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Review article

New and underutilised technologies to reduce maternal mortality and morbidity: what progress have we made since Bellagio 2003?

VD Tsu, PS Coffey

PATH, Seattle, WA, USA
Correspondence: Dr VD Tsu, PATH, 1455 NW Leary Way, Seattle, WA 98107, USA. Email vtsu@path.org

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In 2003, maternal health experts met in Bellagio, to consider new and underutilised technologies vital to pregnancy-related health services in low-resource settings. Five years later, we examine what progress has been made and what new opportunities may be on the horizon. Based on a review of literature and consultation with experts, we consider technologies addressing the five leading causes of maternal mortality: postpartum haemorrhage, eclampsia, obstructed labour, puerperal sepsis, and unsafe abortion (pregnancy termination and miscarriage). In addition, we consider technologies related to obstetric fistula, which has received more attention in recent years.

Keywords Developing countries, maternal morbidity and mortality, technologies.

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Introduction

As demonstrated in the recent Countdown to 2015 report,[1] progress in achieving the Millennium Development Goal of reducing the maternal mortality ratio by 75% has been uneven. While much attention has rightly been focused on ensuring skilled attendance and comprehensive emergency obstetric care,[2,3] it is also important to consider what improvements have been made in the essential technologies available to health workers and communities who want to prevent or manage obstetric complications. Health technologies usually refer to products (e.g. equipment, supplies, information materials, or education tools) but can also refer to techniques or procedures. Because they do not function in isolation from health systems or communities, they are both affected by and have impact on the profound problems facing health systems today. Technologies can play supportive, enabling, or constraining roles, for example, in the face of shortages of trained health staff or resource-starved infrastructure. Technologies can affect both coverage and quality of care, especially critical for maternal mortality reduction as noted by Shankar *et al.*, and therefore deserve focused attention.[4]

In 2003, a diverse group of maternal health experts met in Bellagio, Italy, to consider new and underutilised technologies that could play critical roles in pregnancy-related health services in low-resource settings.[5] Completely new technologies or new applications of existing technologies were considered as well as those that were already known but still not widely used in low-resource settings as long as they were actually feasible for use where resources and infrastructure are constrained. The meeting limited its deliberations to those direct and common causes of maternal death: postpartum haemorrhage (PPH), pre-eclampsia/eclampsia, obstructed labour, puerperal sepsis, and abortion (termination of pregnancy and miscarriage). In addition, auxiliary technologies related to transport and communication for obstetric emergencies and vitamin A supplementation were considered. Based on a set of background papers[6] and 3 days of discussion, the group developed a set of recommendations on priority technologies and critical next steps.[7]

Five years later, it is useful to see what progress has been made, where things have stalled, and what new opportunities may be on the horizon. Because of the great attention that has been directed at obstetric fistula in recent years, we broadened the scope slightly to consider this major cause of devastating and long-lasting morbidity and its repair together with the previously discussed five major sources of mortality. Despite the barriers to technology adoption and successful use identified at Bellagio,[8] the allocation of more financial

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resources, the accumulation of new evidence, and the powerful voices for change (e.g. the Women Deliver meeting in London in 2007) have helped spur progress on several of the priority technologies identified 5 years ago.

Methods

This paper employed an iterative three-part process, starting with a consultation with the authors of the earlier Bellagio papers about progress with earlier technologies and recent advances, followed by a review of the literature of the past 5 years using PubMed and Google (for technologies), and further consultations with additional experts on maternal health issues based on leads from the literature or from colleagues. We narrowed the focus to clinical technologies because of space constraints, leaving aside interesting technologies related to cell phones and other digital technologies, novel transportation ideas, and broader health system technologies like health information systems. We focus primarily on those areas where progress has been made, usually because of either the availability of new supporting evidence on effectiveness or supply improvements, and those that seem to have the highest likelihood of having a meaningful impact on maternal mortality or morbidity. However, we also consider technologies that show promise but need further evidence of their value. Technologies where little or no progress has been made are summarised in Table 1 but not discussed in the text.

Postpartum haemorrhage

PPH continues to be the dominant cause of maternal death in Africa and Asia, costing an estimated 140 000 women their lives each year and leaving nearly 2 million more women struggling to recover from the debilitating effects of anaemia.[21,22] Five technologies were identified as priorities during the Bellagio workshop, three related to PPH prevention (active management of third stage of labour [AMTSL], misoprostol, and oxytocin in the Uniject™ device [Becton, Dickinson and Company, Franklin Lakes, NJ, USA]) and two to treatment of serious haemorrhage (antishock garment and balloon tamponade). Because of the considerable attention that has been focused on PPH in recent years, there has been real progress in most of the identified technologies.

Table 1. Technologies where little or no progress has been achieved

Technologies
Balloon tamponade for treatment of PPH[9,10]
Magnesium sulphate for prevention and treatment of eclampsia
Use of antihypertensive drugs in women with mild-to-moderate hypertension to prevent pre-eclampsia[11–13]
Urine dipstick tests for early detection of pre-eclampsia
Symphysiotomy as a technique to manage obstructed labour[14–17]
Low-dose vitamin A or beta-carotene supplementation[18,19]; better targeting needed according to Bangladesh results[20]

In the area of prevention, AMTSL is now more widely established. Some research has been completed suggesting that early cord clamping is not a significant advantage for the mother and may disadvantage the newborn; therefore, a revision in the recommended components of AMTSL has been made.[23,24] The World Health Organization (WHO) is now organising a randomised noninferiority trial in eight countries to compare a simplified regimen of oxytocin and uterine massage with a regimen that adds controlled cord traction to the oxytocin and uterine massage to evaluate the effects of controlled cord traction (M. Gülmezoglu, WHO, Geneva, pers. comm., August 2008).

Uterotonics for PPH prevention

The availability and usefulness of oxytocin packaged in an inexpensive plastic, prefilled syringe (i.e. Uniject device) has been of great interest. Studies in Angola and Vietnam have demonstrated that oxytocin delivered in Uniject devices has the expected protective effect of oxytocin delivered by standard syringes and that the devices are highly acceptable to midwives, particularly those practicing alone or in difficult circumstances.[25–27] In three districts in Mali, oxytocin was administered as part of AMTSL to about 15 000 women giving birth in referral and community-level health centres in 2007. Matrones (auxiliary midwives with about 6 months of training) were able to successfully deliver the oxytocin with no more problems than more highly trained midwives, obstetric nurses, and physicians. There were also no additional complications related to misuse of oxytocin in the health centres where oxytocin in Uniject devices was administered for AMTSL. Having oxytocin in a prefilled format with an assured dose can potentially reduce the risk of misuse, which remains a serious concern for the government as they consider allowing auxiliary midwives to administer the drug for the prevention of PPH (S. Engelbrecht, PATH, Seattle, pers. comm., August 2008). Instituto Biológico Argentino (www.e-biol.com.ar), a pharmaceutical company in Argentina, has now received regulatory approval for its product of 10 iu of oxytocin in a 1 ml Uniject device and will proceed to seek WHO prequalification (for marketing to United Nations agencies) and register it in other countries in the region in 2009. An Indian company, Gland Pharma (www.glandpharma.com), is also investigating the feasibility of establishing production in the near future.

Use of misoprostol to prevent PPH in low-resource settings has also been demonstrated now in three relatively large, randomised controlled trials using 600 micrograms orally or sublingually in primary care or community settings where conventional injectable uterotonics were not available.[28,29] A placebo-controlled trial in rural India showed

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a significant reduction in PPH, need for emergency transfer, blood transfusion, and surgical interventions for those receiving misoprostol from auxiliary nurse midwives during home or subcentre deliveries.[30] While most studies have been carried out with 600 micrograms, there is some evidence that 400 micrograms is equally effective and might have fewer adverse effects.[31,32] A Cochrane review updated in 2007 noted that while misoprostol is still less effective than oxytocin and is associated with significantly higher rates of shivering and fever, it does show promising results when compared with placebo and is more feasible for use where injection skills are not present.[32,33]

Misoprostol is now registered in a growing number of low-income countries for obstetric indications, including Bangladesh, India, Nepal, Nigeria, Tanzania, Uganda, and Zambia, with applications pending in Ethiopia and Indonesia.[34] Venture Strategies, a nonprofit organisation that works with medical leaders, government officials, and pharmaceutical manufacturers to find ways to make high-quality, low-cost, off-patent products available to low-income people through market distribution systems, is also working with manufacturers in Bangladesh and Egypt to ensure availability and to bring the cost down, since the 600 microgram dose currently costs more than double the cost of oxytocin (with a syringe).

One new development in prevention has been an initial study on the use of uterine massage to reduce PPH incidence. A study of 200 women randomised to routine AMTSL with oxytocin or routine AMTSL plus intermittent uterine massage saw an 80% reduction in use of additional uterotonics (95% CI: 0.08–0.50) and significantly lower mean blood loss at 60 minutes postpartum with massage.[35] However, more research is needed, and the challenge is in designing an ethical study of what to do when oxytocin is not available.

Management of severe PPH

There has been relatively less progress in the area of treatment of PPH. Additional data from Nigeria and Egypt suggest that use of the nonpneumatic antishock garment (NASG) in hospital settings among women already experiencing severe PPH results in reduced blood loss and faster time to recovery from shock, but there are still no randomised trials or studies of use outside hospitals.[36] A randomised cluster trial of early application of the NASG at midwifery-led clinics is now continuing in Zambia and Zimbabwe; final results are not expected for 3–5 years.[37] Interest in the use of misoprostol for treating PPH is growing although evidence of its efficacy or appropriate dosing is limited. Most studies to date have been of its use after oxytocin was given prophylactically.[38] Finally, balloon tamponade has been described in several small case series conducted in referral hospitals but has yet to be systematically evaluated or extended to secondary-level facilities. However, as the least invasive and most rapid of the various medical and surgical responses to persistent PPH, it is recommended as a first response to try in low-resource settings.

Pre-eclampsia and eclampsia

Hypertensive disorders of pregnancy, manifest mainly in pre-eclampsia and eclampsia (PEE), account for about 9% of maternal deaths in Africa and Asia and about one-quarter of maternal deaths in Latin America and the Caribbean.[21] The technologies identified 5 years ago continue to be the key issues: scaling up use of magnesium sulphate for both prevention and treatment of eclampsia, nutritional supplements, and antiplatelets to prevent PEE, and methods for early detection of PEE or elevated risk for PEE.

Scaling up use of magnesium sulphate

Magnesium sulphate is the anticonvulsant of choice for both prevention and treatment of eclampsia.[39,40] While use of the drug in low-resource settings occurs on a limited basis,[41–45] the practice is not yet widespread at least for pre-eclampsia management despite the clear findings of the Magpie trial more than 5 years ago.[46,47] The drug, although inexpensive, has limited availability in some low-resource settings for a variety of reasons.[48–51]

At the Workshop on Magnesium Sulphate for the Management of Pre-eclampsia and Eclampsia held at Oxford University in 2007, there was broad agreement that a prepackaged kit could be a useful way to ensure that hospitals have all the components needed for successful treatment, but in fact there still is no consensus about the exact regimen to use.[52] Current accepted regimens for magnesium sulphate use include a loading dose of 4 g administered intravenously with 10 g given by intramuscular injection followed by maintenance doses of 5 g administered either by intramuscular injection or a continuous intravenous infusion.[40] A recent study in India confirmed the earlier success in Dhaka of a low-dose regimen.[53,54] The remaining questions are: whether a purely intramuscular regimen can be safely used in places where skills and equipment for intravenous use are not available and, if so, what it would take to validate that regimen; whether a loading dose alone is sufficient for most women with pre-eclampsia;[55] and whether calcium gluconate is necessary if only intramuscular administration is used. Resolution of these issues is critical if the 'eclampsia kit' is to be as efficient and affordable as possible and also represent best practice.

Meanwhile, the safety and acceptability of an affordable, simple, flow-controlled pump, SpringFusor (Go Medical Industries, Subiaco, Australia) is currently being tested in India.[56] This new technological approach to deliver treatment for pre-eclampsia holds promise as it would simplify the nursing care requirements and perhaps reduce some of the resistance to adopting magnesium sulphate.

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Nutritional supplements and antiplatelets for prevention

The value of nutritional supplements is now clearer than it was 5 years ago. Results from a WHO double-blind multicentre randomised trial determined that pregnant women with low dietary calcium intake who supplement their diets with 1.5 g calcium/day experienced significantly lower rates of eclampsia (RR: 0.68; 95% CI: 0.48–0.97) and severe gestational hypertension (RR: 0.71; 95% CI: 0.61–0.82).[57,58] A Cochrane review concluded that calcium supplementation during pregnancy also reduces the risk of pre-eclampsia (12 trials, 15 206 women: RR: 0.48, 95% CI: 0.33–0.69) and that the greatest benefit was for high-risk women and women with low baseline calcium intake.[59] Community-based studies to test ways to effectively deliver calcium supplementation before and in early pregnancy are now needed, particularly in low-resource settings.[59,60] By contrast, recent studies and systematic reviews have not borne out the earlier promise of vitamin A or vitamin E with regard to reduced risk of pre-eclampsia.[61,62]

The benefits of antenatal use of antiplatelets, primarily low-dose aspirin, have been confirmed, although for the target population that would benefit most appropriate dose and optimal timing are still not clear. A Cochrane review of trials including more than 30 000 women, with several of the studies carried out in the past 5 years, estimated a modest 17% reduction in the risk of pre-eclampsia associated with use of antiplatelet agents (RR: 0.83; 95% CI: 0.77–0.89).[63] Subsequently, a meta-analysis of individual patient data showed no clear difference in benefit when using more or less than 75 mg of aspirin or beginning treatment before or after 20 weeks of gestation.[64] Using the UK prices, both aspirin and calcium supplementation appear to be cost-effective interventions[60] and risk-free in the case of calcium. However, that assessment needs to be conducted in low-resource settings also, and strategies for delivering these interventions to the women who need them (who often initiate antenatal care quite late in pregnancy) must be developed.

Risk assessment and early detection

The identification of new biomarkers for pre-eclampsia screening has shown promise. The most advanced tests are markers for angiogenic factors, such as placental growth factor and soluble vascular endothelial growth factor receptor (sVEGFR1, also referred to as sFlt1). A recent systematic review demonstrated that its predictive value is higher late in pregnancy.[65] Currently, a WHO multicentre observational study of changes in serum and urinary angiogenic proteins during pregnancy in seven countries[11] and clinical trials of sVEGFR1 and placental growth factor (PlGF) by several pharmaceutical companies are underway (A. Karumanchi, pers. comm., July 2008). After reviewing 11 studies of tests for detecting various forms of proteinuria, Meads *et al.*[60] concluded that none of the tests was sufficiently accurate to be recommended for routine use in screening asymptomatic women.

Obstructed labour

An estimated six million women suffer obstructed labours each year, often enduring days of agony that end with the death of the baby and often the mother.[22] Those women who survive may live with years of fistula and the urinary and/or faecal incontinence and social isolation it brings. Prevention consists primarily of adequate childhood nutrition and delayed childbearing until skeletal growth is completed,[66] so the role of technology is in management once obstruction or nonprogressive labour has occurred.

Risk factors and early detection

The most important tool to ensure timely management is the partograph (or partogram), designed to help birth attendants recognise when to intervene in the labour process. Despite the fact that partographs have been in use for decades, many staff are still unaware of them or do not know how to use them.[67–69] Training interventions in Angola[70] and Indonesia[71] have been able to improve knowledge and practice. Following successful results from a small crossover trial in India, the standard WHO partograph has been simplified from a composite format that included both a latent and active phase to a version that starts with the active phase.[72] Results from this trial concluded that the simplified partograph was more user-friendly, more likely to be completed, and less likely to lead to caesarean sections (the action line was crossed significantly more often in the composite partograph group). A randomised controlled trial of 3000 women in England compared the effect of 2-hour versus 4-hour action lines on birth outcomes.[73] Results from this trial confirm the usefulness of the 4-hour partograph currently used by WHO. At this point, it is probably more important to concentrate on training and supportive supervision than to make further refinements of the technology.

With regard to prediction of obstructed labour to guide referral for facility-based delivery, a recent study in Cameroon found that a combined measure of maternal height and external pelvimetry achieved a 47.7% positive predictive value of dystocia among nulliparous women with specificity of 92%.[74] This is better than maternal height alone and may be a useful triage measure, although more data on reliability are needed. Using handheld, portable ultrasound machines to screen pregnant women in rural settings for possible fetopelvic disproportion, malposition, or multiple pregnancies has also been proposed (G. Perkin, pers. comm., March 2008). This approach requires careful evaluation of feasibility and cost-effectiveness since the equipment is still relatively expensive for use at lower levels of care.

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Assisted delivery and caesarean section

For assisted vaginal delivery, vacuum extractors are extremely useful. As evidenced in Ecuador, their use can be safe and effective in low-resource settings.[75] In recent years, there has been more evidence gathered on the new rigid plastic Kiwi™ OmniCup, a disposable vacuum extraction device that has a posterior cup design and a handheld vacuum source called a PalmPump™ (Clinical Innovations, Murray, UT, USA). While an observational study of 1000 Canadian women indicated a high rate of success with vaginal delivery achieved in 87.1% of the women,[76] two other studies that randomised participants to the OmniCup or a conventional device found that the OmniCup device had a higher failure rate.[77,78] The affordability of a disposable device is questionable in any case, so there is still a need to find a better device for low-income settings.

When vaginal delivery is not possible because of failure to progress in labour, fetopelvic disproportion, or fetal malpresentation, caesarean section is a life-saving intervention for mothers. Although caesareans are extremely common, there are many variations in the numerous steps involved and no agreed standard practice. A 2008 Cochrane review of techniques for caesarean section summarises the best available evidence on specific aspects of the surgery.[79] The authors conclude that simplified surgical techniques offer advantages that may be especially important in low-resource settings. The simplified Joel-Cohen-based (Joel-Cohen, Misgav-Ladach) techniques use a straight transverse abdominal incision (higher than the Pfannenstiel incision), manual separation of the abdominal wall layers to minimise sharp dissection, a transverse incision of the myometrium not larger than the amniotic sac, uterine closure in a single layer, and nonclosure of the peritoneum. Results from an evidence-based review suggest that use of Joel-Cohen-based methods result in less blood loss, shorter operating time, less fever and pain, and shorter time to postoperative recovery when compared with the Pfannenstiel method of caesarean.[80] They also use less suture material, which may be important where such resources are limited.

In addition to using a transverse lower abdominal wall opening and uterine opening using Joel-Cohen-based methods, the reviewers recommend (1) placental removal with cord traction,[81] (2) intra- or extra-abdominal repair of the uterus,[82] (3) nonclosure of both peritoneal layers, (4) closure of subcutaneous tissues, and (5) skin closure with interrupted sutures. Although results of a Cochrane review of single-layer versus double-layer closure of the uterine incision suggest that single-layer closure is associated with less blood loss, postoperative pain, and shorter procedure and hospital stay,[83] other observational studies demonstrated that use of a single-layer closure led to increased uterine rupture in subsequent pregnancies.[84,85] Based on the available evidence, Hofmeyr *et al.*[79] recommend that in low-resource settings, where caesarean sections are often performed by relatively junior staff under difficult circumstances and where women may not always be able to access caesarean surgery during subsequent pregnancies, the most cost-effective practice is to use spinal analgesia, Joel-Cohen-based abdominal incision, and double-layer closure of the uterus.

Puerperal sepsis

While infection accounts for a small proportion of maternal deaths in the industrial world, it still causes 10–12% of maternal mortality in Africa and Asia.[21] Bellagio workshop participants identified the root causes of puerperal sepsis as being related to health system failures and noncompliance with long-established infection prevention and management procedures, rather than lack of appropriate technologies.

Routine vaginal cleansing is one technology with potential to address puerperal sepsis. A recent pilot study in Pakistan demonstrated that traditional birth attendants could safely use a 0.6% chlorhexidine vaginal and neonatal wipe during labour and that it was well tolerated and accepted by rural mothers.[86] Trials of vaginal wipes at varying concentrations using neonatal and infection-related morbidity as end-points are underway in South Africa, Zimbabwe, and Pakistan.[87] Confirmatory randomised controlled trials of vaginal wipes in low-resource settings and technology refinements related to optimal chlorhexidine concentration, preparation, volume, dosing, and cost are still needed before scaling up this intervention.[87,88]

The usefulness of antiseptic hand rubs or wipes is still uncertain, particularly in home deliveries and low-resource facilities. While antimicrobial handwashing agents may be better able than soap and water to remove bacteria, physical removal with soap or tap water alone was more effective for reducing viral contamination.[89] Ensuring that facilities and homes have adequate water supplies may be the highest priority at this time. Measures to reduce perineal trauma during labour and resulting infection—such as antenatal perineal massage using sweet almond oil—show some promise and need further investigation.[90]

Unsafe abortion

Increasing the accessibility of safe and affordable methods for termination of pregnancy and for managing postabortion (or post-termination) complications (PAC) and incomplete miscarriage using the existing technologies of manual vacuum aspiration (MVA) and misoprostol were considered a high priority by the Bellagio working group.[8] The main advances in this area have been the accumulating evidence on the safety and effectiveness of misoprostol. PAC refers primarily to management of haemorrhage and infection that are addressed elsewhere in the paper; guidelines for this are now relatively well established.[91]

The combination of mifepristone and misoprostol continues to be the recommended regimen for first-trimester-induced

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pregnancy termination, although questions of timing and dose continue to be debated. However, the cost and limited availability of mifepristone has led to the evaluation of misoprostol alone and in combination with methotrexate. In a review of first-trimester medical terminations, regimens using misoprostol alone were generally effective (84–96%) and were similar to those regimens using misoprostol with methotrexate (70–97%).[92] In a subsequent study, retrospective analysis of data from nearly 8700 clinical records from a women's health centre in Latin America found that efficacy was significantly higher for combined methotrexate regimens compared with misoprostol alone.[93] Since methotrexate is inexpensive and widely available, combined methotrexate regimens (oral or intramuscular methotrexate followed a few days later by misoprostol) may be important to consider in places where access to mifepristone is limited.

For second-trimester pregnancy termination, where the highest incidence of morbidity and mortality occurs, misoprostol-only regimens also appear to be highly effective at least for pregnancies between 13 and 22 weeks and perhaps up through 26 weeks according to a review by Ho *et al.*[94] A recent study in South Africa found a single regimen of misoprostol alone (400 micrograms orally and 800 micrograms vaginally) was successful in 91% of 273 women (both first and second trimester).[95]

For treatment of incomplete pregnancy termination and miscarriage, a systematic review by Blum *et al.* that includes four recent studies in Africa concludes that a 600 microgram dose of oral misoprostol alone will achieve efficacy greater than 90%.[96] A remaining question is whether 400 micrograms sublingually will work as well, and several trials are underway to address this question.[96]

MVA technology has been improved in recent years. The plastic material in Ipas cannulae has been upgraded from polyethylene to polypropylene allowing them to be autoclaved for reuse where that is permitted.[97] The double-valve aspirator has also been redesigned to improve cleanability and allow for boiling or autoclaving, with very little increase in cost.[98] There is also new evidence from a study in South Africa and Vietnam that midlevel providers can provide MVA as safely as doctors can.[99]

There is a growing consensus that in resource-constrained settings neither pregnancy tests nor ultrasound is essential for routine postabortion assessment, and that bimanual examination and clinical history can determine most cases.[100]

Obstetric fistula

While obstetric fistulas generally do not cause many maternal deaths, they are the source of heartbreaking morbidity for millions of women. WHO estimates that more than 2 million young women live with untreated obstetric fistula and that between 50 000 and 100 000 new women are affected each year.[101] Until 2003, when the United Nations Population Fund and partners initiated the Campaign to End Fistula, the experiences of women suffering from obstetric fistula were relatively hidden from public view.[102,103] Prevention of fistula involves either primary prevention of obstructed labour or prompt management of obstructed labour before fistulas can form (as discussed above).

Fistula repair

Standard repair techniques have been established for fistula based on the degree of involvement of associated organs such as the bladder, other abdominal viscera, ureteral orifices, as well as vaginal stenosis. The value of the Martius graft, recommended and used by many as a way to promote tissue repair after fistula surgery, has been questioned as a result of a retrospective case review at the Addis Ababa Fistula Hospital in Ethiopia that showed no particular benefit from it in the hands of an experienced surgeon.[104] While a randomised trial is needed to confirm these findings, if repair could safely be performed without the graft it would reduce operating time and the need for postoperative analgesia and eliminate an additional wound site for possible infections and wound breakdown.[104] Experts in fistula repair in Ethiopia have also suggested that the duration of catheterisation after repair surgery could safely be reduced from 14 days to 10 days among less-complicated fistula cases.[105]

Managing urinary incontinence associated with fistula

In developing countries, some anecdotal reports exist with regard to the use of synthetic tension-free vaginal tape for slings in women with stress incontinence after vesicovaginal fistula repair. However, high rates of erosion of the mesh into the bladder and/or urethra can occur (S. Arrowsmith, pers. comm., July 2008). While there are some promising new sling technologies, formal evaluation of the risks and benefits of sling technologies with women suffering from obstetric fistula has not been conducted, and assessment of these approaches must be documented.[106]

Anecdotal reports suggest that nonsurgical treatments for urinary incontinence are being applied in low-resource settings on a case-by-case basis. These include the use of urethral plugs such as the VIVA urethral plug and FemSoft urethral insert (www.1800femsoft.com/).[107,108] These single-use, sterile devices are designed to be removed when the woman urinates. The Addis Ababa Fistula Hospital has reported successful use of the FemSoft insert among a few women, including reuse up to 14 days, but acknowledges the difficulties of initial cost and reuse of 'disposable' devices.[109] Use in low-resource settings of external urethral barriers such as the FemAssist device, a dome-shaped silicone urethral cap (Insight Medical, Bolton, MA, USA), has not been reported and may be even less feasible. The new technologies described here must be evaluated to determine if they are safe and effective in the very

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specialised population of women who suffer from obstetric fistula.

Conclusions

As one might expect, we see a mixed record of progress, but there are encouraging signs. Five years is not very long in the technology development cycle, especially when clinical trials are needed to demonstrate efficacy. Some technologies now have a stronger evidence base—such as misoprostol for PPH prevention where oxytocin is not available, misoprostol-only regimens for second-trimester pregnancy termination, and simplified caesarean section techniques—and deserve wider adoption. Some technologies that were ready 5 years ago for scaling up to widespread use—such as magnesium sulphate, symphysiotomy, and partographs—have made relatively little headway and still await concerted introduction efforts. Research that is planned or already underway—for example, on the NASG or the value of misoprostol for the treatment of severe PPH—will provide critical guidance on these potentially life-saving interventions within the next year or two. Technologies for which clinical research has demonstrated their value—such as calcium supplementation to prevent pre-eclampsia—now need operational research to see how best to implement them in low-resource settings in an acceptable and sustainable manner. Technologies that show promise in high-resource settings will need more research to prove that they can deliver similar benefits in low-resource settings where facilities, provider skills, and patient populations may be less favourable. Table 2 summarises the technologies discussed and the types of actions that are still needed to advance them. There remain substantial gaps where we need a better understanding of the underlying science or creative engineering inputs to devise better technological solutions, such as better tests for proteinuria for pre-eclampsia prediction, and affordable devices for urinary incontinence secondary to obstetric fistula.

Participants left Bellagio in 2003 with high enthusiasm and hopes for a significant impact on maternal mortality. Some of the progress noted here has been because of the efforts of those who participated in the workshop. Efforts must be redoubled now to scale up what we know and to translate the scientific advances that have been achieved into practices that are appropriate and sustainable for low-resource settings where the greatest mortality occurs. We must inspire researchers to turn their attention to the problems that continue to endanger women and their babies. And we must continue to advocate to governments and donors for resources to be devoted to finding solutions (both technological and political) for these persistent and deadly problems that haunt women. Without these solutions, we will not achieve the Millennium Development Goal of improving maternal health by 2015.

Table 2. Proposed priority actions

Mortality/morbidity cause	Clinical/operational research	Enhance technology availability	Translate into general practice or use
PPH	Efficacy of uterine massage alone; role of controlled cord traction; effectiveness of NASG in nonhospital settings; efficacy of balloon tamponade in secondary facilities; efficacy of misoprostol for treating PPH	Misoprostol—inexpensive 600 micrograms dose; affordable NASG	AMTSL; oxytocin in the Uniject™ device
Pre-eclampsia, eclampsia	Dose and efficacy of intramuscular magnesium sulphate; delivery strategies for calcium supplementation; effectiveness of prophylactic use of antiplatelets and target populations; validation of biomarkers for screening tests; efficacy of prophylactic use of antihypertensive drugs	Magnesium sulphate; affordable urine dipstick tests for proteinuria	Magnesium sulphate—standard regimen
Obstructed labour	Validation of external pelvimetry as screening test		Partograph; symphysiotomy; simplified caesarean section techniques
Puerperal sepsis	Effectiveness of chlorhexidine vaginal wipes		
Unsafe abortion	Efficacy of misoprostol alone or in combination with methotrexatefor induced abortion		MVA for induced abortion and PAC
Obstetric fistula	Effectiveness of fistula repair without Martius graft; safety of shorter duration of catheterisation after fistula repair surgery; safety and effectiveness of urethral plugs or other barriers	Affordable urethral plugs	Basic fistula repair techniques

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Details of ethics approval
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