see Chapter 5). Practicing clinicians regularly counsel women regarding the risk of hysterectomy after cesarean section for placenta previa. Studies suggest that the combination of multiparity, history of previous cesarean section and delivery by cesarean section should alert the obstetrician to a significant risk of hysterectomy secondary to placenta accreta/percreta. Combining the odds ratios generated individually by the UKOSS case–control study for these three conditions, the risk could be over 50 times that of the normal pregnant population.

OUTCOMES OF WOMEN WHO SUFFER SEVERE ADVERSE MATERNAL MORBIDITY

Few studies follow up outcomes beyond survival and immediate morbidity. Studies of postnatal morbidity in general populations (low- and high-risk women analysed together) found that problem prevalence is high and persists for a prolonged period of time after delivery[47,65]. Glazener *et al.*[65] looked at a random sample of deliveries (high and low risk) in a teaching hospital in Scotland and showed that 87% of women suffered at least one health problem after delivery and in 76% problems persisted for 2 months postpartum. Problems ranged from urinary or bowel problems to perineal pain or breakdown, breast problems and persistent vaginal discharge. A case–control study of outcome 6–12 months postpartum compared women who had and had not suffered SAMM[47]. Cases were twice as likely to attend accident and emergency departments, possibly related to the underlying morbidity and its follow-up, but this circumstance clearly points to a continuing burden on health services with personal, family and economic costs. Cases also suffered slightly more postnatal depression than controls (who were not entirely 'normal' as they included women with operative deliveries and smaller hemorrhages). While this difference was not statistically significant, cases also scored higher on the Edinburgh Postnatal Depression Scale. Significantly more cases than controls (50% vs. 29%, 95% CI for the difference 9.7–33%, $p < 0.001$) were reluctant to re-establish sexual relations with their partners for fear of becoming pregnant, suggesting that a negative experience in one pregnancy may prevent a woman from achieving the family she initially intended[47]. Women with stillbirths are almost always excluded from postnatal studies[65], although a higher proportion of them also suffer SAMM by the nature of underlying conditions (e.g. abruption). Only half of the studies of SAMM quoted give data about perinatal loss. Thus, the figures quoted above are likely underestimates of the true spectrum of postnatal morbidity.

Potential measures to decrease SAMM secondary to PPH

Agreement on definitions and categorizations for comparisons

Before designing studies into effective interventions for reducing SAMM, it is necessary to develop standardized definitions for severe morbidity and its main causes. A pragmatic definition could be based on a mixture of parameters, as outlined in Table 3. Knight *et al.*[54] also suggest that the ICD classification of PPH should be revised to separate atonic PPH from other causes, particularly due to morbid placental adherence, in order to enable meaningful comparisons to be made between different countries. These authors postulate that the definition should not differ depending on mode of delivery, as the physiological impact of losing blood depends on the volume lost. Obviously, even if there were identical blood losses, the specific morbidity and healing from abdominal or vaginal operations or tears will differ.

Accurate estimation of blood loss

Measuring blood loss accurately is notoriously difficult, but some studies have improved this by using a blood collector bag[66] (see Chapters 9–11). Training programs incorporating clinical reconstructions that include algorithms to facilitate visual estimation of blood loss improved the accuracy of such estimation[67,68]. Routine use of a modified obstetric early warning score (or MEOWS) may aid recognition of hypovolemia where estimated blood loss is inaccurate[69].

Address primary prevention risk factors for PPH

Decreasing major hemorrhage involves trying to reduce all risk factors for PPH (Table 4). In high income countries, increasing age and obesity are contributing to increasing use of oxytocin in labor as well as the

Table 5 A comparison of four recent studies of obstetric hysterectomy

Author, year of publication	*Eniola* et al.[23] *UK, 2006*	*Rossi* et al.[24] *USA, 2010*	*Zwart* et al. *(LeMMON)*[20] *Netherland, 2008*	*Knight* et al. *(UKOSS)*[30] *UK, 2007*
Setting type of study number of cases number of deliveries (denominator)	Mar 1997–Feb 1998, SE Thames Population based cohort *n* = 22 cases 48,865 deliveries >24 weeks	1993–2008 high income countries Systematic review of studies looking at hysterectomies in the first 48 h postpartum (excluded Eniola *et al.* as that included PPH >24 h) *n* = 981 cases	Aug 2004–Aug 2006 prospective population cohort study 1606 cases of MOH (defined as 2000 ml) 358,874 deliveries 4.5/1000 *n* = 107 cases	UK wide Feb 2005–Feb 2006 Case–control reporting *n* = 318 cases, 614 controls Total no deliveries in UK estimated 775,186 during that period (Office of National Statistics)
Hysterectomy rate	0.45/1000 deliveries	0.8–2.28/1000 deliveries in US 0.2–5/1000 deliveries in the review	0.29/1000 (*n* = 107) 13% and 10% after failed embolization or intrauterine balloon, respectively	0.41/1000 deliveries
Mortality	4.5% (1 death : 22 hysterectomies)	2.6% (26 deaths : 981 hysterectomies)	Death not reported	0.6% (1 death : 150 hysterectomies)
Risk factors	Multiparity 71% Previous CS 33% CS index pregnancy 68% Placenta previa 24%	Multiparity 78% Previous CS 46% CS in index pregnancy 73% Abnormal placentation Previous gynecological surgery 15.8%	Risk factors for hysterectomy not separated from risk factors for hemorrhage	Age >35 (OR 2.42) Parity >3 (11%) Multiple pregnancy (OR 2.3) Previous CS (28%) (OR 3.52) CS index pregnancy (OR 7.13) Placenta previa (37%) (OR 24 for minor, 232 for major) Placenta accreta (39%)
Cause of bleed leading to hysterectomy	Atony 50% Uterine rupture 0%	Adherent placenta 38% Atony 29% Uterine rupture/dehiscence 12% Placenta previa 7% Abruption 2%	Uterine rupture 0.06% Placenta previa 40% Atony 38.5%	Atony 53% Adherent placenta 39% Uterine rupture 8% Extension of uterine incision at delivery 6% (3 for malignancy)
Long-term morbidity	Transfused 100% Urinary tract injury 21% Repeat surgery 38% Poor health 6–9 months postnatal More than 25% scored >13 on the Edinburgh postnatal depression score (i.e. at risk of significant depression)	Transfused 44% Urinary tract injury 16% Return to theater for bleeding or repeat laparotomy 4.9% 56% of women had conservative management techniques, no detail as to which, 44% went straight to hysterectomy Short-term morbidity similar for total and subtotal hysterectomy	ITU admission 27%	2-day ITU stay 84% Damage to structures 21% Severe morbidity 19% Bladder damage 3 times more likely if accreta than if atonic PPH

CVA, cerebrovascular accident; DIC, disseminated intravascular coagulation; HELLP, hemolysis, elevated liver enzymes, low platelets; ICU, intensive care unit; ITU, intensive therapy unit; MOH, massive obstetric hemorrhage (1500 ml in some studies, 2500 ml in others); PET, pre-eclampsia; PPH, postpartum hemorrhage; SAMM, severe adverse maternal morbidity

rising cesarean section rate[9,54]. Independently of one another, obesity, oxytocin use and cesarean section are risk factors for hemorrhage. The limited length of pregnancy means society-wide public health interventions might be better placed to address obesity.

Multiple pregnancy is another risk factor which, in low income countries, has been more likely to be spontaneous and therefore not preventable. In the UK, however, recent Human Fertilisation and Embryology Authority (HFEA) targets are encouraging greater use of single embryo transfers to reduce the risks associated with IVF multiple pregnancy, including PPH[70,71]. However, there are many countries where larger numbers of embryos are still being transferred (US, Eastern Europe, India), thus contributing to PPH and other obstetric morbidities.

Availability of cheap, effective drugs to use in low resource and out of hospital settings is important. Misoprostol is one such drug which is heat stable and easy to administer in a home birth setting. Studies in Africa have shown reduced rates of PPH when it is used, and its administration does not require trained birth attendants[72,73]. Sublingual administration may be most effective[74,75], and the women can self-administer easily[73], further reducing the cost of an already cheap intervention (see Chapters 32–35).

Basic antenatal care

This cannot be overemphasized, as ample evidence shows that antenatal follow-up decreases a woman's risk at labor and delivery[41,76]. Antenatal screening for complications, treatment and prevention of anemia, cleanliness during delivery, the presence of a skilled birth attendant and active management of the third stage of labor are all basic requirements advocated by WHO[77]. Staff attending deliveries in the primary care sector need to be trained to recognize PPH early and have access to simple drugs to treat it (e.g. misoprostol, ergometrine)[72], as well as to recognize when to refer to a more specialized center[54]. In rural South Africa, health-worker problems were identified as the cause of substandard care in 35–49% of cases[54] out of a total of 65% where substandard care was an issue. Factors identified were delay in diagnosis, treatment, referral and monitoring.

Training, teamwork and skills

Effective teamwork is paramount for timely interventions. Algorithms or diagrams of expected co-ordinated actions may help identify what needs to be done and by whom, especially when several actions need to be undertaken simultaneously as in brisk PPH[78].

Clear management protocols and regular skills-drills training may both contribute to the maintenance of high standards in units[8,27]. Non-adherence to guidelines has been identified as a risk factor for increased maternal morbidity[8,79], whereas dissemination of guidelines and skills-drills are associated with improved adherence to the agreed protocols and reduction in PPH[79]. However, recent research in France has generated conflicting results regarding the efficacy of adherence to guidelines on actual incidence of major PPH. One of the studies involved 19 maternity units within a regional French perinatal network[80] and the other involved 106 units in six regions[81]. Both showed that prompt recognition and aggressive management of PPH improved care, and increased the use of surgery in management, whereas the prevalence of major PPH did not alter. This may be explained by different risk factors dominating the progression from small to large PPH (e.g. previa), and suggests that interventions additional to improved recognition and secondary prevention are necessary to make an impact on PPH rates[81]. Important factors involve multiprofessional training within the local unit and integrating teamwork training within the clinical teaching itself[82].

Access, transport and organizational change

Twenty per cent of avoidable SAMM in rural South Africa is due to organizational or administrative causes such as the shortage of essential drugs, ambulances and recruitment and retention of experienced staff[41]. These factors are less prominent in high income countries. However, implementation of guidelines and issues such as staff training and effective audit usually occur at organizational levels. Geller *et al.*[49] analysed the 'preventability' of events along the continuum of severe morbidity to near-miss to death and concluded that the same factors contributed to the outcome in all categories (Figure 1). These were patient factors (13–20%), system factors (33–47%) and provider-related factors (90%), mainly incomplete or inappropriate management[49]. Patient factors are potentially the hardest to rectify, especially in low income countries where access to education is limited. System factors figure higher in the US (33–47%)[49] than in South Africa (20%)[41], possibly because failures of well-established systems (as in the US) are likely to have a greater impact than in settings where transport or administrative systems are not established in the first place, e.g. in rural Africa[41]. Provider-related factors have been more prominent as a cause of substandard care in the US (90%)[49] than in primary care settings in South Africa (35–49%)[41]. This is more likely due to the non-availability of specialist staff in the latter, with staff performing to the best of their ability in light of skills they possess. Expected standards change with time, place and facilities, so it is not unsurprising that provider-related factors continue to feature even in low mortality settings.

Health systems

Wider factors relating to health systems can move a woman both up and down the risk pyramid for severity of morbidity. Social exclusion, education and inequality can be tackled at governmental level in both low and high income countries[2,76]. Access to contraception, safe legal abortion and antenatal care can all be addressed. Health service planners may have to

provide outreach antenatal services for travelers, teenagers and the mentally ill[2]. The lack of universal coverage for health insurance in the US may play a role, as women most at risk are often not insured[49,83]. The population in major cities is changing, due to increased migration especially from deprived areas or as a result of war and conflict. Access to 24-hour interpreters should become standard and might lead to significant reductions in severe morbidity[2].

CONCLUSION

The UK triennial Confidential Enquiries into Maternal Deaths started in 1952, and the latter part of the 20th century witnessed a gradual decline in maternal mortality. Maternal death is now rare in high income countries, although still prevalent in low income countries. Severe adverse maternal morbidity (SAMM) is prevalent throughout the world, mostly due to treatable conditions. Poor, socially excluded women suffer most, but hemorrhage can strike any woman. For meaningful comparisons to be made, standardized, simple definitions need to be designed and agreed upon as the benchmark for future research.

Hemorrhage accounts for the largest proportion of severe morbidity but is not a major cause of maternal mortality, at least in developed countries[12]. This suggests that registering SAMM would be a valuable way to monitor and improve the quality of maternity services. Several population-based studies in countries such as Scotland, The Netherlands and Australia demonstrate that national morbidity surveys are feasible. Studies are needed at national level as numbers of SAMM cases are relatively small, and trends are easier to analyse. As the causes of maternal deaths can be different from those of SAMM[12], it is most useful to have the two systems running in parallel to aid understanding of the relationship. This has been achieved in Scotland for the past 8 years. The UKOSS rare obstetric register system has been working nationwide in the UK since 2005. The recent study on peripartum hysterectomy showed that there was one death for every 150 hysterectomies performed for hemorrhage, thus reinforcing the value of morbidity and mortality surveys running in parallel.

It is important to continue to monitor trends. In high income countries recognized risk factors for hemorrhage such as age, obesity and cesarean section rates are rising. The current cesarean section rate in the UK is 23%, and it is as high as 50% in Latin America[84,85]. Globally, interventions aimed to reduce a specific morbidity (e.g. cesarean section in obstructed labor to prevent a ruptured uterus) may increase the risk of a different subsequent morbidity (e.g. placenta accreta in previous cesarean section scar or uterine rupture in attempted vaginal birth after cesarean section). Overall, obstetric morbidity may thus rise, fall or remain unchanged, but information to guide high quality practice relies on robust, continuous, population-based SAMM audits.

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