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INTRAPARTUM-RELATED DEATHS: EVIDENCE FOR ACTION 2

Obstetric care in low-resource settings: What, who, and how to overcome challenges to scale up?

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ABSTRACT

Background: Each year, approximately 2 million babies die because of complications of childbirth, primarily in settings where effective care at birth, particularly prompt cesarean delivery, is unavailable. *Objective:* We reviewed the content, impact, risk-benefit, and feasibility of interventions for obstetric complications with high population attributable risk of intrapartum-related hypoxic injury, as well as human resource, skill development, and technological innovations to improve obstetric care quality and availability. *Results:* Despite ecological associations of obstetric care with improved perinatal outcomes, there is limited evidence that intrapartum interventions reduce intrapartum-related neonatal mortality or morbidity. No interventions had high-quality evidence of impact on intrapartum-related outcomes in low-resource settings. While data from high-resource settings support planned cesarean for breech presentation and post-term induction, these interventions may be unavailable or less safe in low-resource settings and require risk-benefit assessment. Promising interventions include use of the partograph, symphysiotomy, amnioinfusion, therapeutic maneuvers for shoulder dystocia, improved management of intra-amniotic infections, and continuous labor support. Obstetric drills, checklists, and innovative low-cost devices could improve care quality. Task-shifting to alternative cadres may increase coverage of care. *Conclusions:* While intrapartum care aims to avert intrapartum-related hypoxic injury, rigorous evidence is lacking, especially in the settings where most deaths occur. Effective care at birth could save hundreds of thousands of lives a year, with investment in health infrastructure, personnel, and research—both for innovation and to improve implementation.

1. Introduction

1.1. Why focus on care at the time of childbirth?

Childbirth is the time of greatest lifetime risk of mortality for a mother and her baby [1]. An estimated 42% of the world's 535 900 annual maternal deaths are intrapartum-related; these deaths are closely linked to the deaths of 1.02 million babies during labor and 904 000 intrapartum-related ("birth asphyxia") neonatal deaths [1–3]. Intrapartum-related insults also result in an unknown burden of disabilities and impairments—perhaps 1 million children each year [4]. In this Supplement, we follow the shift away from the term "birth asphyxia" as recommended by a series of consensus statements [1]. We use the term "intrapartum-related" for cause of death and "neonatal encephalopathy" for the acute complications manifesting soon after birth [5–7].

The advent of modern obstetric care, particularly intrapartum monitoring, the use of forceps and vacuum extraction, and cesarean delivery, has been correlated with historical declines in perinatal mortality in high-resource settings [8–13]. Prompt obstetric interventions are crucial to prevent intrapartum-related fetal hypoxic injury and maternal morbidity and mortality associated with obstetric emergencies. As the first paper in this series indicates, intrapartum obstetric complications are strong predictors of perinatal death [1]. For example, antepartum hemorrhage in the eighth month of pregnancy

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is associated with a 3- to 6-fold increased risk of perinatal death, while obstructed labor, malpresentation, and breech are associated with a 7- to 85-fold increased risk. Furthermore, certain obstetric risk factors, such as maternal pyrexia and chorioamnionitis, may be synergistic with intrapartum hypoxia, markedly elevating the risk of neonatal encephalopathy [14–16]. Intrapartum risk factors more strongly predict perinatal death than prepregnancy (RR range, 1–5) and prenatal risk factors (RR, range 2–14), which have previously been the focus of risk screening tools for obstetric risk and are further examined in the fifth paper in this series [17].

Thus, the prompt emergency management of high priority intrapartum complications, or earlier effective identification and management of the related intrapartum risk factors (RR range, 2-85), may potentially reduce the substantial burden of fetal hypoxic injury [18].

1.2. Current coverage and constraints, key challenges

Neonatal mortality and maternal mortality are inversely associated with coverage rates of skilled birth attendance, emergency obstetric care (EmOC), and neonatal intensive care, at least in ecological analysis [1]. The countries with the highest rates of neonatal mortality (NMR>45) have the lowest rates of skilled attendance (median 46% vs 100% in countries with NMR<5), cesarean delivery (3% vs 17%), and physician density (11 per 100 000 population vs 131/100 000). The density of skilled personnel is 15-fold lower in the highest mortality settings, and in many low-resource settings these are the only personnel legally permitted to perform assisted vaginal delivery or cesarean delivery [19]. Thus, an enormous obstetric care *coverage gap* disadvantages the world's poor—60 million births occur annually outside of hospitals, 52 million of these without a skilled provider [20]. At least three-quarters of neonatal deaths and a similar proportion of maternal deaths occur in these suboptimal care settings [1]. Furthermore, a substantial *quality gap* exists because of failure to monitor pregnancy and labor, identify complications, and provide timely life-saving interventions. Population-level data are not available regarding the quality of obstetric care such as fetal heart rate monitoring and use of the partograph [19], but it is clear in both high-income and middle-income countries [21] that many intrapartum-related neonatal deaths have avoidable factors. Finally, obstetric care coverage has wide urban–rural and rich–poor *equity gaps*. In Sub-Saharan Africa and South Asia, rates of skilled birth attendance are 5-fold higher in the highest versus lowest wealth quintiles [1]. In Sub-Saharan Africa, in rural versus urban areas respectively, rates of skilled birth attendance are 29% versus 75%, and cesarean delivery rates are 1% versus 5% (Fig. 1).

1.3. Objectives of this review

In this paper, the second in a series that focuses on reduction of intrapartum-related deaths, we systematically review approaches during labor and birth to reduce these deaths in low-resource settings, including clinical interventions and strategies to increase coverage and quality. We evaluate impact on mortality outcomes including intrapartum-related neonatal mortality rate, early neonatal mortality rate (ENMR), neonatal mortality rate (NMR), intrapartum-related stillbirth rate, stillbirth rate (SBR), perinatal mortality rate (PMR), and maternal mortality ratio (MMR). We also consider non-fatal intermediate outcomes including neonatal encephalopathy and low Apgar score. We use the GRADE (Grading of Recommendations Assessment, Development, and Evaluation) System to assess evidence quality and make recommendations [22].

This paper interprets available evidence for addressing high risk/high prevalence obstetric complications in the context of constraints in resource-constrained settings. We build on recent comprehensive reviews [23] and previous World Health Organization (WHO) guidelines that have made recommendations for care during normal childbirth [24], emergencies in pregnancy and childbirth [25], and newborn emergencies [26].

While there is a major supply-side gap for obstetric care, with long distances to facilities and lack of staff and equipment, there are also other barriers including financial constraints, cultural practices, and lack of empowerment of women to seek care, as well as wider health systems and governance issues. This paper focuses on supply-side constraints for childbirth care. Other papers in this series review linking families and facilities, including overcoming delays to care [17], and what can be done for 60 million non-facility births [27]. Neonatal resuscitation is an important adjunct to emergency obstetric care and is reviewed in the third paper [28]. Perinatal audit has potential to improve quality of care [29]. The final paper outlines a health systems approach to care at birth [19].

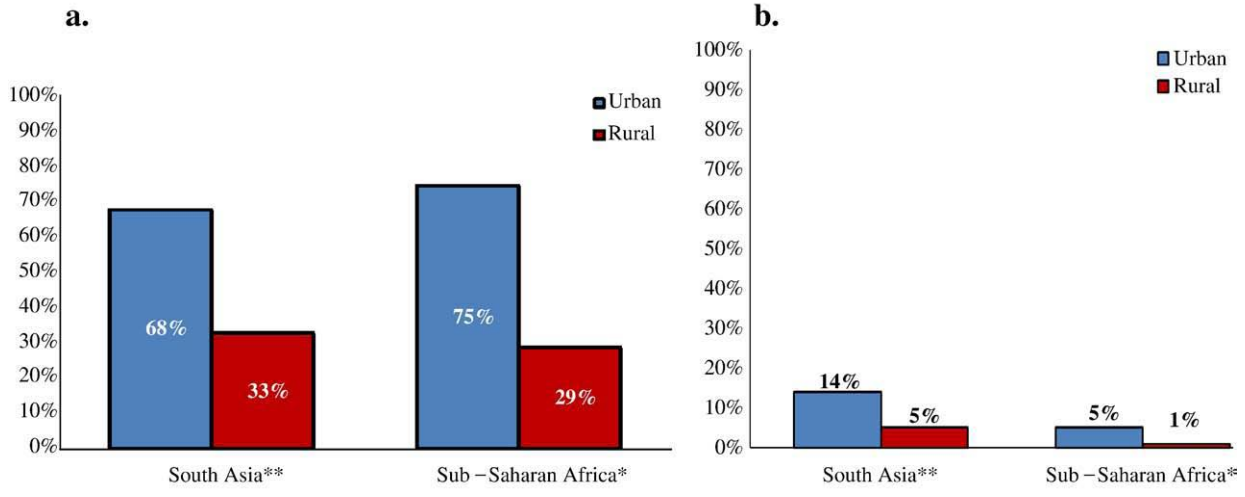

Fig. 1. Variation in rates of cesarean delivery performed for women in urban and rural populations. a. Skilled attendance at birth. b. Cesarean delivery. * Sub-Saharan Africa includes: Benin, Burkina Faso, Cameroon, Chad, Congo, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia, and Zimbabwe. ** South Asia includes: Bangladesh, India, Nepal, and Pakistan. Source: New analysis based on Demographic and Health Surveys 2000–2007; averages weighted to population.

2. Methods for searches, abstraction, and synthesis

Methods for the literature review are described in detail in the first paper in this series [1]. Searches of the medical literature were conducted using PubMed, Popline, EMBASE, LILACS, IMEM, African Index Medicus, Cochrane, and World Health Organization (WHO) document databases. Initial searches were conducted in November 2002 and September 2007; focused searches were updated in May 2009. Keyword searches for this manuscript are shown in an appendix in the online version (Appendix A). All effect sizes reported are relative percentage mortality rate reduction, as opposed to absolute percentage reduction.

The level of evidence was assessed using the GRADE system [30] criteria to evaluate the quality of the evidence (high, moderate, low, or very low) and given a recommendation for programmatic application (strong, weak, conditional). We use an adaptation of GRADE developed by the Child Health Epidemiology Reference Group (CHERG) specifically for low- and middle-income settings [31]. As our specific interest is for intrapartum-related ("birth asphyxia") outcomes, this is a particular constraint, as cause-specific data are limited [1].

3. Evidence for interventions to prevent and manage intrapartum complications

We review the evidence for impact on intrapartum-related mortality and morbidity of interventions to prevent and manage intrapartum complications, organized by obstetric emergency entry points with priority given to the entry points with the highest risk/population attributable risk for intrapartum-related mortality, notably: (1) obstructed labor; (2) breech position; (3) suspected fetal distress, (4) hemorrhage; (5) severe hypertension/pre-eclampsia; (6) post-term; and (7) intra-amniotic infection (Table 1). There are some important risk factors and complications not covered here, notably maternal diabetes and gestational diabetes. There are very limited data from low-income settings at present on prevalence, risk, and feasible interventions—this is an area to be highlighted for more research, especially in South Asia, which has a high prevalence of type II diabetes.

In reviewing the evidence we pay particular attention to:

1. The possibility that interventions that have not been proven effective in trials from high-resource settings could be effective in low-resource settings where there is greater scope for improvement in care.
2. The effect of the clinical context in shaping risk-benefit calculations regarding specific interventions: for example, availability of safe cesarean delivery. If cesarean delivery is unavailable but the mother's or baby's life would be lost without intervention, interventions that increase the risk of cesarean delivery, such as oxytocin induction with unripe cervix, are discouraged, while alternatives to cesarean delivery may be appropriate.
3. Novel or unexplored solutions to extend coverage of interventions including the need for further testing of these strategies. Such innovations may also have important implications for cost savings and service provision in high-resource settings.

3.1. Obstructed/prolonged labor

Obstructed labor affects between 3%–6% of live births [32], and is a major contributor to maternal and perinatal morbidity and mortality accounting for an estimated 43 000 maternal deaths annually. Obstructed labor is also the highest-risk obstetric condition for perinatal mortality, with reported adjusted odds ratio of up to 80-fold [1]. Obstructed and/or prolonged labor can result from cephalopelvic disproportion, fetal malpresentation or malposition, or inefficient uterine contractions (atony). Obstructed labor is usually managed via instrumental delivery or cesarean delivery, or labor augmentation for uterine atony, although other procedures such as symphysiotomy may have been relatively neglected (Table 1).

3.1.1. Slow progress of labor

3.1.1.1. Presenting problem. The first stage of labor is considered delayed if the rate of cervical dilation in the active phase is lower than 1 cm per hour. A second stage of labor exceeding 2 hours in a primigravida and 1 hour in a multipara (plus 1 hour if epidural anesthesia has been given) is considered delayed [33].

3.1.1.2. Evidence for partograph use. The partograph was designed to monitor the progress of labor where intrapartum surveillance may be limited by staff shortages and lack of experienced staff [34,35]. The partograph (also called the partogram) is a paper form designed to encourage regular assessment of maternal and fetal condition once active labor is established; alert and action lines provide objective guidance for intervention. The alert line reflects the average rate of cervical dilation of the slowest quintile of term primigravidas, if dilation slows or ceases, the partograph plot will cross the alert line [36]. Higher rates of perinatal mortality are associated with delays of 4 hours or more after the alert line, so the action line is 2–4 hours after the alert line, which prompts interventions to accelerate labor or perform cesarean delivery [37–39].

Individually randomized trials of use of the partogram in a clinical trial setting are useful for comparing variations in partogram design. Yet few studies have assessed partograph versus no partograph, the impact of which would be underestimated in higher-resource settings where all women have close surveillance by experienced clinicians, who may make similar decisions whether or not the partograph is used. Several studies examining partograph use have reported perinatal outcomes (Table 2). A Cochrane review of partograph versus no partograph found a non-significant reduced risk of cesarean delivery overall (2 studies, n = 1590; RR 0.64; 95% CI, 0.24–1.7), which was statistically significant in low-income settings (1 study, n = 434; RR 0.38; 95% CI, 0.24–0.61) [40]. There was no effect on the proportion of 5-minute Apgar scores lower than 7; perinatal mortality was not reported. In a large prospective WHO study in South East Asian hospitals (1994) [41], partograph use was associated with reduced prolonged labor (from 6.4% to 3.4%), need for augmentation (20.7% to 9.1%), emergency cesarean delivery (9.9% to 8.3%), and stillbirth (0.5% to 0.3%).

The WHO has developed a simplified partograph without the latent phase of labor [42] that has been shown in one trial to be more user-friendly ($P = 0.002$) and more likely to be completed than the composite partograph, while being associated with fewer cesarean deliveries and comparable perinatal and maternal outcomes. Outcome evaluation of the effectiveness of the simplified partograph at scale is needed, linked with improved fetal heart rate monitoring devices. In low-resource settings, partograph use is recommended for monitoring all women in labor, and can serve as a guide for timely referral to Comprehensive Emergency Obstetric Care (CEmOC) facilities.

3.1.1.3. Evidence for mother's position during labor. A mother's position during labor and birth may affect her comfort, the progress of labor, the baby's position, placental perfusion, and her ability to bear down effectively.

Cochrane reviews have associated upright postures with shorter first stage of labor (mean difference –0.99 hr; 95% CI, –1.60 to –0.39 hr), less use of epidural analgesia (RR 0.83; 95% CI, 0.72–0.96), and a trend toward fewer cesarean deliveries (RR 0.73; 95% CI, 0.51–1.07), with possible increased risk of postpartum hemorrhage [43]. In contrast, supine laboring positions increase the risk of fetal acidosis and prolonged labor [44]. Hands-and-knees position in late pregnancy and/or during labor showed no statistically significant reduction in

Table 1
Summary of interventions (preventive and operative) for reducing intrapartum-related fetal–neonatal death and disability, with GRADE evidence of impact, risk-benefit considerations, and alternatives in low-resource settings.

Obstetric complication entry point	Specific condition or indication	Intervention strategy	Evidence according to GRADE		Impact estimates from Cochrane reviews (if available)	Risk-benefit considerations in low-resource settings	Feasibility issues and alternatives in low-resource settings
			Level of evidence	Recommendation strength			
1. Obstructed/prolonged labor (including malposition/ malpresentation, multiple gestation, cephalopelvic disproportion, uterine atony, etc).	Slow labor/failure to progress (inefficient uterine contractions, uterine atony)	Active management (amniotomy plus oxytocin augmentation) Cesarean delivery for failure to progress	Low (high-resource settings)	Weak	No statistically significant intrapartum-related outcomes [201]	Very modestly decreased risk of cesarean; increased risk of intrauterine infection if aseptic technique cannot be or is not observed; risks of uterine hyperstimulation and fetal distress from oxytocin use [48,201]. Uterine rupture risk of oxytocics with prior uterine incision(s), esp. classical.	Not advised in women with prior cesarean, multiple gestations, or areas with high prevalence of HIV or hepatitis or seropositive patients. May be inadvisable as routine practice where sanitary conditions and/or cesarean access are poor.
	Delayed second stage	Controlled fundal pressure	Low	Weakly not recommended	–	Non-operative, widely used, but theoretical risk of fetal injury including brain damage, risk of maternal uterine rupture or anal sphincter tears; can worsen shoulder dystocia if present	Fundal pressure one of few options where operative delivery unavailable – more research required. See Table 3: Alternatives to cesarean
		Instrumental delivery	Low	Conditional	No RCTs of instrumental delivery versus none	See Table 4: Alternatives to cesarean	See Table 3: Alternatives to cesarean
		Symphysiotomy	Very Low	Strong	–	See Table 4: Alternatives to cesarean	See Table 3: Alternatives to cesarean
	Shoulder dystocia	Prevention by induction for suspected macrosomia*	Low	Weakly not recommended	Shoulder dystocia: RR 1.06 (95% CI, 0.44–2.56) [60] [Among diabetic women] Macrosomia: RR 0.56 (95% CI, 0.32–0.98); 0 vs 3 cases of shoulder dystocia [61]	Benefits of non-operative option, vs risk of inaccurate estimation of fetal size, risks of induction including fetal distress (Table 5)	See Table 3: Alternatives to cesarean
		Management using therapeutic maneuvers with cesarean delivery for failure to deliver	Very low	Strong	5-min Apgar <7: RR 0.44 (95% CI, 0.02–10.61)	Sequence of maneuvers used in clinical practice has never been tested for effectiveness (episiotomy, McRobert, suprapubic pressure, posterior traction, finger traction on arm, rotation of shoulders, and tocolysis followed by cesarean delivery)	Rarely seen, posing challenge for low-volume maternity facilities. Training should include practice on a mannequin and regular obstetric drills
	Uterine rupture	Emergency laparotomy plus uterine repair or hysterectomy	Very low	Strong	No outcome data	Access to cesarean delivery limited, risks of cesarean (Table 4). Greater skill required for emergency hysterectomy	No alternatives in areas lacking cesarean/ hysterectomy capability
2. Breech presentation	Breech identified after 34 weeks of gestation	External cephalic version*	Low-moderate (High-resource setting) Very low (Low-resource setting)	Strong	PMR: RR 0.51 (95% CI, 0.05–5.54) 5-min Apgar<7: RR 0.76 (95% CI, 0.32–1.77) [202]	Reduces risk of breech birth, and cesarean, but no statistically significant impact on perinatal outcome. Risks (cord prolapse, fetal distress, and fetal injury) increase with fetal growth restriction, uterine bleeding, prior cesarean, fetal abnormalities, twin pregnancy, hypertensive disorders. Some breech positions due to position of cord and should not be reversed.	Particularly useful in settings in which safe cesarean is not consistently available, but recommendations suggest continuous ultrasound and a skilled physician to undertake the procedure
		Planned (elective) cesarean section	Moderate (High-resource setting) Low (low-resource setting)	Strong (High-resource setting) Weak-Conditional (low-resource setting)	PM or neonatal morbidity: RR 0.33 (95% CI, 0.19–0.56) PMR: RR 0.29 (95% CI, 0.10–0.86) [203]	Eliminates risk of injury or obstruction of aftercoming head; reduced risk of perinatal or neonatal death. Risk-benefit of cesarean (Table 4)	Risks in subsequent pregnancy where cesarean access poor (see Table 4). Vaginal breech delivery safe and feasible for complete or frank breech **if** provider is skilled, fetal head flexed, and no CPD.
	Breech presentation identified in labor	Emergency cesarean delivery	Low	Strong	–	Higher risk of perinatal morbidity and mortality than planned cesarean	See Table 3: Alternatives to cesarean
3. Suspected fetal distress	Decreased or absent fetal movement, cord accident, fetal heart rate/blood flow changes, thick meconium	Fetal monitoring methods: See Tables 6 and 7					
		Amnioinfusion	Moderate	Weak	*For meconium staining* neonatal encephalopathy: RR 0.09 (95% CI, 0.02–0.49) 5-min Apgar <7 (RR 0.45; 0.27–0.75) and a trend toward reduced PMR (RR 0.34; 0.11–1.06) [82]	Risk of intra-amniotic infection	

					For umbilical cord compression PMR: RR 0.51 (95% CI, 0.11–2.24) Birth asphyxia: RR 0.32 (95% CI, 0.15–0.70) [83] 5-min Apgar <7: RR 0.54 (95% CI, 0.30–0.97)		
		In utero resucitation	Low	Strong	Lower risk of base deficit ≤ 12 mEq/L (RR 0.68; 95% CI, 0.45–1.0) Lower risk of NICU admission (RR 0.47; 95% CI, 0.27–0.81) in resuscitated group [18]	May resolve fetal distress and avoid cesarean delivery, may avoid need for neonatal resuscitation, particularly relevant where cesarean is unavailable and/or great distances to EmOC health facilities	Requires access to tocolytics and capacity to administer
4. Severe hypertensive disorders of pregnancy (esp. pre-eclampsia and eclampsia)	Highly elevated maternal blood pressure, with or without proteinuria (chronic hypertension, pregnancy-induced hypertension, HELLP); seizures (eclampsia)	Antihypertensive drugs if systolic>160 mm Hg or diastolic > 110 mm Hg (no particular anticonvulsant superior)	Low	Weak	PMR: RR 0.98 (95% CI 0.88, 1.10) 5-min Apgar <7: RR 1.02 (95% CI 0.85, 1.22)	Potential toxicity, continuous maternal and electronic fetal monitoring advised.	Adequate fetal monitoring may be unavailable; lack of diagnostic capacity in some settings to monitor maternal organ function
		Anticonvulsant drugs (IV magnesium sulfate)	Very low	Conditional	Eclampsia: RR 0.41 (95% CI, 0.29–0.58, NNT 100) Placental abruption: RR 0.64 (95% CI, 0.50–0.83; NNT 100) [204]	Potential toxicity (rare) vs presence of seizures (or risk of eclampsia in severely pre-eclamptic patients); low cost and availability of MgSO4 in low-resource settings	Many settings lack monitoring capability for oxygen saturation, resuscitative equipment, catheterization, calcium gluconate for hypermagnesemia. NB: Severe malaria can resemble eclampsia.
		Early or rapid delivery for severe pre-eclampsia or eclampsia (Induction or elective or emergency cesarean)	Low (high-resource settings) Very low (low-resource settings)	Strong (high-resource settings) Strong (low-resource settings)	–	Risks and benefits associated with induction and elective cesarean in low-resource settings, especially iatrogenic prematurity (Tables 2 and 7)	Constraints associated with induction and cesarean delivery in low-resource settings (Tables 2 and 7)
5. Antepartum hemorrhage	Suspected placenta previa	Ultrasound confirmation of previa to confirm diagnosis, plan elective cesarean	Low	Moderate	–	Perinatal mortality reduced with diagnosis prior to labor. Ultrasound may not be available. Anticipate hemorrhage with vaginal delivery. Cesarean for previa increases risk of uncontrollable hemorrhage and complications including infection, injury of maternal bowel/bladder, and/or hysterectomy; consider surgical skill and access to safe blood transfusion (Table 4)	Impractical and hazardous at population level to diagnose without ultrasound. Rapid delivery may be risky or impossible where instrumental delivery, blood bank, and/or cesarean are unavailable, but few alternatives exist
		Cervical cerclage	Moderate	Weak. Not recommended in low-resource settings	5-min Apgar <7: RR 0.19 (95% CI, 0.04–1.00) likely attributable to reduced preterm birth, not prevention of hypoxic injury [110].	Procedure can cause hemorrhage or infection; requires diagnosis of placenta previa (difficult in low-resource settings)	Capacity to diagnose previa and insert stitch limited in settings without ultrasound and trained practitioners. No acceptable alternatives
	Placental abruption	Rapid delivery (labor induction or augmentation with or without instrumental delivery; or emergency cesarean), blood transfusion	Very low	Strong	No outcome data [110]	Access to cesarean limited, risks of cesarean (Table 4), access to safe blood transfusion	Alternatives to cesarean (see Table 3)
6. Post-term pregnancy	Suspected post-term pregnancy	Membrane sweeping at or after 41 weeks of gestation	Very low	Weak		Prostaglandin release often induces labor; more likely effective in true post-term pregnancy than pregnancy with incorrect gestational assessment. Risk of infection or premature membrane rupture	Training needed to minimize risks of infection or membrane rupture
		Routine induction of labor at 41–42 weeks	Moderate (high-resource settings) Low (low-resource settings)	Strong (high-resource settings Weak (low-resource settings)	PMR: RR 0.30 (95% CI, 0.09–0.99) Apgar<7: RR 0.85 (95% CI, 0.48–1.48) at 41 completed weeks; RR 0.24 (95% CI, 0.05–1.10) at 42 completed weeks	Reduced PMR and cesarean for fetal distress; reduced meconium aspiration. Risks associated with induction (Table 7)	May be inadvisable where few women have early ultrasound and/or intrapartum fetal surveillance and/or cesarean is unavailable
7. Maternal intrauterine infection	Tender uterus, fever, rapid fetal heart rate, offensive amniotic fluid	Antibiotics plus delivery	Low (indirect from high-resource settings)	Strong	No documented impact on intrapartum-related outcomes; however, reduced risk of chorioamnionitis and/or endometritis	No evidence of impact on all-cause neonatal mortality [122]; low risk intervention, but management depends on gestational age (risk of infection vs risk of prematurity)	Rapid delivery usually indicated; emphasis on prevention may be best strategy in resource-poor settings (prenatal screening for infections, minimal vaginal exams, clean hands, cautious use of amniotomy)

* Preventive interventions.

Table 2
Intrapartum monitoring impact using the partograph.

Intervention/study	Setting	Baseline MMR (per 100 000) and NMR (per 1000)*	% skilled attendance*	Impact percentage reduction in mortality rate *(measure of association, number of deaths)* SBR	ENMR	PMR	NMR	MMR	Investigator and year
Before-and-after comparison of pregnancy outcomes using partograph versus standard intrapartum care	Multicentre trial in 4 pairs of hospitals in SE Asia (Indonesia (2), Thailand (1), Malaysia (1))	MMR: Indo: 450 Malay: 53 Thail: 50 NMR: Indo: 17 Malay: 5 Thail: 9	Hospital-based: 81%	38% (IP SB) *(n = 148)*	-		-		WHO Safe Motherhood program [41] 1994
Comparison of avoidable perinatal deaths in hospital between 1971–76 and 1977–79 (partograph implemented with standard protocols to decrease high rate of avoidable IP SB)	Rural Tanzania, small hospital serving population of 75 000 with ~24% deliveries in hospital	MMR: not available NMR: 35	Deliveries mainly by "medical aides" National rate: 39%	-	-	40% *(n = 173)*	-	-	Van Roosmalen [205] 1989
Comparison of outcomes for women who crossed the alert and action lines on the partograph	Senegal Pikine hospital and four peripheral maternity clinics	MMR: 430 NMR: 35	Midwives and CHWs National rate: 47%	46%[b] (IP SB) *(N = 10)*					Dujardin et al. [206] 1992
Ongoing audit with implementation of changes, including management guidelines, use of partograph, and training	South Africa rural district health service 1991–1995 21 112 births	MMR: 150 NMR: 17	>80% National rate: 84%	-	-	36%[a] *(n = 653* weight >1000 g)	-	-	Wilkinson [207] 1997
Cluster-RCT comparing the WHO partograph with standard midwifery care	Medan City, Indonesia. 626 pregnant women serviced by midwives	MMR: 420 NMR: 17	Maternity-home-based using midwives National rate: 73%	38% (fetal death; OR 0.62; 95% CI, 0.17–2.19)	30% (OR 0.70; 95% CI, 0.16–3.11)	-	-	-	Fahdhy [208] 2005
Before-and-after study of use of partograph in breech delivery	Indonesia, Thailand, Malaysia, subset of WHO 1994 study	MMR: Indo: 450 Malay: 53 Thail: 50 NMR: Indo: 17 Malay: 5 Thail: 9	Hospital-based, 1740 breech presentations	42% (breech SB, 1.1% *(n = 8)* vs 1.9% *(n = 16)*, *P* = 0.163)	-	-	-	-	Lennox [209] 1998

Abbreviations: MMR, maternal mortality ratio; NMR, neonatal mortality rate; SBR, stillbirth rate; ENMR, early neonatal mortality rate; PMR, perinatal mortality rate.
* For MMR, NMR, and skilled birth attendance where data were not reported in the study, we sought data regarding national status on MMR, NMR, and skilled birth attendance from UN databases to give the context.
[a] Avoidable deaths reduced from 19% to 0%, with a high of 30%.
[b] 46% reduction in fresh stillbirth rate if intervention commenced when alert line crossed rather than waiting for action line.

malpresentation, malposition, or operative delivery [45]. The supine position should be avoided during labor and birth; women who wish to be mobile during first stage and upright during second stage of labor should be encouraged and assisted to do so.

3.1.1.4. Evidence for active management of the progress of labor.
Active management of the progress of labor (distinct from active management of the third stage of labor to prevent postpartum hemorrhage) may prevent dystocia and reduce cesarean delivery rates. Active management involves strict criteria for the diagnosis of labor, early amniotomy, early oxytocin (with high-dose oxytocin in case of inefficient uterine action), and continuous intrapartum professional support (see item 4.4) [46,47].

A Cochrane review of active management to prevent slow labor among women in spontaneous labor reported a slightly reduced risk of cesarean delivery in the actively managed group (RR 0.88; 95% CI, 0.77–0.99, risk difference 1.47%, NNT = 68) and modestly reduced time from admission to birth (mean difference 1.1 hr; 95% CI, 0.41–1.82 hrs) [48]. There were no differences in perinatal morbidity or mortality indicators. Another Cochrane review of an active management package of care among low-risk women also found a modest reduction in cesarean risk, but no impact on perinatal outcomes (Table 1) [49]. Active management in both studies was associated with increased risk of uterine hyperstimulation and possible fetal heart distress, probably as a consequence of monitoring bias.

In Kalafong, South Africa, because of human resource constraints, nursing staff were insufficient to provide the continuous intrapartum support component of active management. A randomized controlled trial (RCT) was conducted comparing expectant management (vaginal exams every 4 hours, with oxytocin infusion only after the action line was crossed) with a protocol of "aggressive" management (use of the partograph and vaginal exams every 2 hours, with oxytocin infusion if the alert line was crossed). The trial reported a significantly lower risk of cesarean delivery in the aggressively managed group (RR 0.68; 95% CI, 0.50–0.93). Labors were also shorter, but there was no difference in neonatal outcomes; the authors concluded that early oxytocin is more effective than delayed use, but caution that this strategy requires more intensive nursing, although nursing burden is offset by more rapid labors [49].

Because each of the components of active management of labor has associated risks, including infection, hyperstimulation, and fetal distress, and need for cesarean, which may be of greater importance in low-resource settings, active management requires further study in these settings.

3.1.1.5. Evidence for the use of fundal pressure. Fundal pressure, a routine obstetric practice in many low- and high-resource settings, involves application of manual pressure to the uterine fundus directed toward the birth canal to avoid prolonged second stage and/or operative delivery (Table 3).

Fundal pressure is controversial, as anecdotal reports have associated its use, particularly if forceful, with maternal and fetal morbidities. In Turkey, a small RCT (n = 197) of fundal pressure reported no differences in duration of second stage of labor or fetal-neonatal morbidity or mortality between the control and intervention groups; however, mean pO2 was lower and mean pCO2 was higher in the fundal pressure group compared with controls (both measures were still in the normal range) [50]. A possible contributing factor was that fundal pressure was applied in the intervention group regardless of the progress of labor. Another RCT using an inflatable girdle also found no difference in duration of labor [51]. Data on intrapartum-related mortality and non-fatal outcomes associated with fundal pressure for delayed second stage would be particularly relevant to low-resource settings where assisted births or cesarean delivery is unavailable. Fundal pressure is not recommended for routine care, as its effectiveness and safety in women with a prolonged second stage of labor

Table 3
Alternatives to cesarean delivery in low-resource settings.

Alternative option GRADE evidence/recommendation	Description	Evidence of risk and benefit	Advantages and applications	Constraints
Fundal pressure* Low quality of evidence/Weak recommendation against	Application of manual pressure to the top of the uterus toward the birth canal to assist spontaneous vaginal delivery	Anecdotal reports of uterine rupture, maternal anal sphincter tears [210,211], neonatal fractures, or adverse neurological outcome; 2 small RCTs showing no impact of fundal pressure on duration of 2nd stage of labor (when used whether or not labor was delayed) and no neonatal encephalopathy (intervention or control) [50]	- May reduce prolonged labor and/or need for instrumental delivery - Relevant where assisted delivery, cesarean unavailable - Inflatable girdle can be used	Widely practiced but further research needed to determine effectiveness and optimal technique to reduce risk of maternal or fetal injury
In utero resuscitation* Low quality of evidence/Strong recommendation for	If fetal distress likely caused or worsened by uterine hyperstimulation, stopping oxytocin infusion and/or tocolysis can improve placental perfusion. Advised while preparing for cesarean section (ACOG) or during emergency transfer	RCT of in utero resuscitation for non-reassuring cardiotocography indicated lower risk of base deficit ≤12 mEq/L (RR 0.68; 95% CI, 0.45–1.0) and lower risk of NICU admission (RR 0.47; 95% CI, 0.27–0.81) in resuscitated group [18]	- May resolve fetal distress and avoid cesarean delivery - May avoid need for neonatal resuscitation - Particularly relevant where cesarean delivery is unavailable and/or great distances to EmOC health facilities	Requires access to tocolytics and capacity to administer
Instrumental delivery (vacuum extraction or forceps) Moderate quality of evidence/ Conditional recommendation for	Utilization of mechanical methods of traction applied to the fetal head to facilitate delivery	No RCTs of instrumental delivery vs none, only between methods, few with mortality outcomes [212]	- Can avoid cesarean delivery if unavailable or inadvisable - May be best option if fetal station precludes cesarean - Inexpensive manual vacuum extractor available [53]	Availability of equipment Choice of instrument depends on experience and preference of birth attendant
Symphysiotomy* Low quality of evidence/Strong recommendation for	An emergency procedure to widen the pubic symphysis during obstructed labor	No trials of symphysiotomy. Review of 5000 cases found very favorable results [54]	- May be life-saving where cesarean unavailable or culturally unacceptable - Quick, minimal equipment, local analgesia - "Modern" (partial) symphysiotomy has low morbidity and associated maternal mortality - Avoids increased uterine rupture risk in subsequent pregnancies associated with cesarean [213]	Strong global opposition as rarely practiced in high-resource settings, viewed as poor substitute for cesarean. Not an option after failed forceps Provider must be trained (teaching video on WHO Reproductive Health Library)

* Requires further research.

are unknown. Because it is so widely used, further research is important to provide adequate evidence for its use to be discouraged or promoted.

3.1.1.6. Evidence for instrumental birth. Instrumental birth (also called assisted vaginal delivery) utilizes traction applied to the fetal head in cases of obstructed or prolonged second stage of labor to accelerate birth, and is one of the components of Basic Emergency Obstetric Care (BEmOC). Either forceps or a vacuum extraction device (also called a *ventouse*) can be used to provide traction. The use of either instrument has been associated with birth trauma, although rates of injury are extremely low when performed by well-trained practitioners. Instrumental delivery may be conducted in an effort to avoid cesarean delivery or where cesarean delivery is unavailable. The risks and benefits to both mother and baby of cesarean delivery compared with vaginal delivery should be carefully considered in low-resource settings, particularly where cesarean delivery capabilities at facilities are suboptimal or women may not have ready access to safe repeat cesarean delivery during subsequent pregnancies, placing them at risk for uterine rupture and maternal death (Table 3).

Historical data suggest an ecological association between introduction of forceps (with aseptic technique) and declining perinatal mortality [8,12]; however, there are no RCTs of instrumental delivery versus no intervention, and virtually all data comparing forceps to vacuum extraction are from high-resource settings. A Cochrane review of vacuum extraction versus forceps found that few studies reported mortality outcomes; the review identified no statistically significant difference in mortality (OR 0.80; 95% CI, 0.18–3.52) or Apgar scores comparing vacuum versus forceps, respectively [52]. Vacuum extraction was associated with a slight increase in risk of neonatal injury (cephalhematoma and retinal hemorrhage) but a significantly lower risk of maternal trauma (OR 0.41; 95% CI, 0.33–0.50) and a trend toward lower risk of cesarean delivery (OR 0.56; 95% CI, 0.31–1.02). Vacuum extraction attempts were more likely to fail than forceps (OR 1.69; 95% CI, 1.31–2.19). A meta-analysis of vacuum extraction versus forceps found a statistically non-significant reduction in stillbirth risk (OR 0.60; 95% CI, 0.07–5.00) [13].

While instrumental birth clearly has the potential to be life-saving, there is a dearth of evidence comparing any instrumental birth mode with cesarean delivery, other intervention, or non-intervention. The optimal choice of instrument appears to depend largely on provider skill and availability of equipment. Vacuum extraction may be preferable where available based on its association with lower maternal morbidity, fewer cesarean deliveries, and superiority for managing certain fetal malpositions (e.g. deflexed occipital posterior). Inexpensive manual vacuum extractors are available that may expand access to this intervention, which is weakly recommended based on the lack of data on its use from low-resource settings [53].

3.1.1.7. Evidence for the use of symphysiotomy. Symphysiotomy is a surgical procedure to widen the pubic symphysis, which has recently been revisited as an alternative to cesarean delivery in some settings (Table 3). Reviewing more than 5000 documented cases of symphysiotomy in the literature, Bjorklund [54] demonstrated that symphysiotomy: (1) compares favorably with cesarean delivery in terms of risk for the mother's life and is equal to cesarean delivery in terms of risk to the newborn's life as PMR in 4 studies from 1973 to 1995 was 37 out of 307 (12.1%) versus 66 out of 571 (11.6%) in symphysiotomy versus cesarean cases, respectively; (2) confers a permanent enlargement of the mother's pelvic outlet while avoiding a cesarean scar and risk of subsequent uterine rupture; and 3) severe long-term complications are rare. Maternal postoperative pain and discomfort is an issue; however, this may be comparable to post-cesarean section pain. The authors also observed that symphysiotomy has been successfully used for the obstructed aftercoming head of the breech baby, and is appropriate in women who are poor candidates for surgery and/or anesthesia, including those with intrauterine infection. Ersdal et al. [55] confirmed that symphysiotomy results in a permanent widening of the symphysis joint while avoiding a cesarean scar, which facilitates future vaginal deliveries in women with a contracted pelvis. The "modern" form (partial symphysiotomy or Zarate procedure, developed in the early 20th century) has very low risk of maternal morbidity and mortality [56], although fetal and neonatal outcomes are infrequently reported.

When performed by a trained provider, symphysiotomy is a safe and important alternative to cesarean delivery [57]. Unfortunately, global opposition to symphysiotomy has cast the procedure as a poor substitute for cesarean delivery, and many providers are inexperienced with the symphysiotomy technique. Limited available data suggest that symphysiotomy is life-saving; further operational research is needed regarding training of providers and strategies for overcoming biases against the procedure. Symphysiotomy is strongly recommended where cesarean delivery is not available or culturally unacceptable [58,59] or the balance of risks may differ (Table 4). In its forthcoming version of the IMPAC manual, the WHO is endorsing symphysiotomy as a valuable additional management alternative in selected cases of prolonged labor. Further research on safety and effectiveness is encouraged.

3.1.2. Shoulder dystocia

3.1.2.1. Presenting problem. Shoulder dystocia occurs when birth becomes obstructed after birth of the baby's head and is fatal for the baby if not quickly resolved; various obstetric maneuvers have been described to overcome the obstruction.

3.1.2.2. Evidence for prevention of shoulder dystocia. Strategies to prevent shoulder dystocia include early induction of labor for suspected macrosomia (especially in women with gestational diabetes mellitus) and a prophylactic McRobert maneuver (flexion of the woman's thighs towards her chest during the second stage of labor, performed with or without suprapubic pressure to dislodge the anterior shoulder).

A Cochrane review of induction for suspected macrosomia found a trend toward reduced neonatal trauma (brachial plexus injury or fracture) in induced versus expectantly managed groups (0/183 vs 6/189) [60]. Another Cochrane review of elective induction at 38 weeks in diabetic women documented a reduced risk of macrosomia in the active induction group (RR 0.56; 95% CI, 0.32–0.98); all 3 cases of mild shoulder dystocia occurred in the expectantly managed group [61]. A Cochrane review of the prophylactic McRobert versus therapeutic maneuvers found a non-significant reduction in cases of shoulder dystocia (RR 0.44; 95% CI, 0.17–1.14) and proportion of infants with 5-minute Apgar score less than 7 (RR 0.44; 95% CI, 0.02–10.61) [62]. There is insufficient evidence to recommend any preventive procedures; larger trials are needed.

Table 4
Cesarean delivery in low-resource settings: Balancing risks and benefits.

Risk-benefit considerations
• Elective/planned safer than emergency if cesarean delivery is inevitable • Consideration of alternatives to cesarean delivery (Table 3) • Maternal age and future childbearing intentions ◦ Consider access to safe cesarean delivery for future pregnancies (risk of uterine rupture) • Availability of safe blood transfusion in case of hemorrhage • Simplified cesarean (Misgav-Ladach/modified Misgav-Ladach) vs conventional (Pfannensteil-Dorffler/traditional lower midline cesarean) ◦ Simplified procedure associated with shorter operating time, less blood loss, and shorter postoperative maternal fever and complications [214] ◦ Insufficient data to assess risk of intrapartum-related perinatal outcomes or risk of uterine rupture in subsequent pregnancy by method ◦ Observational data suggests less risk of subsequent uterine rupture with double layer closure of the myometrium

Alternatives to general anesthesia
• Spinal anesthesia • Ketamine • Local anesthesia: WHO recommends local anesthesia as a safe alternative, especially in emergency situations, where general anesthesia/spinal/ketamine, or anesthetist, not available [25].

Advantages of local anesthesia	Disadvantages of local anesthesia
Does not require transfer from facility if local anesthetics available	Delivery is more challenging, as bowel and omentum may interfere, adhesions from prior cesarean delivery may cause difficulty, and delivery of baby in deep transverse arrest more difficult [215] Mother may experience more pain
Lower risk of fever, headache, pain and nausea after procedure	Pfannensteil incision should not be performed with local anesthesia (takes longer, retraction poorer, requires more anesthetic)

3.1.2.3. Evidence for management of shoulder dystocia. A sequence of maneuvers to manage shoulder dystocia (Table 1) has been developed in clinical practice but never assessed for effectiveness [63,64]. Despite this lack of evidence, because shoulder dystocia is rapidly fatal for the baby all birth attendants should be trained in empirical methods of resolving shoulder dystocia, including practice on a mannequin and regular obstetric drills [65,66]. This is particularly critical for small obstetric care centers, as shoulder dystocia may be rarely encountered where caseloads are light, thus requiring frequent refresher trainings to maintain competence.

3.1.3. Uterine rupture

3.1.3.1. Presenting problem. Uterine rupture is loss of integrity of the myometrium that may result from dehiscence of a prior cesarean delivery scar, dysfunctional or obstructed labor, uterine hyperstimulation with uterotonics, and high parity. When oxytocin or other uterotonic drugs are administered inappropriately to induce or augment labor, particularly by unskilled attendants, there is a risk of uterine hyperstimulation or rupture, increasing the risk of intrapartum hypoxic injury [67,68]. Traditional herbal uterotonics place both the mother and the fetus at risk for hypoxic insult and increase the risk of intra-amniotic infection when inserted directly into the vagina [69–71].

3.1.3.2. Evidence for management of uterine rupture. Uterine rupture is a life-threatening condition that is diagnosed clinically, and accepted standard of care is laparotomy and uterine repair or hysterectomy. Strategies to reduce the risk of uterine rupture include avoidance or reduced dosage of uterotonic agents for labor induction or augmentation (Table 5), use of the partogram to diagnose prolonged labor, and avoidance of "unnecessary" cesarean deliveries to reduce the risk of

Table 5
Induction of labor in low-resource settings: Balancing risks and benefits.

When induction may be unwise	
Absolute risk reductions in perinatal mortality after induction are small (e.g. for post-term pregnancy, 368 labor inductions needed to avoid one perinatal death) [216]. Induction in low-resource settings may pose more risk than benefit: • Where gestational age is not confirmed via ultrasound early in pregnancy. • Where Bishop score<6 and/or cervical ripening fails. • Where tocolytics are not available to counteract uterine hyperstimulation. • In HIV-positive patients (if amniotomy is performed). • For multiple pregnancy or grand multiparity [217,218]. • Where intrapartum monitoring capability is limited or ineffective. • Where safe cesarean delivery is unavailable. • In primiparous women (lower success rate of induction than in multiparas).	
Potential risks of induction	**Potential benefits of induction**
Increased risk of perinatal mortality or disability due to: • Uterine hyperstimulation from labor induction (risk greatest when prostaglandins and/or oxytocin are induction agents). • Iatrogenic prematurity from incorrect gestational estimation [219].	Decreased complications of postmaturity, including meconium aspiration and fetal distress.*
Increased risk of cesarean delivery due to induction-related suspected fetal distress or failed induction.	Reduced perinatal mortality when used for certain indications (e.g. post-term, term PROM)* [128].
Avoiding uterine hyperstimulation and fetal distress	
A premium should be placed on avoiding uterine hyperstimulation in settings without safe cesarean capacity when inducing with unfavorable cervix. Membrane sweeping is one safer option; alternatively, a Foley catheter with extra-amniotic saline infusion (EASI) 50 mL/hr can be supplemented with intravenous oxytocin if necessary, which is as or more effective than prostaglandins when oxytocin is administered (GRADE evidence level: Moderate; Recommendation: Conditional)	
If EASI is not feasible, oral misoprostol 25 μg (dosage may be prepared accurately by dissolving 200 μg tablet in 200 mL potable water and administering 25 mL 2-hourly) can be used with careful fetal surveillance and established protocol [220]. Oral misoprostol has lower risk of uterine hyperstimulation (RR 0.37; 95% CI, 0.23– 0.59) than vaginal misoprostol [221] (GRADE evidence level: Low; Recommendation: Conditional)	

* Studies from high-resource settings.

rupture in subsequent pregnancies (Table 4). There is no evidence from rigorous trials for the optimal management of uterine rupture.

3.2. Breech birth

3.2.1. Presenting problem

Approximately 3%–4% of pregnancies are complicated by breech presentation at term (37–42 weeks), [72] which is associated with an elevated risk of perinatal mortality up to 10-fold compared with normal delivery [1] and of long-term disability or developmental delay (18.7%) [73]. External cephalic version and planned cesarean delivery at term may reduce these risks.

3.2.2. Evidence for external cephalic version for breech presentation

External cephalic version involves manual manipulation of the baby from the breech to the cephalic presentation, with or without the use of tocolytic agents to relax the uterus, with careful fetal heart rate monitoring. Ideally, ultrasound is used to exclude fetal anomalies, multiple pregnancy, and placenta previa and to identify the position of the umbilical cord because external cephalic version should not be performed on some breech-position fetuses. It is usually performed between 36 and 40 weeks of gestation.

A Cochrane review of external cephalic version at term [72] reported a significantly reduced risk of non-cephalic birth (RR 0.38; 95% CI, 0.18–0.80) and cesarean delivery (RR 0.55; 95% CI, 0.33–0.91), but a non-significant reduction in risk of perinatal mortality (RR 0.51; 95% CI, 0.05–5.54) and 5-minute Apgar score less than 7 (RR 0.76; 95% CI, 0.32–1.77). Commencing external cephalic version before term may be more effective; another Cochrane review [74] of 3 RCTs with women at 34–35 weeks of gestation found a decreased risk of non-cephalic birth and cesarean delivery compared with no external cephalic version at term, but no differences in intrapartum-related mortality outcomes were reported. Where access to safe cesarean delivery for breech is limited or unavailable, or where a trial of cephalic vaginal labor is desired, external cephalic version is an important alternative, but requires further testing in settings where ultrasound and cesarean delivery are not available.

3.2.3. Evidence for planned Cesarean delivery for breech presentation at term

Planned cesarean delivery is a strategy to avoid obstructed labor or fetal injury/compromise arising during vaginal breech birth, particularly associated with delivery of the aftercoming head.

A Cochrane review found that compared with planned vaginal breech delivery, planned cesarean delivery was associated with substantially reduced risk of perinatal mortality (excluding fatal anomalies) (RR 0.29; 95% CI, 0.10–0.86) [75]. Risks of complications and perinatal mortality were lower for elective than emergency cesarean delivery; ideally, breech presentation should be diagnosed prenatally to permit planned elective cesarean delivery. Reduction in relative risk of perinatal death was smaller and not significant in countries with a high PMR (RR 0.66; 95% CI, 0.35–1.24) than a low PMR (RR 0.07; 95% CI, 0.02–0.29).

Considering the small absolute risk reduction and no differences in long-term outcomes attributable to planned cesarean, selected vaginal breech delivery may be preferable in some low-resource settings, if the provider has sufficient skills (Tables 3 and 4).

3.3. Suspected fetal distress

3.3.1. Presenting problem

Intrapartum fetal distress has been presumed to indicate fetal hypoxia, which is associated with perinatal morbidity/mortality and long-term disability [76]. In South Africa, the Perinatal Problem Identification Programme found that inadequate intrapartum fetal heart rate monitoring, and consequent failure to identify intrapartum fetal distress and subsequently intervene, were common factors in neonatal deaths [18,77]. Accurate assessment of fetal well-being can improve recognition of and response to suspected distress. However, assessment relies on indirect and complex evidence including fetal movements, heart rate, vascular flow, and/or blood oxygenation, as well as amniotic fluid volume and appearance. The prevalence of diagnoses of fetal distress is directly proportional to the intensity of intrapartum monitoring.

Suspected fetal distress suggests the need for immediate delivery, often by cesarean, although amnioinfusion and in utero resuscitation have been proposed as alternative interventions to resolve distress (Table 1). An important consideration with fetal monitoring is the high rates of false positives for fetal distress associated with most intrapartum fetal monitoring methods, coupled with the poor ability to interpret monitoring results, that may both contribute to unnecessary cesarean deliveries [78].

3.3.2. Evidence for fetal monitoring to identify fetal distress

If continuous cardiotocography were affordable, systematic reviews comparing it with intermittent auscultation found increased rates of cesarean delivery and instrumental deliveries without evidence of long-term benefits (Table 6). Where safe cesarean delivery is not readily available, investment in such costly intrapartum monitoring equipment is not advisable (Table 4). Few options exist for fetal monitoring that are effective, simple, *and* affordable, but some promising monitoring strategies should be implemented and tested in low-resource settings, while others should be avoided (Tables 6 and 7).

Table 6
Fetal monitoring methods to identify fetal distress not recommended for use in low-income settings.

Monitoring strategy GRADE evidence/recommendation	Reasons for not recommending use
Continuous electronic fetal heart rate monitoring (cardiotocography) Moderate evidence/Strongly not recommended	• Expensive equipment and hard to sustain (e.g. expert maintenance, requires disposables). • Requires skill to interpret. • No impact on PMR compared with intermittent auscultation (RR 0.85; 95% CI, 0.59–1.23, n = 33 513, 11 trials). • Significant increase in cesarean delivery (RR 1.66; 95% CI, 1.30–2.13, n = 18 761, 10 trials) and instrumental birth (RR 1.16; 95% CI, 1.01–1.32, n = 18 151, 9 trials). • Reduction in neonatal seizures (RR 0.50; 95% CI, 0.31–0.80, n = 32 386, 9 trials) but trend toward increased risk of cerebral palsy (RR 1.74; 95% CI, 0.97–3.11, n = 13 252, 2 trials) [222].
Electronic fetal electrocardiogram assessment Moderate evidence/Strongly not recommended	• Complex and costly equipment, including scalp electrode. • Requires high level of expertise. • Risk of infection, requires ruptured membranes. • No advantage over cardiotocography alone in reducing PMR (RR 1.64; 95% CI, 0.5–5.28), neonatal encephalopathy (RR 0.37; 95% CI, 0.14–1.00), or 5-min Apgar <7 (RR 0.78; 95% CI, 0.56–1.08) [223]. • Inappropriate for settings with high HIV or hepatitis prevalence.
Fetal pulse oximetry Low evidence/Strongly not recommended	• Expensive equipment. • Technical problems obtaining adequate quality records [224]. • Slight reduction in risk of cesarean delivery (RR 0.68; 95% CI, 0.47–0.99); no impact on PMR, neonatal encephalopathy (RR 0.34; 95% CI, 0.01–8.44), or 5-min Apgar<7 (RR 0.71; 95% CI, 0.17–2.91) compared with cardiotocography alone
Assessment of amniotic fluid for meconium as indicator of distress Very low evidence/Weakly not recommended	• Very poor correlation between meconium staining and fetal condition [225–227]. • Meconium passage may be related to fetal maturity, transplacental exposure to smooth muscle stimulants such as herbal alkaloids, castor oil, rather than distress; alternatively, may be response to short-lived episode of fetal hypoxia.

Optimal monitoring options need not be expensive or intensive: an RCT in an urban hospital in Harare, Zimbabwe, found that intermittent use of the hand-held Doptone device compared with continuous cardiotocography led to similar rates of cesarean delivery (28% versus 24%) and comparable fetal outcomes [79]. A robust hand-held Doptone using wind-up technology rather than batteries has been developed for use in low-resource settings. In a limited clinical trial, women in labor preferred it to the Pinard stethoscope or cardiotocography [80]. A key research gap in the available arsenal of fetal monitoring is techniques to assess fetal distress in low-resource settings.

3.3.3. Evidence for amnioinfusion

Amnioinfusion refers to the augmentation of amniotic fluid with sterile saline, which may dilute meconium (if present) and thereby reduce the risk of meconium aspiration, and/or alleviate cord compression to correct fetal hypoxia. Amnioinfusion has been piloted in a low-resource setting without electronic fetal monitoring using a low-cost catheter [81].

One Cochrane review studied amnioinfusion for meconium staining [78]. Two studies in settings with limited peripartum surveillance reported a lower risk of meconium aspiration syndrome (RR 0.25; 95% CI, 0.13–0.47); neonatal ventilation or neonatal intensive care unit admission (RR 0.52; 95% CI, 0.37–0.73); and a trend toward reduced perinatal mortality (RR 0.37; 95% CI, 0.13–1.01). Neonatal encephalopathy was substantially reduced in one trial (649 women; RR 0.07; 95% CI, 0.01–0.56). In well-resourced settings, amnioinfusion for meconium-stained amniotic fluid had no statistically significant effect on substantive maternal or perinatal outcomes other than

Table 7
Fetal monitoring methods to identify fetal distress recommended for use in low-income settings.

Monitoring strategy GRADE evidence/recommendation	Description	Feasibility in low-income settings	Constraints
Intermittent auscultation Very low evidence/Strong recommendation	Listening to fetal heart with Pinard stethoscope to detect the baseline heart rate as well as early or late fetal heart rate decelerations.	• Inexpensive, non-invasive. • Preserves freedom of movement. • Essential for confirmation that baby is alive.	• Requires well-trained practitioner. • Less comfortable for mother than monitoring with Doptone. • Effectiveness in improving perinatal outcome not yet assessed.
Simplified umbilical artery Doppler Moderate evidence/Strong recommendation	Abnormal umbilical artery waveforms have been linked with adverse perinatal outcomes [228] and Doppler in high-risk pregnancies has been linked with reduced risk of perinatal death (RR 0.71; 95% CI, 0.50-1.01) compared to no ultrasound [229]. A simplified version of the Doppler ultrasound is a portable, continuous wave apparatus without ultrasound imaging.	• Less expensive than traditional Doppler; low-cost personal computer screen can be used as display. • Requires minimal training for low-level health workers [230]. • Could also be used as a screening test for fetal well being in early labor.	• More research needed to develop low-cost Doppler devices for low-income settings. • Effectiveness of simplified device in setting has not been tested.
Fetal blood sampling Low evidence/Conditional recommendation	Used to detect hypoxia and regarded as "gold standard" of fetal well being, involves oxygenation analysis of blood sample from fetal scalp.	• Recommended if equipment is available and infection risk to fetus is minimal.	• Requires expensive blood gas analyzer equipment and trained technician. • Requires ruptured membranes. • Fetal infection risk in areas with high HIV or hepatitis.
Doptone (hand-held Doppler) Moderate evidence/Weak recommendation	Hand-held device to detect fetal heart movement and count the fetal heart rate, either manually or displayed on an LED screen.	• Less technically challenging than auscultation. • Can identify late fetal heart rate decelerations. • Lower PMR (2/312 vs 14/625) and neonatal encephalopathy (1/312 vs 17/625) than with auscultation [79].	• Requires considerable provider training and skill to interpret. • Dependent on batteries/electricity, but robust wind-up version available.

neonatal ventilation or neonatal intensive care unit (NICU) admission (3 studies, 472 women; RR 0.45; 95% CI, 0.23–0.90) [82] and cesarean delivery (RR 0.70; 95% CI, 0.49–1.00). A second Cochrane review of amnioinfusion for umbilical cord compression [79] found a statistically non-significant reduction in perinatal mortality (RR 0.51; 95% CI, 0.11–2.24); however, significant reductions in risk of "birth asphyxia" (RR 0.32; 95% CI, 0.15–0.70) [83] and 5-minute Apgar less than 7 (RR 0.54; 95% CI, 0.30–0.97). For managing fetal distress, amnioinfusion is a weakly recommended intervention, and a priority area for further research.

3.3.4. Evidence for in utero resuscitation

In utero resuscitation (intrauterine resuscitation) is a strategy to minimize or resolve fetal distress likely caused or worsened by uterine hyperstimulation, whereby oxytocin infusion is stopped and/or tocolytics and respired oxygen are administered with the mother in the left lateral recumbent position, theoretically allowing time and improved placental perfusion for the baby to recover from fetal acidosis. The procedure can be performed in conjunction with amnioinfusion if membranes are ruptured. In utero resuscitation is advised by the American College of Obstetricians and Gynecologists (ACOG) while preparing for cesarean delivery or during emergency transfer [84,85].

There is no evidence from rigorous trials for an impact of in utero resuscitation on intrapartum-related outcomes, but an RCT of in utero resuscitation for non-reassuring cardiotocographic tracings showed that the resuscitated group had a lower risk of base deficit of 12 mEq/L or lower (RR 0.68; 95% CI, 0.45–1.0) and lower risk of NICU admission (RR 0.47; 95% CI, 0.27–0.81) [18]. Further research on in utero resuscitation is urgently needed.

3.3.5. Further research areas

In addition to further operational and effectiveness research on the recommended strategies in Table 7, other options hold promise for identifying and/or managing fetal distress in low-income countries (presented below in order of feasibility and promise), but cannot yet be recommended:

- ***Clinical fetal arousal tests:*** Noise or vibration can be used to stimulate fetal response (movement or heart rate changes) as reassurance of fetal well being; there is a high level of correlation in fetal condition assessment between fetal arousal testing and fetal blood sampling [86]. Minimal or no electronic equipment is needed (e.g. electric shaver or toothbrush, a soft drink can, or physically jostling the baby or stimulating the fetal scalp) [87–90]. Effectiveness of this strategy has not been assessed in RCTs but is promising.
- ***Amniotic fluid volume assessment*:** While abnormal amniotic fluid levels are clearly associated with adverse perinatal outcomes, ultrasound assessment of amniotic fluid volume has not demonstrated an impact on perinatal outcome [91]. Further research is needed on the accuracy of clinical assessment of amniotic fluid volume and the impact of subsequent interventions.
- ***Enquiring about fetal movement on admission:*** In cases of inadequate placental perfusion and infections, fetal movements usually decrease then cease some days before intrauterine death [92,93]; maternal perception of decreased movement may provide early warning of fetal distress. The intervention requires no equipment and minimal training but does require uniform prenatal education of mothers. A large cluster RCT in Europe included in the systematic review [89] found that prenatal fetal movement counting identified babies at risk of death, but had no impact on the actual number of deaths. It is possible that the effect of the intervention was obscured by contamination, as informal fetal movement counting could not be prevented in the control group. Rates of unexplained fetal death were considerably lower in both groups than before commencement of the trial. The scope for inquiry about fetal movements to improve outcomes may be greater in settings where general knowledge of the significance of fetal movements is lower. This would need to be confirmed by trials in such settings.

3.4. Management of hypertensive disorders in pregnancy

3.4.1. Presenting problem

High blood pressure with or without proteinuria complicates 5% of all pregnancies and 11% of first pregnancies [94]. Pre-eclampsia (high blood pressure with proteinuria) and eclampsia (seizures) occur in 2%–8% of pregnancies [95] and increase the risk of maternal death, premature delivery, and perinatal mortality [96] associated with impaired utero-placental blood flow causing fetal hypoxia or placental abruption [97]. Risk of perinatal mortality may be increased 2- to 14-fold, also varying with severity of the condition [1].

Antiplatelet agents and calcium supplementation have been shown to prevent pre-eclampsia [98], but the only known cure for severe pre-eclampsia and eclampsia is giving birth, which increases the risk of neonatal morbidity and mortality in preterm pregnancies [99]. Antihypertensives and anticonvulsants can be used in pregnancy to treat hypertensive disorders, but some anticonvulsant and antihypertensive drugs cross the placenta and may harm the fetus.

3.4.2. Evidence for use of antihypertensives

Well-designed, large trials that evaluate the effect of antihypertensives on maternal, fetal, and neonatal outcomes are lacking. A Cochrane review of all trials of antihypertensives found that all drugs substantially reduced high blood pressure, but found no statistically significant differences in rates of perinatal or neonatal morbidity or mortality between any two antihypertensives [97]. The review recommended that high-dose diazoxide, ketanserin, nimodipine, chlorpromazine, and magnesium sulfate (except to prevent eclamptic seizures) should be avoided owing to the increased risk of other adverse events. Additionally, extreme and/or rapid lowering of blood pressure can compromise utero-placental blood flow and fetal oxygenation.

3.4.3. Evidence for use of anticonvulsants

Intravenous or intramuscular magnesium sulfate is the anticonvulsant of choice, superior to diazepam or phenytoin, for preventing and treating eclamptic fits [100], and appears to neither cause harm nor confer benefit to the fetus. A Cochrane review of magnesium sulfate to prevent eclampsia in women with pre-eclampsia found no impact on stillbirth (RR 0.99; 95% CI, 0.87–1.12), perinatal death (RR 0.98; 95% CI, 0.88–1.10), neonatal death (RR 1.16; 95% CI, 0.94–1.42), or 5-minute Apgar score less than 7 (RR 1.05; 95% CI, 0.52–2.12) [101]. For women with severe pre-eclampsia at risk of seizures, magnesium sulfate is inexpensive and suitable for use in low-resource settings, and should be considered if there is concern about the risk of eclampsia. However, use of magnesium sulfate remains limited in many low-resource settings owing to lack of availability, fear of adverse effects, confusion regarding routes of administration, and dosing uncertainty [102].

Preliminary evidence suggests that the antihypertensive drug labetalol may reduce the risk of eclampsia in women with pre-eclampsia [103]. As oral labetalol would be easier to administer in low-resource settings that magnesium sulfate (which requires parenteral administration and intensive monitoring), research to determine its effectiveness is a priority.

3.4.4. Evidence for early or rapid birth

The mode of birth in severe pre-eclampsia and eclampsia (after stabilization of blood pressure, administration of anticonvulsants, and in utero resuscitation) is still controversial. Observational studies suggest similar outcomes of planned cesarean delivery versus induction [104], with worse outcomes for emergency cesarean [105], which is indicated for fetal distress. Pre-eclampsia usually resolves after birth, though close monitoring of maternal blood pressure and

neurological status for 24–48 hours postpartum is strongly advised [106].

3.5. Antepartum hemorrhage

3.5.1. Presenting problem

Antepartum hemorrhage, or significant vaginal bleeding in the second half of pregnancy, occurs in 3.5%–5% of all pregnancies and is an important contributor to maternal and perinatal morbidity and mortality [1,107]. Half of all cases are caused by placenta previa (where a placenta partially or completely overlies or is implanted in the cervix, around 0.5% of pregnancies) or placental abruption (separation of the placenta from the uterus, 1%–2% of pregnancies) [108]; less commonly, uterine rupture or placenta accreta are implicated [109]. Patients with placental abruption usually present with bleeding, uterine contractions (unless the uterus has ruptured), abdominal tenderness, signs of fetal distress, and/or hypovolemic shock.

3.5.2. Evidence for mortality effect or intermediary outcomes

There is little evidence for optimal management of pregnancies at risk of antepartum hemorrhage, although immediate delivery is commonly undertaken, either via induction and/or active management of labor (often with instrumental delivery), or cesarean delivery. Intravenous fluids or blood transfusion may be needed to restore blood volume.

3.5.3. Evidence for management of placental abruption

Placental abruption is diagnosed clinically, and its usual management is rapid birth. There is no evidence from RCTs for the optimal management of placental abruption in any setting [110].

3.5.4. Evidence for management of placenta previa

Ultrasound has radically improved screening, diagnosis, and management of placenta previa and placenta accreta, and perinatal mortality associated with placenta previa has subsequently declined [107]. Cervical cerclage (a stitch to hold the cervix closed) is thought to prevent or slow the dilation of the cervix, which may reduce the incidence of detachment and hemorrhage in case of a low-lying placenta. A Cochrane review of cervical cerclage versus no cerclage in placenta previa cases found a borderline significant reduction in Apgar score less than 6 at 5 minutes (RR 0.19; 95% CI, 0.04–1.00), but this was likely mediated more by prevention of prematurity rather than reduction in intrapartum-related neonatal deaths [110].

3.6. Post-term pregnancy

3.6.1. Presenting problem

Perinatal mortality risk increases in pregnancies that progress beyond 42 weeks of gestation, which has led to policies of labor induction between 40 and 42 weeks to reduce risks of postmaturity, meconium aspiration, and cesarean deliveries for fetal distress [111,112]. The risk is moderate compared with many of the other conditions listed here (aOR 1.5) but the prevalence may be high, so the population level effect is likely significant [1].

3.6.2. Evidence for membrane sweeping

Sweeping of the placental membranes, performed at or beyond term, entails inserting a finger through the cervix and separating the membranes from the lower uterine segment with a circular motion. Membrane sweeping disrupts decidual cell lysosomes and releases prostaglandins, in some cases stimulating cervical ripening and/or the initiation of labor. A Cochrane review found that membrane sweeping was significantly associated with reduced risk of pregnancy continuation beyond 41 weeks (RR 0.59; 95% CI, 0.46–0.74) and 42 weeks (RR 0.28; 95% CI, 0.15–0.50) [113], but no difference in perinatal outcome was observed. However, all pregnancies in the trial settings were closely monitored, and both intervention and control groups were offered routine labor induction at 41 or 42 weeks. Where medical labor induction is unavailable or inadvisable (Table 5), routine membrane sweeping could potentially hasten onset of labor and improve perinatal outcome. Membrane sweeping is more likely to be effective in true post-term pregnancy than pregnancies with incorrectly estimated gestational age and is weakly recommended at or beyond 40 weeks of gestation if early ultrasound dating of gestational age is available. Membrane sweeping requires rigorous trials in low-resource settings.

3.6.3. Evidence for elective induction of labor

Many physicians in high-resource settings routinely induce labor at 41 or 42 completed weeks of gestation to reduce the risks of fetal morbidity and mortality. A Cochrane review of labor induction in normal pregnancies at or beyond term found a non-significant reduction in PMR at 41 completed weeks (RR 0.25; 95% CI, 0.05–1.18) or 42 completed weeks (RR 0.41; 95% CI, 0.06–2.73), but when all post-term inductions at 41 completed weeks or more were analyzed together, a statistically significant reduction in PMR was observed (RR 0.30; 95% CI, 0.09–0.99) [114]. Risk of meconium aspiration syndrome was also significantly reduced in the group induced after 41 weeks (RR 0.29; 95% CI, 0.12–0.68) and non-significantly after 42 weeks (RR 0.66; 95% CI, 0.24–1.81). A trend toward reduced risk of 5-minute Apgar score less than 7 was also reported (RR 0.24; 95% CI, 0.05–1.10). While evidence is moderate for labor induction at 41–42 weeks of gestation in high-resource settings, absolute risk reduction is small and multiple factors should be considered in decisions to induce labor in low-resource settings, including difficulty in precisely determining gestational age [115] (Table 5).

3.7. Maternal infection

3.7.1. Presenting problem

Intra-amniotic infection (chorioamnionitis) and fetal cerebral hypoxia be a synergistic for brain injury and neonatal encephalopathy [116–118]. Clinical diagnosis is based on presence of unexplained maternal fever, rapid fetal heartbeat, tender uterus, and/or foul-smelling amniotic fluid. Although prevalence data are poor, both subclinical and symptomatic intra-amniotic infections have been associated with preterm prelabor rupture of membranes (pPROM) and preterm labor [119,120], as well as labor abnormalities, increased need for oxytocin, and increased risk of cesarean delivery. In addition, maternal fever alone has been shown to be an independent risk factor for intrapartum-related mortality and neonatal encephalopathy, with an adjusted OR of approximately 10-fold [15,121].

3.7.2. Evidence for antibiotics for chorioamnionitis and prelabor rupture of membranes

Research on treatment of chorioamnionitis has investigated different parenteral antibiotic treatment regiments and the effect on neonatal and maternal morbidity [122–124]. In one small study (n = 45) comparing intrapartum versus postpartum ampicillin and gentamycin for the treatment of intraamniontic infection, there was a non-significant reduction of neonatal mortality, sepsis, and pneumonia [125]. There were no studies that reported the effect on intrapartum-related outcomes.

A Cochrane review of antibiotic administration for pPROM reported that antibiotic treatment was associated with a significant reduction in risk of chorioamnionitis (RR 0.57; 95% CI, 0.37–0.86), and longer time to delivery (RR 0.71; 95% CI, 0.58–0.87), as well as major markers of neonatal morbidity, but no statistical differences in perinatal mortality were reported (RR 0.90; 95% CI, 0.74–1.10) [126].

A Cochrane review of prophylactic antibiotics in cases of prelabor rupture of membranes (PROM) found no statistically significant differences in perinatal mortality (RR 0.98; 95% CI, 0.14–6.89), 5-minute Apgar score less than 7 (RR 0.98; 95% CI, 0.28–3.34) [122,127], or chorioamnionitis (RR 0.60; 95% CI, 0.30–1.18) [127]. However, risk of endometritis was significantly reduced (RR 0.09; 95% CI, 0.01–0.73).

A Cochrane review of antibiotics to manage intra-amniotic infection reported a non-significant reduction in all-cause neonatal mortality (RR 0.25; 95% CI, 0.01–5.75), but the sample size was very small [122].

Although the evidence is low, treatment of chorioamnionitis with antibiotics and delivery should be standard of care for all pregnant women and is strongly recommended for low-income settings given the high case-fatality rate of early onset neonatal sepsis. Antibiotic therapy (excluding clavulanic acid) is beneficial for the management of preterm PROM, but not for preterm labor with intact membranes. There is insufficient evidence to recommend antibiotic prophylaxis or immediate delivery for term PROM [128], but research for interventions to prevent PROM and prevent and treat chorioamnionitis or maternal pyrexia, particularly with ruptured membranes, is needed. As digital vaginal examinations increase the risk of ascending infection, they should be avoided or minimized in patients with pPROM and PROM, especially in latent phase labor.

3.8. Summary of evidence for intrapartum care interventions

Rigorous evidence for interventions during labor to reduce the risk of perinatal death and particularly intrapartum-related deaths is scarce. While data from high-resource settings support planned cesarean for breech presentation and post-term induction, data from low-income countries are severely lacking, and risks of these interventions in low-resource settings may outweigh the small absolute reductions in risk (Tables 3 and 5). Several alternatives to cesarean delivery (Table 3), including instrumental delivery and symphysiotomy, are life-saving and scalable, but have not been tested in rigorous RCTs, and would require investments in equipment and/or training. Evidence for some benefit of amnioinfusion in middle-income settings is promising, but comes primarily from a meta-analysis of small studies; further research is needed to determine whether amnioinfusion is safe, effective, and feasible in low- and middle- income countries. Simple and inexpensive interventions such as partograph use, external cephalic version, and in utero resuscitation have shown no impact on perinatal mortality outcomes in high-resource settings, but require further investigation of potential impact in resource-constrained settings. Finally, there is a dearth of simple, feasible, effective interventions for several important risk factors for intrapartum-related injury, such as antepartum hemorrhage and intra-amniotic infection.

4. Delivery of intrapartum care in low-resource settings

The global deficit of more than 4 million trained health workers is most acute where maternal and perinatal mortality are highest, especially in Sub-Saharan Africa and much of South Asia [129]. For example, Malawi has 1.1 doctors and 25.5 nurses per 100 000 population, compared with 230 doctors and 1212 nurses per 100 000 population in the United States [129]. In the highest mortality settings, skilled birth attendant (SBA) coverage reaches only 46%, and median coverage of cesarean delivery is 3%, well below the minimum expected 5% level recommended by the UN [1].

The prevailing challenge for low- and middle- income regions is how to increase the supply, quality, and equity of obstetric care in settings of extreme human resource constraints. In this section, we address innovative supply-side strategies to strengthen Emergency Obstetric Care (EmOC) at the facility level, which is merely one aspect of the strengthening activities needed globally to reach the poor. Later in this series, we address demand-side strategies to increase care seeking and utilization of obstetric services, and link families to facility-based obstetric care [17]; provision of skilled childbirth care within the community [27]; and perinatal audit as a quality-improvement strategy [29].

4.1. Intrapartum care packages

The two primary maternal health strategies promoted by the United Nations to reduce intrapartum-related maternal mortality are: (1) universal access to a skilled birth attendant for all mothers during childbirth; and (2) ensuring prompt, universal access to EmOC [130]. A skilled birth attendant is a facility-based or community-based medically trained provider with midwifery skills including monitoring the progress of labor, augmenting labor, normal childbirth using aseptic technique, actively managing the third stage of labor, newborn resuscitation, and appropriate referral for mothers requiring advanced interventions [131].

Specific packages and standards for EmOC have been defined for different levels of the health system, although overlap and ambiguity in contents of various obstetric care packages have generated substantial confusion and debate [132,133]. Ideally, all women would have access to essential obstetric care, which includes intrapartum monitoring with early detection and management or referral of complications. BEmOC is comprised of 6 key non-surgical "signal functions": the use of intravenous/intramuscular antibiotics, intravenous/intramuscular oxytocics, intravenous/intramuscular anticonvulsants, manual removal of retained placenta, removal of products of pregnancy, and assisted vaginal delivery. CEmOC functions include all BEmOC functions plus cesarean delivery (which typically requires an operating theater) and blood transfusion [133]. One CEmOC and 4 BEmOC facilities are recommended per 500 000 population to adequately service the 15% of deliveries estimated to experience complications (Fig. 2) [134].

The evidence for the impact of EmOC packages has recently been systematically reviewed [135]. Evidence of the impact of the package on perinatal mortality has not been evaluated as a whole and hence data are based primarily on low-quality historical trends and ecologic data. An expert Delphi process estimated that universal application of BEmOC and CEmOC packages together may avert 75% of intrapartum-related neonatal deaths—very high impact yet currently low coverage (Fig. 1) [135] (GRADE evidence level: Low; Recommendation: Strong).

4.2. Strategies to improve quality of EmOC packages

4.2.1. Strategy definition

Delay in diagnosis, failure to implement appropriate interventions correctly or at all, and poor teamwork have been shown to contribute to suboptimal outcomes in obstetric emergencies [136]. Several innovative strategies, including in-service training, obstetric simulations and drills, rapid response teams, safety checklists, and intrapartum risk assessment aim to minimize delay and error in EmOC provision by improving knowledge, competency, and skill retention of providers. Training courses, such as ALARM, ALSO, and Life-Saving Skills, can train providers to better manage obstetric emergencies [137–139]. Obstetric simulations and drills involve the practice of specific clinical algorithms or action plans in response to simulated obstetric complications and emergencies to identify deficiencies and improve teamwork (Panel 1) [65]. Educational tools for training courses and drills may include formal classroom lectures, internet modules, computer-based simulations, model-based simulations with medical equipment, and real-time observed experiences on the maternity ward [140]. Surgical Safety Checklists have been shown to reduce surgical complications (half of which are preventable), iatrogenic infection, and anesthesia-related errors by improving team communication [141].

4.2.2. Evidence for in-service training, obstetric simulations and drills, and rapid response teams

Only two studies reported perinatal outcomes associated with training, obstetric drills, and/or rapid response teams. In a tertiary care hospital in Bristol, UK, the Practical Obstetric Multi-Professional Training (PROMPT) Course was used to train midwives to monitor labor and manage obstetric emergencies including shoulder dystocia,

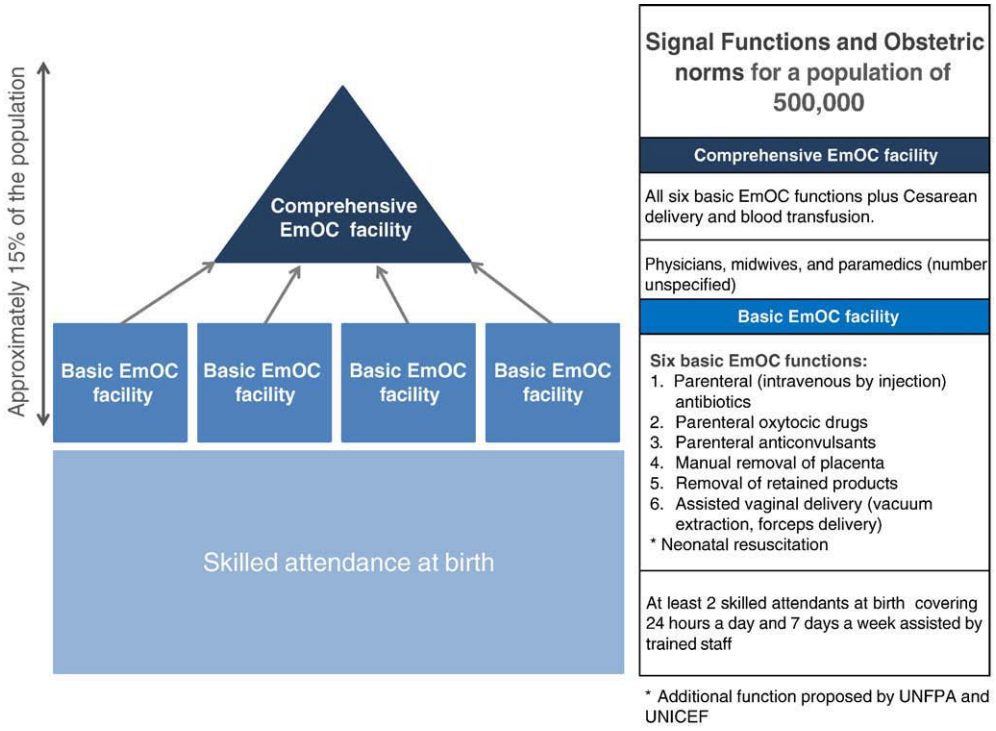

Fig. 2. Summary of United Nations standards for provision of obstetric care services. Source: UNICEF, WHO, UNFPA [133] 1997.

postpartum hemorrhage, eclampsia, twin/breech delivery, and neonatal resuscitation. Before-and-after training comparisons showed a significant reduction in 5-minute Apgar scores less than 6 (86 versus 44 per 1000 births, RR 0.50; 95% CI, 0.26–0.95) and neonatal encephalopathy (27 versus 14 per 1000 births, RR 0.51; 95% CI, 0.35–0.74) [142]. Rates of emergency cesarean delivery increased from 9.3% to 11.4%, potentially owing to improved monitoring and early recognition of complications. The same Bristol-based investigators also assessed the impact of shoulder dystocia drills; standardized procedures and checklists included in these training exercises improved physician practices and skill retention for up to 1 year [143–145]. A before-and-after comparison associated shoulder dystocia drills with reduced risk of neonatal injury and brachial plexus injury at birth (RR 0.25; 95% CI, 0.11–0.57 and RR 0.31; 95% CI, 0.13–0.72, respectively) [146].

A recent review of EmOC training programs in hospitals that have reported subsequently improved outcomes identified labor wards as more effective training settings than simulated facilities. The review identified the following common features of successful programs: institution-level incentives for training; multi-professional training; integration of teamwork training with clinical instruction; and use of high-fidelity simulation models such as mannequins [136].

In southern Vietnam, an EmOC Life-Saving Skills and refresher cesarean delivery training course was given to midwives and physicians [147]. Recognition and appropriate management of life-threatening obstetric emergencies improved in both intervention primary clinics and secondary hospitals; no intrapartum outcome data were reported.

Rapid response capability appears critical (Panel 1); a small prospective study in Finland reported significantly shorter decision-to-delivery intervals when an emergency cesarean team was available in-hospital versus on-call (13.5 ± 0.7 min vs 23.6 ± 0.9 min). Significantly fewer intrapartum stillbirths occurred among cases managed by the in-hospital versus the on-call team (0/60 vs 3/41, $P = 0.05$). Most adverse outcomes occurred after delays of 20 minutes or more; one case of neonatal encephalopathy occurred in the control group [148] (GRADE evidence level: Low; Recommendation: Strong).

4.2.3. Evidence for safety checklists

Implementation of the WHO Surgical Safety Checklist in 8 hospitals led to significantly reduced surgical mortality (from 1.5% to 0.8%, $P = 0.003$), and surgical morbidity (from 11% to 7%, $P < 0.001$) [141]. In each facility, deficiencies in baseline practices were identified and a surgical checklist, including 19 items covering the basic practices of safe anesthesia, infection prophylaxis, and effective teamwork, was implemented. Complication rates were reduced most in low-income settings, and 6 process indicators of quality of care significantly improved across all sites (GRADE evidence level: Moderate; Recommendation: Strong).

4.2.4. Evidence for intrapartum risk screening and preparedness for neonatal resuscitation

Anticipating which infants may require neonatal resuscitation could aid EmOC teams in emergency preparedness, but 20%–76% of infants requiring neonatal resuscitation have no risk factors [149,150]. An intrapartum risk stratification system to triage a "Neonatal Resuscitation Team" attending primarily moderate and some high-risk deliveries in a Canadian hospital [151–153] identified 80% of newborns requiring positive pressure ventilation (PPV). The strongest predictors of need for PPV (OR>2) included multiple pregnancy less than 35 weeks, maternal hypertension, preterm birth less than 34 weeks, use of general anesthesia, shoulder dystocia, meconium stained liquor, and emergency cesarean delivery. A similar approach of risk stratification with modified risk factors could assist in triaging limited staff skilled in resuscitation to attend deliveries (GRADE evidence level: Very Low-Low; Recommendation: Weak-conditional).

4.2.5. Implications

There is limited evidence, primarily from high-resource settings, that quality improvement measures may improve provider recognition and management of obstetric complications and subsequent perinatal outcomes. Most life-threatening intrapartum complications become clinically apparent either during or just before labor, and treatment is time-dependent [154]. Quality-improvement strategies could speed the delivery of appropriate interventions and save lives [155]. Training programs in neonatal resuscitation in low-resource

facility settings have resulted in improvements in provider competency and intrapartum-related outcomes [28]. EmOC training could have similar or greater impact but these programs have yet to be evaluated for outcome effects. Team preparedness, risk screening, and appropriate triage could target rapid intervention to urgent cases. Safety checklists can be used with any of the above strategies as a tool to decrease preventable and/or iatrogenic morbidity and mortality. Application of this concept to childbirth care is in process, with WHO leading development of a Safe Childbirth Checklist.

4.3. Continuous labor support/continuity of care in childbirth

4.3.1. Strategy definition

Shortages of physicians and nursing cadres in many low-resource settings lead to low staff-to-patient ratios, which preclude one-to-one support and monitoring of labor [156]. Shift changes further diminish the likelihood that women will receive care from the same provider(s) throughout labor. Hospital policies in many low-income countries prohibit companions of laboring women from entering the maternity ward, leaving many women to labor unattended. This lack of continuous care stands in stark contrast to the widespread custom of traditional birth attendants and/or female relations providing touch, verbal encouragement, assistance with birthing positions, and food/drink to women during labor and the early postpartum period at home [157]. A lack of continuous intrapartum care in an unfamiliar environment has been theorized to contribute to increased maternal stress, anxiety, and exhaustion, prolonged labor [158], and suboptimal intrapartum monitoring [159,160].

4.3.2. Evidence for mortality effect or intermediary outcomes

A Cochrane review of 13 RCTs in multiple countries (Table 8) found that compared with no support, presence of a female supportive companion was associated with shorter labor duration (mean difference 0.42 hrs, 95% CI, −0.83 to 0.04), reduced risk of cesarean delivery (RR 0.91; 95% CI, 0.83–0.99), 5-minute Apgar score less than 7 (RR 0.72; 0.51–1.02), intrapartum analgesia (RR 0.89; 95% CI, 0.82–0.96), instrumental vaginal delivery (RR 0.89; 95% CI, 0.82–0.96), and dissatisfaction with the birth (RR 0.73; 95% CI, 0.65–0.83). Benefits were greater if the companion was not a hospital employee: in this subgroup, the reduced risk of poor 5-minute Apgar was statistically significant (RR 0.36; 95% CI, 0.14–0.90). Investigating the impact of non-hospital employees as companions, an RCT in an urban Botswana hospital found that female relatives providing intrapartum support were associated with a lower risk of intrapartum analgesia (53% vs 73%), augmentation (13% vs 30%), amniotomy (30% vs 54%), vacuum extraction (4% vs 16%), and cesarean delivery (6% vs 13%) [161].

Other studies from urban high-resource settings corroborate the positive impact of providing continuous support to women in labor, including significantly lower rates of cesarean delivery [162] and meconium staining [163] (RR 0.51; 95% CI, 0.28–0.94), with higher maternal satisfaction with birth (GRADE evidence level: Low; Recommendation: Strong) [163,164].

4.3.3. Implications

Continuous intrapartum support is associated with decreased stress, pain, and anxiety during labor, and subsequent decreased intervention, modest improvements in neonatal outcomes, and higher maternal

Table 8
Evidence for the effect of continuous support during labor on intermediate outcomes.

Intervention/study	Setting and population	Intermediate Outcomes	Investigator & year
Meta-analysis on the effects of continuous, one-to-one intrapartum support on maternal and infant outcomes. Support included nurses, midwives, doula, family member or friend (a childbirth professional or an individual with knowledge about the process of labor). Control groups did not have continuous intrapartum support.	16 trials from 11 countries including 13 391 women (4 trials from Mexico, Guatemala, South Africa, Botswana)	Supported women had: • Shorter labor (mean difference 0.42 hrs, 95% CI, 0.83–0.04). • Higher likelihood of spontaneous vaginal delivery (RR 1.07; 95% CI, 1.04–1.12). • Lower risk of intrapartum analgesia (RR 0.89; 95% CI, 0.82–0.96). • Lower risk of instrumental birth (RR 0.89; 95% CI, 0.82–0.96). • Lower risk of cesarean birth (RR 0.91; 95% CI, 0.83–0.99). • Less dissatisfaction with childbirth (RR 0.73; 95% CI, 0.65-0.83). • Greater benefits when provider was not hospital staff, and started early in labor. • Not associated with significantly decreased low 5-min Apgar scores (RR 0.72; 95% CI, 0.51–1.02), although sub-analysis of trials using non-hospital caregiver yielded significantly lower risk (RR 0.36; 95% CI, 0.14–0.90). • No differences in perineal trauma.	Hodnett et al. [157] 2006
RCT of continuous female family member present during labor.	Hospital setting, Urban Gaborone, Botswana	Mothers with companions had: • Higher rate of spontaneous vaginal delivery (91 vs 71%). • Less intrapartum analgesia (53 vs 73%). • Less augmentation of labor (oxytocin 13 vs 30%; amniotomies 30% vs 54%). • Fewer assisted (vacuum 4% vs 16%) and cesarean (6% vs 13%) deliveries.	Madi et al. [161] 1999
Follow-up evaluation of postpartum outcomes after RCT of continuous labor support by lay doula. Pregnancy outcomes included in Cochrane review.	Urban hospital, New Jersey, USA	• Doula supported women were more likely to report positive prenatal expectations about childbirth. • More positive perceptions of infants, support from others, and self-worth. • More likely to breastfeed within first hour of life and by time of postpartum interview.	Campbell et al. [164] 2007
RCT of presence of companion during labor and delivery. Companion of choice was most frequently child's father or pregnant woman's mother.	Urban hospital, Sao Paulo, Brazil	• Women with companion had greater satisfaction with care received, medical guidance, and delivery experience for vaginal deliveries. • No significant differences in type of delivery, fetal heart rate, Apgar scores, NICU admission, birth weight, breastfeeding initiation, or mortality. • Lower rate of meconium stained fluid in support group (RR 0.51, 95% CI 0.28-0.94)	Bruggemann et al. [163] 2007
Retrospective evaluation of birth outcomes with and without doula support over 7-year program. Multivariate regression models to control for confounding factors.	Urban hospital, Boston, USA	• Statistically significant reduction in cesarean birth for primiparous women cared for by midwives. • Higher rates of breastfeeding intent and early initiation rates.	Mottl-Santiago et al. [162] 2007

satisfaction with birth. Providing or permitting continuous dedicated intrapartum support bridges the gap between traditional intrapartum care practices and hospital policies. Culturally sensitive intrapartum support could encourage more women to give birth in facilities.

Barriers to widespread implementation of continuous support include resistance from healthcare providers; additionally, in over-burdened health facilities, space and sanitation considerations may hinder implementation [156]. Support appears to lead to fewer interventions, with associated cost savings for health systems, and impact appears to be higher when the provider is familiar to the woman; a doula or female relation may be more effective than hospital-based providers, alleviating some portion of the caregiving burden on nursing staff at little or no cost. This promising and highly feasible intervention warrants more widespread implementation and evaluation.

4.4. Task-shifting and use of alternative cadres to provide EmOC

4.4.1. Strategy definition

Task-shifting maximizes available human resources by redistributing specific tasks from highly qualified professionals to the least-specialized professional capable of performing the task safely and reliably, including general practitioners or non-physician clinicians (NPCs) such as nurse-aides, midwives, surgical technicians, medical or clinical officers, and community-based workers. Task-shifting has been widely embraced in Sub-Saharan Africa, where numbers of NPCs exceed physicians [165] in several countries. Ethiopia, Mozambique, Zambia, and Malawi have accelerated training of NPCs [166]. In some Sub-Saharan countries (including Ethiopia, Malawi, Mozambique, and Tanzania), the national training curriculum for NPCs includes training in cesarean delivery; NPCs perform cesarean deliveries in at least 5 African countries [165,167,168]. Task-shifting may also mean having midwives perform instrumental deliveries, or using nurse-aides to provide intrapartum supervision to enable midwives or physicians to handle obstetric emergencies [140]. In other cases, new cadres of workers, such as surgical technicians, may be created to bridge the human resource gap [169,170].

4.4.2. Evidence for mortality effect (including safety) or intermediary outcomes

Population-level data are lacking (Table 9), but several studies report promising results of shifting intrapartum care functions to general practitioners or NPCs.

In Mozambique, assistant medical officers (*tecnicos de cirurgia*, or TCs) are the principal providers of emergency surgical care, including cesarean delivery. TCs receive 3 years of training in general surgery, obstetrics/gynecology, orthopedics, trauma, emergency and intensive care, with biweekly supervised clinical emergency shifts. An evaluation comparing cesarean deliveries (n = 2071) conducted by TCs versus obstetricians found no clinically significant difference between

Table 9
Evidence for alternative cadres for intrapartum care.

Intervention/study	Setting	Skilled attendance and cesarean delivery rates (%)	Intermediate outcomes	Investigator and year
Analysis of 2071 consecutive cesarean deliveries comparing outcomes by medical assistants trained for surgery versus obstetricians at Maputo Central Hospital.	Mozambique	National SBA: 44% Cesarean delivery: 1.9%	• 46% of surgeries performed by assistant medical officers, 53% by obstetricians. • No difference in indications for surgery. • Increased risk in superficial wound separation in assistant medical officer-conducted surgeries (OR 2.2; 95% CI, 1.3–3.9) • No other significant differences in other outcomes (total wound rupture, SBR, ENND, prolonged hospital stay or maternal death)	Pereira et al. [171] 1996
Prospective evaluation of 2131 consecutive obstetric surgeries comparing outcomes by clinical officers (non-physician mid-level providers) versus medical officers in 38 district hospitals	Malawi	National SBA: 54% Cesarean delivery: 3.1%	• 88% of emergency obstetric operations performed by clinical officers; 12% by medical officers. • No significant difference in SBR or ENND between surgeries by clinical vs medical officers. • No significant difference in maternal postoperative outcomes (fever, infection, wound dehiscence, or maternal death).	Chilopora et al. [174] 2007
Cross-sectional study of 12 178 consecutive obstetric operations by "tecnicos de cirurgia" (TCs) (non-physician mid-level providers) versus medical officers in 34 health units.	Mozambique	National SBA: 48% Cesarean delivery: 1.9%	• TCs performed 57% of major obstetric surgeries in Mozambique. • TCs perform 92% of surgeries in rural district hospitals. • Higher retention of TCs in district hospitals (88% after 7 years), compared with medical officers who tended to move to urban, provincial hospitals (0% retention after 7 years).	Pereira et al. [183] 2007
Evaluation of cesarean deliveries (n = 2305) conducted by obstetricians, general practitioners, and district clinical officers with 6 months' training in emergency surgery	Burkina Faso	National SBA: 54% Cesarean delivery: 0.7%	• Neonatal CFR 99 per 1000, 125 per 1000, and 198 per 1000 in surgeries conducted by obstetricians, general practitioners, and district clinical officers, respectively. • Authors estimate refresher courses and closer supervision could reduce the higher CFR among clinical officer-led cesareans to 161.5 per 1000 [176].	Hounton et al. [176] 2009
Description of experiences and outcomes of surgical procedures by nurse-surgeons at 2 rural hospitals	Rural northwest Zaire	National SBA: 70% Cesarean delivery: 4.0%	• 321 cesarean deliveries, 87% by nurse-surgeons. • CFR for cesarean by nurse was 1%. • 13 nurse-surgeon-led laparotomies for uterine rupture with 1 death.	White et al. [231] 1987
Historical description of rural health service in Malaysia, tiered pyramidal system task-shifting to medical auxiliary staff (indigenous midwives, junior laboratory assistants) to reach majority of rural population.	Rural Malaysia	National SBA ~25% *[from article; 1957]*, Cesarean delivery: undocumented	• Indigenous midwives attended 32% of registered births in 1970. • 46% reduction in IMR, 54% reduction in MMR* (from baseline IMR 75.5 per 1000, MMR 320 per 100 000 in 1957).	Chen et al. [232] 1973

Abbreviations: MMR, maternal mortality ratio; NMR, neonatal mortality rate; SBR, stillbirth rate; ENMR, early neonatal mortality rate; PMR, perinatal mortality rate.
Historical data should be interpreted with caution as many other factors may have influenced the reduction.
* For MMR, NMR, and skilled birth attendance where data were not reported in the study we sought data regarding national status from UN databases to give the context.

TCs and obstetricians in indications for cesarean, associated interventions, or serious complications including stillbirth and neonatal or maternal death [171]. Complication rates were low at 0.4%, postoperative mortality was 0.1%, and TCs could competently conduct complicated surgeries, including obstetric hysterectomies [172]. To alleviate the heavy workload on TCs (who manage all types of surgeries), qualified midwives with 3 years' midwifery training are now being given 4 years' additional training in obstetric surgery to become maternal health nurses (*enfermeiras de saúde maternal*). Assessment of retention in rural and hard-to-serve areas showed a zero retention rate for obstetricians at 2 years, but 88% for NPCs.

In Malawi, where there are fewer than 5 national obstetricians in public service, non-physician clinical officers perform most cesarean deliveries at district hospital level. An evaluation of their performance found a maternal case fatality rate (CFR) of 1.3% and a perinatal CFR of 13.6%, which may be higher than if a fully qualified surgical team had been in place, but well below rates where cesarean is unavailable [173,174].

In rural Zimbabwe, nurse-aides were trained to conduct low-risk deliveries to enable doctors and nurses to manage primigravidas and high-risk deliveries. Nurse-aides conducted 57% of all deliveries with a PMR of 5 per 1000, suggesting that nurse-aides could competently attend appropriately identified low-risk births in this setting [175].

In Burkina Faso, an evaluation of cesarean deliveries (n = 2305) conducted by obstetricians, general practitioners, and district clinical officers (who had 6 months' training in emergency surgery) found neonatal CFRs of 99 per 1000, 125 per 1000, and 198 per 1000, respectively, although case fatality rates are notoriously hard to assess between cadres of workers at different sites owing to many confounding factors. The authors suggest that refresher courses and closer supervision could reduce the higher CFR among clinical officer-led cesareans and also show that the cost per newborn death averted is much lower for the NPCs at 200 international dollars, compared with 11 757 for the obstetricians [176].

South Asian countries have also been utilizing task-shifting to address specialist shortages. Throughout India, general practitioners with MBBS degrees are being trained in surgery, obstetrics, and anesthesiology to alleviate shortages of specialists [177–179], although only a small number are currently performing these tasks. Nurses are being trained to administer magnesium sulfate for eclampsia and misoprostol to prevent postpartum hemorrhage [180]. Other South Asian countries have undertaken task-shifting to expand access to anesthesia (including training nurse-anesthetists, medical officers, and anesthesia assistants); evidence from Nepal and Bangladesh suggests that these efforts have resulted in expanded coverage of EmOC [179].

In a politically unstable part of Burma where facility-based care is infeasible, task-shifting of EmOC functions to first-level health workers, community health workers, and traditional birth attendants has resulted in an innovative mobile health system (Panel 2).

Task-shifting employing EmOC teams has also shown promise. In Senegal, teams comprised of an anesthetist, a general practitioner with 6 months' training in obstetrics including cesarean delivery, and a nurse-auxiliary trained as a surgical assistant were introduced as part of a national plan to provide EmOC at new operating theaters, a plan operationalized in only 3 districts [168]. In one district for which baseline data were available, the proportion of stillbirths during cesarean delivery declined non-significantly from 23 per 100 cesarean deliveries in referral hospitals to 12 per 100 in all hospitals after the opening of the operating theatre; overall rates of stillbirth remained unchanged (GRADE evidence level: Low; Recommendation: Conditional).

4.4.3. Evidence regarding cost-effectiveness

General practitioners and NPCs are cheaper to train and pay than specialists, with lower turnover, particularly in rural areas. In Mozambique, cost per major obstetric surgery for TCs was $39 versus $144 for obstetricians/gynecologists [181]. In Burkina Faso, the estimated average cost per averted newborn death for an obstetrician-led team compared with a general practitioner-led team was 11 757 international dollars (due largely to personnel availability and larger teams in urban settings), and 200 international dollars for a general practitioner-led team versus a clinical officer-led team. An international dollar is a hypothetical unit of currency with the same purchasing power of the US dollar in the US in the year 2000. Improving CFRs among clinical officers through training and supervision could make them even more cost-effective.

4.4.4. Implications

Mounting evidence supports task-shifting in the provision of life-saving intrapartum care, particularly for providing cesarean delivery or other EmOC functions such as managing antepartum or postpartum hemorrhage or pre-eclampsia/eclampsia in areas with poor access to EmOC. Although successful examples of safe task-shifting exist, ensuring quality of care requires standardized and rigorous training and supportive supervision, a lack of which often underlies health workforce shortages. Additionally, individuals with low status (e.g. midwives, nurse-aides) may be denied learning opportunities or adequate supervision [167]. In Malawi, NPCs who felt they were treated fairly by their managers reported high job satisfaction and eagerness to take on new responsibilities [182].

Even where providers can be capably trained to perform new tasks, logistical and health systems issues pose challenges to task-shifting schemes. Providing EmOC in unstable regions like Burma requires mobile and rapid response of providers. The Senegal experiment documented failures in meeting obstetric need, attributable to delays between training and readiness of operating theaters, limitations of centralized training, slow scale up, career path dissatisfaction, and absent team members who rendered the team non-functional [168]. Achieving sustainability requires incentivization (including adequate salary increases) and a clear career path for providers, especially physicians. As in Senegal, Burkina Faso has experienced a high turnover of physicians with additional training owing to lack of reward and heavy workload [168,176]. Dissatisfaction is less common among non-physicians; surgical assistants in Senegal were pleased with their training, and Mozambique has seen higher retention of TCs than physicians in rural areas and district hospitals [168,183].

Evidence suggests that team-building is paramount to effective task-shifting, as scalability and sustainability of these initiatives require immense dedication, coordination, and leadership [168]. Task-shifting often garners resistance from specialists and professional groups, who fear that NPCs cannot provide high-quality care or being replaced by NPCs [167]. A district surgery training program that included task-shifting in Ethiopia failed during follow-up when specialists refused to supervise trained general practitioners [184]. NPCs have been most accepted in circumstances where needs are great, NPCs prove they can provide safe and effective care, and skills are perceived as shared rather than encroached upon [185–187]. Alternative cadres need defined roles with standardized and assessed competency levels, which will facilitate recognition of their legitimacy. Regulations regarding specific tasks they may perform, as well as strategies to protect them from liability, are also needed. Although seen largely as a supply-side strategy, task shifting has demand-side implications; NPCs including nurse-aides, health officers, midwives, and community-based workers might enhance acceptability and lead to improved care seeking.

4.5. Summary of intrapartum care provision strategies

A recent review linked staff shortages with poor quality EmOC, and warned that poor quality services discourage facility use [188]. Promising supply-side strategies should be employed more widely to improve both the quality and coverage of EOC and EmOC in settings "where there are no doctors." Comprehensive strategies are needed including early identification of complications, rapid transfer and

Table 10
Summary of GRADE recommendations for care in childbirth to reduce intrapartum-related adverse outcomes.

Strongly recommended	Conditionally recommended	Weakly recommended (effectiveness, feasibility or risk-benefit concerns)	Possible options: not currently recommended; more research needed
Clinical intrapartum care interventions			
• Use of the partograph • Intermittent assessment of fetal heart rate • *In utero* resuscitation • Simplified umbilical artery Doppler • Symphysiotomy • Maneuvers to manage shoulder dystocia • Emergency laparotomy plus uterine repair or hysterectomy for uterine rupture • External cephalic version for breech presentation • Early delivery for severe pre-eclampsia or eclampsia • Early delivery for placental abruption • Antibiotics and early delivery for intra-amniotic infection	• Instrumental delivery • Planned Cesarean for breech presentation • Anticonvulsant drugs for pre-eclampsia/eclampsia • Ultrasound confirmation of placenta previa with planned Cesarean section	• Active management of labor • Use of Doptone • Fetal scalp blood sampling • Amnioinfusion for meconium stained amniotic fluid and umbilical cord compression • Antihypertensive drugs for severe hypertension • Cervical cerclage for suspected placenta previa • Membrane sweeping for post-term pregnancy[a] • Routine induction for post-term pregnancy[a]	• Fundal pressure • Clinical fetal arousal tests • Amniotic fluid assessment • Induction for suspected macrosomia[a]
Intrapartum care provision strategies			
• Obstetric drills on labor wards with high-fidelity simulations (for shoulder dystocia, Cesarean section) • Rapid response teams • Safety checklists (surgical safety, Cesarean, general childbirth) • Continuous intrapartum support from a familiar individual	• Task-shifting to NPCs for Cesarean section, anesthesia, and intrapartum monitoring		

[a] Provided that early-gestation ultrasound dating is available.

referral, and infrastructural investment to ensure widespread availability of quality life-saving interventions delivered with minimal delay and error [155,189]. Training programs and drills have shown some evidence of reduction of intrapartum-related morbidity; however, training strategies and materials are still needed for low-resource settings. Surgical checklists have been shown to reduce surgical complications, and are being adapted for cesarean delivery and general intrapartum care. Continuous intrapartum support from a relative can improve cultural acceptability of facility-based births and cost-effectively reduce the need for interventions, while reducing the care-giving demands on overburdened nursing staff.

Public-private partnerships such as the Chiranjeevi Scheme in India can incentivize private practitioners to serve poor and marginalized populations and increase access to skilled attendance and EmOC [190–192]. However, long-term assessment of impact on perinatal health outcomes is lacking and more rigorous operational research is needed. Task-shifting may increase availability of EmOC and life-saving interventions in remote, low-resource settings where interventions are needed most. NPCs in some settings have been shown to perform obstetric surgeries as competently as and more cost-effectively than obstetricians. As with the other strategies reviewed, task-shifting is not a stand-alone solution and cannot remedy the gaping deficit of well-trained health professionals in resource-poor settings; rather, it should complement comprehensive plans for human resource capacity-building [193].

5. Considerations for programs

5.1. Summary of evidence

There is a dearth of evidence supporting the effectiveness of obstetric interventions in the reduction of intrapartum-related injury, and yet, this evidence gap is worse in low-resource settings where the deaths are highest. None of the intrapartum interventions reviewed showed strong evidence of impact for reducing intrapartum-related mortality from trials in low-resource settings. Few studies reported perinatal mortality let alone intrapartum-specific outcomes. Evidence from RCTs in high-resource settings may not be directly applicable to low-resource settings (Tables 1, 2, 4, 6 and 7). Other interventions, such as amnioinfusion, show statistically significant positive impact on intermediate intrapartum outcomes in middle-income countries, but feasibility, scalability, and effectiveness questions require operational research in low-resource settings.

We placed a premium on highlighting interventions that would be expected to be effective in a setting of suboptimal background care, even if the level of evidence is low, or trials in high-resource settings indicate negligible impact. In summary, some interventions with low levels of evidence from high-resource settings, such as use of the partograph, in utero resuscitation, management of shoulder dystocia, and symphysiotomy, still merit conditional or strong GRADE recommendations (Table 10). Simple, low-cost interventions requiring minimal training inputs may be safer and/or more feasible alternatives to resource-intensive interventions such as cesarean delivery, although virtually all require further effectiveness and operational research. It is possible that for some interventions we considered, such as the use of the partograph or external cephalic version, that absolute risk reductions would be greater and reach statistical significance in well-designed trials in low-resource settings, but further research is required. Disappointingly few evidence-based options exist for some important causes of intrapartum injury and death in low-resource settings, including intrauterine infection and antepartum hemorrhage.

Some interventions for which evidence is strongest may not be justifiable in light of the small absolute risk reductions that have been observed in high-resource settings and heightened risks in low-income settings e.g. risk of iatrogenic prematurity of induction in the absence of accurate gestational age dating; or risks of unsafe cesarean delivery for breech, particularly if a provider skilled in vaginal breech deliveries is available (Tables 3 and 5).

Some promising strategies to increase coverage of emergency obstetric care with demonstrated benefit to health outcomes include obstetric drills, safety checklists, continuous intrapartum support, and task-shifting (Table 9). Immediate and substantial investment is needed to fund research on efficacy, effectiveness, and feasibility of delivering such interventions at scale and especially in rural and hard to reach areas, and in settings with recent or ongoing conflict.

Devices and Tools	Current technology for possible use in low-resource settings	Development needs before device can be employed at scale
Prenatal screening		
Fundal height assessment tools	- Fundal height assessment	- None needed
Ultrasound	- Hand-held, portable ultrasound , including models with USB connection using PC monitor display (with adequate resolution for diagnostic accuracy)  - Ultrasound belt to minimize need for skilled operator [197]	- Field trials of usage - Distribution (has US FDA clearance and Asian distributor) - Training aids for ultrasound technicians
Umbilical artery Doppler ultrasound	- Simplified Doppler umbilical artery ultrasound (using PC monitor)	- Field trials needed, widespread distribution - Simple training aids (operation manual, interpretation of waveforms)
Intrapartum fetal monitoring		
Monitoring labor progress devices/tools	- Partograph 	- Standard, simplified partograph with outcome-validated action points
Fetal heart rate monitoring Auscultation Doptone Cardiotocography	- Auscultation using Pinard stethoscope  - Hand-held wind-up Doptone Doppler [198, 199] 	- Simple training aids for Pinard stethoscope and Doptone interpretation - Field trials of wind-up Doptone devices, widespread distribution - Additional user-friendly, low-cost, durable, accurate alternative-powered fetal heart rate monitors capable of detecting late decelerations without need for complex interpretation
Acid-base balance / Pulse oximetry monitoring	- Wind-up pulse oximeter (oxygen saturation monitor) (under development) [199]	- Field trials of wind-up oxygenation monitor, distribution
Oxygen condenser	- None available	- Oxygen condenser using alternative power (solar or wind-up)
EmOC devices		
Intravenous magnesium sulfate for eclampsia	- Pre-dosed magnesium sulfate delivery device without power dependence and with minimal risk of misuse (e.g. Springfusor; Go Medical, Subico, Australia; a spring-driven infusion pump for continuous infusion) 	- Springfusor currently being tested by Gynuity Health Projects). - Packaging this device or pre-dosed magnesium sulfate vials in "eclampsia treatment packs" with calcium gluconate [102] and intramuscular + intravenous supplies, with administration info.
Vacuum extractor (not portable; electricity-dependent)	- Portable, manually-powered, disposable or easily sanitized and reusable vacuum extractor [53, 200] 	- Trials at scale; widespread distribution - Development and trials of symphysiotomy kits with appropriate training aids where cesarean delivery unavailable or not culturally acceptable
Supportive devices to improve quality and availability of EmOC		
High-fidelity training mannequins for managing normal and abnormal birth, shoulder dystocia, vaginal breech delivery, neonatal resuscitation [28]	- Standard birthing simulators current cost over US$3,500 	- Significantly lower cost, durable, easy-to-disassemble-and-sanitize high-fidelity mannequins with culturally appropriate features
Devices for surgery and obstetric emergencies (refrigeration, communication, lighting)	- Solar-powered lighting for surgery when power unpredictable/ unavailable - Solar-powered refrigeration for blood banking • Alternative-powered walkie-talkies to summon EmOC teams	- Pilot projects but needs scaled-up production and broader distribution if successful

* Note reference to specific devices or use of images does not constitute endorsement

Photos sources:

Handheld ultrasound photograph reprinted with permission granted by Direct Medical Systems, Wind-up Doptone Doppler photograph reprinted with permission granted by Freeplay Energy, Pre-dosed magnesium sulfate delivery device photograph reprinted with permission granted by Go Medical/Springfusor® Vacuum extractor photograph reprinted with permission granted by Clinical Innovations, Mannequin photograph reprinted with permission granted by Limbs & Things, Copyright 2009

Fig. 3. Equipment and devices for intrapatum care in low-resource settings: Available options and needed inoovations and actions [197–200].

5.2. Innovation for equipment and devices

Intrapartum care in high-resource settings, including fetal monitoring, diagnostic testing, and operative delivery is an increasingly technology-dependent enterprise focused on assuring fetal well being, with early intervention for complications. These technologies are often unavailable, unaffordable, or impractical in low-resource settings. Several promising examples of feasible, low-cost alternatives have been identified in this review that could facilitate expanded coverage of evidence-based intrapartum interventions (Fig. 3). Some require little more than standardization (partograph) or broader production and distribution (portable ultrasound, simplified Doppler waveform analysis, manual vacuum extractor). Others remain to be developed, such as symphysiotomy kits, and affordable, culturally-appropriate versions of high-fidelity training mannequins, or improved and feasible diagnosis of fetal distress. Additionally, there remains a need for broader adaptation and piloting of training curricula to improve quality of care, including obstetric drills and safety checklists.

5.3. Specific data tracking gaps

Few of the studies we reviewed reported stillbirths disaggregated from composite perinatal mortality; when stillbirths were reported, intrapartum stillbirth rates were seldom provided, and cause-specific mortality data were rarely available for intrapartum fetal deaths or early neonatal deaths. Rates of intrapartum stillbirths are a sensitive measure of the quality of intrapartum care [1]; thus, this data tracking gap perpetuates the invisibility of intrapartum deaths and impedes efforts to prioritize interventions in response to these deaths. A universal cause-specific classification system for stillbirth that is implementable in low-resource settings is urgently needed [23]. Furthermore, the use of an aggregate measure of intrapartum stillbirths and intrapartum-related neonatal deaths should be considered, has been proposed by the UNFPA [194], and is discussed in further detail in the last paper in this series [19].

6. Conclusion

Global policy consensus surrounds the importance of increased skilled attendance at birth as a priority to reduce both maternal and fetal–neonatal complications. Experts broadly agree that a system providing access to EmOC is required to manage obstetric emergencies and that generating demand for services within communities is crucial to reduce delays in access to care [17]. However, universal coverage of CEmOC and skilled birth attendance remain unrealized goals hampered particularly by human resource shortages, but also by lack of evidence and consensus on how to accelerate progress.

In a recent Delphi expert consensus survey, CEmOC was estimated to avert 75% of neonatal deaths due to intrapartum events [135]. New analysis for 193 countries suggests that CEmOC could save an estimated 495 000 neonatal lives per year that are currently being lost to intrapartum-related causes [19]. This analysis is based on national-level modeling and inputting the most recent NMR and cause-of-death estimates, and applying mortality effect estimates in the Lives Saved Tool (LiST) [195] while considering current coverage [196]. These estimates do not include the effect of neonatal resuscitation, which is estimated to avert an additional 30% of intrapartum-related neonatal deaths after the CEmOC effect has been included [19].

In order to close gaps in coverage, quality, and equity for intrapartum care, new recognition is required of the importance of care at the time of birth, and the potential to save hundreds of thousands of newborn lives as well as stillbirths and maternal lives. No time in the human lifecycle is so critical—investment is urgently needed in health infrastructure, personnel, and implementation research in the settings where risk is highest and yet the gaps in care are widest.

7. Conflict of interest

The authors have no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ijgo.2009.07.016.

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Panel 1. Obstetric simulations, drills, and rapid response teams to minimize delay and maximize quality

Obstetric simulations and drills

Obstetric simulations and drills are increasingly advocated as a strategy to reduce provider error and improve team performance in response to time-sensitive scenarios that are too rare, grave, or costly to recreate in real life [233]. In conjunction with these strategies, rapid response teams may be used to coordinate and rapidly mobilize the multiple personnel needed during a specific obstetric emergency [234].

Obstetric simulations and drills are specifically recommended by ACOG and the Joint Commission to improve management of shoulder dystocia, neonatal resuscitation, cesarean delivery, and maternal hemorrhage [66]. They have been most commonly implemented to strengthen and maintain provider skills in managing shoulder dystocia, but are increasingly used to manage other complications such as hemorrhage, eclampsia, and vaginal breech delivery [235–239], as well as more common obstetric procedures such as cesarean delivery [65,240,241].

Simulations and drills may be conducted either in training centers or *in situ* in hospital wards using actors or high-fidelity mannequins. Most employ an algorithm specifying the responsibilities of each team member and a clinical action plan. After the drill, participants analyze video recordings or notes taken during the exercise to identify areas for improvement.

Obstetric simulations and drills have been shown to:

- Improve clinical management of complications, including individual provider technique and team coordination and efficiency [241,242].
- Help develop evidence-based standard management protocols [234,240].
- Reveal deficiencies in supplies and equipment, and encourage preparedness (e.g. “eclampsia boxes”) [240,242].
- Suggest changes to hospital policy [242].

Nursing staff and physicians have responded positively to obstetric drills [65,242] and several studies have shown improvement in post-training management of simulated or actual cases [240].

Rapid response teams

Modeled after code teams for cardiac arrest, obstetric rapid response teams involve a range of personnel capable of rapidly mobilizing administrative support as well as specialists to provide anesthesia, blood transfusion, obstetric nursing and surgical care, and perinatal care. Teams in tertiary facilities in high-resource settings in the United States have used rapid response teams, who can be summoned with a single call to the hospital operator, to implement clinical protocols for early diagnosis and rapid treatment for time-sensitive complications such as emergency cesarean delivery and hemorrhage, including preparedness for surgical intervention in high-risk patients. These teams have led to positive impacts on maternal mortality [243], and in one study, recognition of obstetric emergencies and use of the rapid response team increased 4-fold [244]. In low-resource settings where delays are even more common, formation of such teams may lead to reductions in adverse mortality and non-fatal outcomes, but may be challenging from a human resource perspective.

Panel 2. Providing care for obstetric emergencies in settings with humanitarian crises: The MOM Program in Burma

Of the 20 countries with the highest NMRs and MMRs, almost all are either currently experiencing or have recently experienced conflict, famine, or other humanitarian emergencies. Provision of care in such settings often focuses on interventions that are commodity-based such as water purification or immunizations. Providing care during childbirth is a particular challenge, and innovative service delivery approaches are urgently needed.

Decades of conflict between the Burmese military junta and armed rebels in eastern Burma and oppressive policies against minority populations have led to more than 2 million refugees and 560 000 internally displaced persons. Permanent health facilities and referral systems are not viable. A pilot project, the Mobile Obstetric Maternal Health Workers (MOM) Program, is meeting this challenge by providing mobile, community-based EmOC services. Training in essential maternal health care, including BEmOC, has been provided to 33 first-tier lay Maternal Health Workers (MHWs) at the central Mae Tao Clinic. MHWs can administer intramuscular/intravenous antibiotics and magnesium, perform manual vacuum aspiration and manual removal of placenta, and provide active management of the third stage of labor with misoprostol as there is no cold chain for oxytoxin. In addition to providing 5 of the 6 signal functions of BEmOC, MHWs also utilize "walking blood banks" (pre-typed volunteer donors) and sequential blood screening using heat-stable rapid diagnostic tests to provide direct person-to-person blood transfusion. Subsets of these EmOC services are delivered by second-tier CHWs (antibiotics, misoprostol) and third-tier traditional birth attendants (misoprostol) [245], who also act as referral links to the MWHs. Most services are provided in the home or in thatched huts, which serve as birthing centers. Supervision is provided by the central clinic, with intermittent refresher courses.

The number and type of complications, as well as coverage of the program are monitored through annual population-based cluster-sample surveys and a pregnancy-tracking log. Preliminary comparison with baseline data [246] indicates that in only 1.5 years there has been a substantial increase in EmOC access, from 5.1% skilled attendance to EmOC-trained MHWs attending 59.7% of births. Active management of the third stage of labor with misoprostol increased from near zero to 79.5% [247]. During this period, MHWs provided 25 emergency blood transfusions for pregnancy-related malaria (n = 10), postpartum hemorrhage (n = 4), and complications of abortions n = 6) [248].

Mobile service provision *in* the community rather than centralized services accessed *by* the population was a practical necessity in eastern Burma, and this experience suggests that with careful training and supervision, community-based workers can play a critical role in providing childbirth care including EmOC for those with no services currently. Establishing a 3-tier network of community providers linked to a clinic, and gaining community buy-in required mobilization, trust-building, and time [5]. Further evaluation, especially of outcomes and cost, is required.

Photographs: Maternal Health Workers providing obstetric care for internally displaced villagers in eastern Burma. (Photographs reprinted with permission granted by MOM project, 2009)* *The MOM project is a collaborative effort of the Burma Medical Association, the Mae Tao Clinic, Global Health Access Program, the Johns Hopkins Center for Public Health and Human Rights, and health organizations of Karen, Shan, Karenni, and Mon States; it is funded by the Bill & Melinda Gates Institute for Population and Reproductive Health.*