Quality of basic maternal care functions in health facilities of five African countries: an analysis of national health system surveys

Margaret E Kruk, Hannah H Leslie, Stéphane Verguet, Godfrey M Mbaruku, Richard M K Adanu, Ana Langer

Summary

Background Global efforts to increase births at health-care facilities might not reduce maternal or newborn mortality if quality of care is insufficient. However, little systematic evidence exists for the quality at health facilities caring for women and newborn babies in low-income countries. We analysed the quality of basic maternal care functions and its association with volume of deliveries and surgical capacity in health-care facilities in five sub-Saharan African countries.

Methods In this analysis, we combined nationally representative health system surveys (Service Provision Assessments by the Demographic and Health Survery Programme) with data for volume of deliveries and quality of delivery care from Kenya, Namibia, Rwanda, Tanzania, and Uganda. We measured the quality of basic maternal care functions in delivery facilities using an index of 12 indicators of structure and processes of care, including infrastructure and use of evidence-based routine and emergency care interventions. We regressed the quality index on volume of births and confounders (public or privately managed, availability of antiretroviral therapy services, availability of skilled staffing, and country) stratified by facility type: primary (no caesarean capacity) or secondary (has caesarean capacity) care facilities. The Harvard University Human Research Protection Program approved this analysis as exempt from human subjects review.

Findings The national surveys were completed between April, 2006, and May, 2010. Our sample consisted of 1715 (93%) of 1842 health-care facilities that provided normal delivery service, after exclusion of facilities with missing (n=126) or invalid (n=1) data. 1511 (88%) study facilities (site of 276 965 [44%] of 622 864 facility births) did not have caesarean section capacity (primary care facilities). Quality of basic maternal care functions was substantially lower in primary (index score 0·38) than secondary care facilities (0·77). Low delivery volume was consistently associated with poor quality, with differences in quality between the lowest versus highest volume facilities of –0·22 (95% CI –0·26 to –0·19) in primary care facilities and –0·17 (–0·21 to –0·11) in secondary care facilities.

Interpretation More than 40% of facility deliveries in these five African countries occurred in primary care facilities, which scored poorly on basic measures of maternal care quality. Facilities with caesarean section capacity, particularly those with birth volumes higher than 500 per year, had higher scores for maternal care quality. Low-income and middle-income countries should systematically assess and improve the quality of delivery care in health facilities to accelerate reduction of maternal and newborn deaths.

Funding None.

Lancet Glob Health 2016; 4: e845–55

Published Online September 23, 2016 http://dx.doi.org/10.1016/S2214-109X(16)30180-2

See Comment page e769

Department of Global Health and Population, Harvard T H Chan School of Public Health, Boston, MA, USA (M E Kruk MD, H H Leslie PhD, S Verguet PhD, A Langer MD); **Ifakara Health Institute, Dar es Salaam, Tanzania** (G M Mbaruku MD); **and Department of Population, Family, and Reproductive Health, University of Ghana School of Public Health, Legon, Ghana** (R M K Adanu MBChB)

Correspondence to: Dr Margaret E Kruk, Department of Global Health and Population, Harvard T H Chan School of Public Health, Boston, MA 02115, USA **mkruk@hsph.harvard.edu**

Introduction

The UN's adoption of the Sustainable Development Goals[1] (SDGs) in September, 2015, reaffirmed the reduction of maternal and newborn mortality as global priorities in the coming decades. Although globally mortality has decreased, only nine of 95 countries with high maternal mortality have achieved the target set in the previous round of development goals—the Millennium Development Goals (MDG), a 75% reduction in the maternal mortality ratio from 1990 to 2015.[2,3] The SDGs' targets to reduce maternal mortality to fewer than 70 deaths per 100 000 livebirths and to reduce deaths of newborn babies to fewer than 12 per 1000 livebirths are ambitious.[1] To achieve these goals will require near universal coverage of delivery in health facilities where birth complications can be detected and treated. Increasing delivery coverage has been a focus of global and national efforts during the MDG era and is emphasised by the SDG target on universal health coverage.

To increase use of health facilities for delivery, low-income countries, such as Tanzania, have encouraged women to give birth at the nearest health facility that is designated to handle deliveries. However, not all delivery facilities are equal. Data from low-income and middle-income countries (LMICs) show large variability in maternal mortality in health-care facilities, suggesting inconsistent quality of care.[4] Poor quality of intrapartum care is also strongly associated with newborn mortality.[5] Heterogeneous associations have been shown between delivering in a health-care facility and survival of newborn

Research in context

Evidence before this study

We searched PubMed for articles published between Jan 1, 1990, and June 1, 2016, using search terms "quality (maternal OR obstetric OR delivery OR intrapartum) care", "delivery OR birth OR obstetric volume", "maternal mortality", "neonatal mortality", or "(primary care OR referral OR front-line) AND delivery AND (Africa OR developing countries)". Global efforts to reduce maternal and newborn mortality (in the form of monetary investments, programmes, and calls to action) have emphasised increasing the proportion of births in health-care facilities, partly through expansion of delivery services at primary care facilities near to where women live. Emerging evidence from several settings in India and Africa suggests that increases in births at health-care facilities have not been consistently accompanied by reduced mortality.

Added value of the study

Many studies in high-income countries suggest that quality of neonatal and obstetric care is lower in health-care facilities with few deliveries, which has led to regionalisation of obstetric care. No previous studies, to our knowledge, have systematically assessed the quality of basic maternal care functions in lower-income country health-care facilities or its association with facility birth volume and facility surgical capacity. This information would be relevant to optimise health investments to improve maternal and child survival.

Implications of all the available evidence

Our study found that more than four in ten births delivered at health-care facilities in five sub-Saharan African countries happen in primary care facilities (facilities without caesarean section capacity), which score poorly on a quality of basic maternal care functions index. Quality is higher in facilities with caesarean section capacity (secondary care facilities) and increases with delivery volumes higher than 500 per year. Health systems in lower-income countries will need to be strengthened and potentially reorganised to meet their obligation to provide safe and effective delivery services to mothers and newborn babies.

babies in 67 low-income countries.[5,6] The challenge to ensure consistent quality is greatest in sub-Saharan Africa and south Asia, where mortality is highest and health systems are weakest.[3] Although researchers have identified serious quality deficits at some hospitals, quality of care at lower level facilities (eg, health centres and dispensaries) typically staffed with nurses or nursing aides has come under particular scrutiny.[7–10]

By contrast with the extensive research on quality of obstetric care in high-income countries, systematic research on quality is scarce in LMICs.[7,11,12] This difference could be a result of the overarching focus on use and the scarcity of health system and outcome data on quality.[13] One important question in resource-constrained contexts concerns the safety and quality of low-volume, primary care delivery facilities where pregnant women deemed at low risk of complications are directed to deliver.[10,14] The positive association between volume of deliveries and improved maternal and newborn baby outcomes has been well established in high-income countries. For example, US hospitals and providers with the lowest delivery volumes (<25 deliveries per month in hospitals, <seven per year in health-care providers) had up to 50% more adverse maternal outcomes than hospitals and providers with higher delivery volumes.[15,16]

Evidence of worse maternal and neonatal outcomes in low-volume facilities led high-income countries to concentrate services of obstetric and newborn baby care in large, specialised facilities.[17] Yet, so far no systematic evidence is available about the relation between facility type and delivery volume and their ability to provide competent obstetric care in countries with the highest global burden of maternal and newborn deaths. Care quality can be measured through health-care sensitive outcomes or processes of care, such as performance of minimum recommended clinical actions. Process measures are useful to assess whether a basic threshold of quality has been reached and can provide useful guidance for improvement efforts.

We analyse the quality of basic maternal care functions in health facilities in five sub-Saharan African countries and its association with volume of deliveries and the facility's surgical capacity. We focus on the most essential structures and processes of care that are needed to effectively manage deliveries. We describe the characteristics of poor quality facilities and discuss the implications for health systems and possible national efforts to reduce maternal mortality.

Methods

Study design and data samples

In this analysis, we used data about childbirth deliveries and quality of care in health-care facilities from service provision assessment (SPA) surveys, completed by the Demographic and Health Survey (DHS) programme in five sub-Saharan countries (Kenya, Namibia, Rwanda, Tanzania, and Uganda) between April, 2006, and May, 2010. The data were extracted from two modules of the SPA, the first one a facility questionnaire of service readiness and the second one a health-worker interview, because these were widely asked across countries and contained relevant data on quality. We used SPA surveys that included measures of delivery volume and quality in these modules: three surveys (Kenya in 2010, Tanzania in 2006, and Uganda in 2007) were samples of health facilities designed to be representative of the national and subnational health systems, and two (Namibia in 2009, and Rwanda in 2007) were nearly complete

censuses of the health system. Analysis was restricted to facilities reporting provision of delivery services. We classified facilities on whether they had the capacity to do caesarean sections (secondary care facilities) or not (primary care facilities).[18] The Harvard University Human Research Protection Program approved this analysis as exempt from human subjects review. Patient consent was not needed because these data are publicly available.

Quality of basic maternal care functions index

Although facility mortality (or case fatality) is often used to measure quality in high-income countries, data on both facility mortality and a facility's casemix that could be used to adjust for selection bias (ie, women with more severe illness are referred to higher level facilities, inflating the mortality at these facilities) are not typically available in lower-income countries. In this paper, we thoroughly reviewed publications on maternal care quality and defined a measure of basic maternal care functions (quality of basic maternal care functions index) that should be present in all delivery facilities.[12,19,20] Our index comprises structure and process-of-care elements required for both routine and basic emergency care, which is consistent with guidance that facilities should be equipped to provide high-quality care for all women and at least first-line management of complications.[21] Measures of structures and processes have several useful attributes as they can identify specific deficiencies in the health systems that are actionable, measure a socially relevant endpoint (ie, the ethical obligation of health systems to first do no harm), and are feasible to obtain in lower-income settings.[22]

We compiled a 12-item summative index of quality of basic maternal-care functions consisting of five structural indicators and seven indicators of process-of-care provision for routine and basic emergency care in primary and secondary care settings. Structural indicators were observed by researchers and process-of-care indicators were reported by the facility manager or most senior health worker. Basic elements of structure were skilled provider availability, referral capacity (functional ambulance or plan and capacity to call one), electricity, safe water, and resources for infection control in the delivery room.[19] Process indicators included use of partographs, routine practice of active management of the third stage of labour (AMTSL), and five signal functions (capacity to remove retained products, parenteral oxytocin for haemorrhage past 3 months, parenteral magnesium sulfate for [pre-]eclampsia past 3 months, manual removal of placenta past 3 months, and antibiotics for maternal infection past 3 months) defined by WHO as indicators of facility emergency care capacity (two signal functions [assisted vaginal delivery and neonatal resuscitation] could not be assessed with data from the SPA surveys).[23] All indicators were binary except for infection control (mean of four components of soap and water, gloves, sharps box, and surface disinfectant) and AMTSL (mean of three practices of giving oxytocin to women during third stage of labour, cord traction, and uterine massage; appendix). Quality indicator responses were missing in some facilities, notably AMTSL and parenteral administration of antibiotics, which were not asked in the Tanzania survey. We did multiple imputation for missing values of quality indicators.[24] The sum of the indicators (maximum 12) was converted into a proportion out of 1.

See Online for appendix

Measure of delivery volume

We calculated total delivery volume per year by adding caesarean and non-caesarean deliveries in the past 12 months. We grouped delivery volume into categories using the thresholds 52, 183, 366, and 500 births per year for primary care facilities and 183, 366, 500, 1500, 2500, and 4000 births per year for secondary care facilities. These thresholds were selected for interpretability (52 is one delivery per week, 183 is one every other day, and 366 is one per day) and to reflect international thresholds (eg, 500 births per year) in the USA and UK, and provide a roughly balanced distribution of both facilities and births per category.

We identified covariates that might be associated with quality of care. These included the type of facility (primary or secondary care), the managing authority (public [government or military] or private [faith-based or non-governmental organisation]), and the capacity to provide ART services.[18] Finally, we calculated the number of working clinicians, nurses, and midwives and divided this figure by the number of maternity beds present to gauge skilled staffing level.

Statistical analysis

Because health-care facilities with caesarean section capacity are likely to have greater resources available for basic obstetric care, compared with those without this capability, we stratified analyses by primary versus secondary care. We calculated proportions for binary variables and mean (SD) for continuous covariates.

	Kenya	Namibia	Rwanda	Tanzania	Uganda
Population (in millions)*	44·9	2·4	11·3	51·8	37·8
Population density (per km²)*	79	3	460	59	188
GDP per person (USD$)†	$1246	$5693	$638	$695	$572
Health spending per person ($)‡	$45	$423	$71	$49	$59
Female literacy of population‡§	67%	78%	65%	74%	62%
Maternal mortality (per 100 000 livebirths)†	400	130	320	410	360
Neonatal mortality (per 1000 livebirths)†	24	16	20	20	20
Physicians per 100 000 people‡	19·8	37·4	5·6	3·0	11·7
Facility delivery rate per year (births)‡	61·2	87·4	68·9	50·2	57·4

GDP=gross domestic product. *Data are from 2014.[25] †Data are from 2013.[25] ‡Data are from the most recent year available.[25–33] §Percentage of women of the population who can read and write.

Table 1: **Demographic and health context of study countries**

	All facilities (n=1715)	Primary care facilities (n=1511)	Secondary care facilities (n=204)
Facility characteristics (n=1715)*			
Provides caesarean section services (secondary care settings)	204 (11·9%)	0	204 (100·0%)
Private facilities	473 (27·6%)	365 (24·1%)	109 (53·2%)
ART service available	433 (25·3%)	281 (18·6%)	152 (74·7%)
Staffing (providers per bed)†	2·04 (2·65)	1·81 (1·77)	3·82 (5·72)
Country			
Kenya (2010)	392 (22·9%)	330 (21·8%)	62 (30·6%)
Namibia (2009)	179 (10·4%)	143 (9·5%)	36 (17·7%)
Rwanda (2007)	393 (22·9%)	351 (23·2%)	42 (20·6%)
Tanzania (2006)	421 (24·6%)	392 (26·0%)	29 (14·0%)
Uganda (2007)	330 (19·2%)	295 (19·5%)	35 (17·2%)
Volume of deliveries per year (n [cumulative %])			
≤52	496 (28·9%)	490 (32·4%)	7 (3·2%)
53–183	540 (60·4%)	520 (66·8%)	20 (12·9%)
184–365	295 (77·6%)	268 (84·5%)	28 (26·6%)
366–500	124 (84·9%)	116 (92·2%)	8 (30·3%)
501–1500	185 (95·6%)	114 (99·8%)	70 (64·82%)
1501–2500	39 (97·9%)	2 (100·0%)	37 (82·77%)
2501–4000	17 (98·9%)	1 (100·0%)	16 (90·6%)
>4000	19 (100·0%)	0 (100·0%)	19 (100·0%)
Quality of basic maternal-care functions‡	0·42 (0·24)	0·38 (0·19)	0·77 (0·14)
Distribution of facility births (n=622 864)§			
Facility volume (n [cumulative %])¶			
≤52	12 424 (2·0%)	12 199 (4·4%)	225 (0·1%)
53–183	57 455 (11·2%)	55 168 (24·3%)	2287 (0·7%)
184–365	79 298 (24·0%)	71 307 (50·1%)	7990 (3·0%)
366–500	53 083 (32·5%)	49 715 (68·0%)	3368 (4·0%)
501–1500	148 408 (56·3%)	81 611 (97·5%)	66 797 (23·3%)
1501–2500	75 542 (68·4%)	4473 (99·1%)	71 069 (43·9%)
2501–4000	52 426 (76·8%)	1986 (99·8%)	50 440 (58·5%)
>4000	144 228 (100·0%)	507 (100·0%)	143 720 (100·0%)
Total	622 864	276 965	345 898

Data are weighted n (%), or mean (SD). *Data from Service Provision Assessments surveys in Rwanda and Namibia are self-weighting; data from Kenya, Tanzania, and Uganda are weighted to reflect sampling probability with weights re-scaled to effective sample size per country. †Number of doctors, nurses, and midwives on post on day of the assessment divided by the number of maternity beds or, if no maternity beds, beds for overnight observation or inpatient treatment. ‡Mean (SD) of quality of basic maternal-care functions estimated based on five datasets with missing items imputed. §Number of births calculated based on facility report of annual delivery volume, weighted by sample weights. ¶Data are weighted births.

Table 2: **Health facility characteristics and distribution of facility births in five countries**

Statistics and descriptive figures presenting quality of basic maternal care are based on the mean value across the imputed datasets. All descriptive statistics present weighted data to represent the health systems in the five study countries. We scaled the facility weights based on the contribution of each country to the full sample to ensure consistency between descriptive and analytical results. Scatter plots and regression analyses are unweighted. We plotted observed quality of care and delivery volume and fitted a loess (locally weighted smoothing) curve to visualise the unadjusted association. We did log transformations for the ratio of skilled providers to beds in the health-care facility and delivery volume (replacing 0 with 1). We used regression analyses for the quality index on categories of delivery volume without adjustment (model 1) and then adjusted for the covariates of interest and fixed effects for each country (model 2). The regression analysis was done to explore association rather than imply causation as the association between quality and birth volume can be bi-directional. We completed all regression analyses on each imputed and combined dataset; variance estimates reflect sampling error as well as between-imputation variation.

We did several sensitivity analyses to test the robustness of our results. We assessed the sensitivity of results to the functional form of delivery volume through two models with alternative forms for volume with natural log (sensitivity model 1) and a cubic spline (sensitivity model 2; appendix). We then repeated the analysis using sampling weights to assess the assumption that the included covariates appropriately accounted for study sampling procedures. Finally, although we used multiple imputation to assign values for missing data, we assessed the potential effects of missing data on quality indicators on our findings by replacing all missing items with the most extreme values (0 and 1 in turn) and recalculating quality (appendix).

We did multiple imputation using R statistical software (version 3.3.0; R Foundation for Statistical Consulting, using the Amelia II package).[24] We completed all other analyses in Stata (version 14.1).

Role of the funding source

There was no funding source for this study. The corresponding author had full access to all the data in the study and had the final responsibility for the decision to submit for publication.

Results

We used data from the five countries' SPA surveys that assessed 2F746 (98% response) of 2813 health-care facilities selected between April, 2006, and May, 2010. Maternal and neonatal mortality in the study countries are high in the presence of low health spending and few health personnel. Namibia, the only middle-income country, had the highest coverage of institutional deliveries (87·4%) and the lowest maternal mortality ratio (130 deaths per 100 000 livebirths; table 1).

1842 (67%) of 2746 health-care facilities provided delivery services. After excluding facilities with missing (n=126) or invalid (n=1) data for delivery volume, we included 1715 (93%) of 1842 health-care facilities in our analytical sample. Study facilities reported 1 291 815 deliveries per year, adjusted to 622 864 births to account for oversampling of larger facilities (table 2). 1511 (88%) health-care facilities were not equipped to undertake caesarean sections (primary care facilities; table 2; appendix). These primary care facilities attended

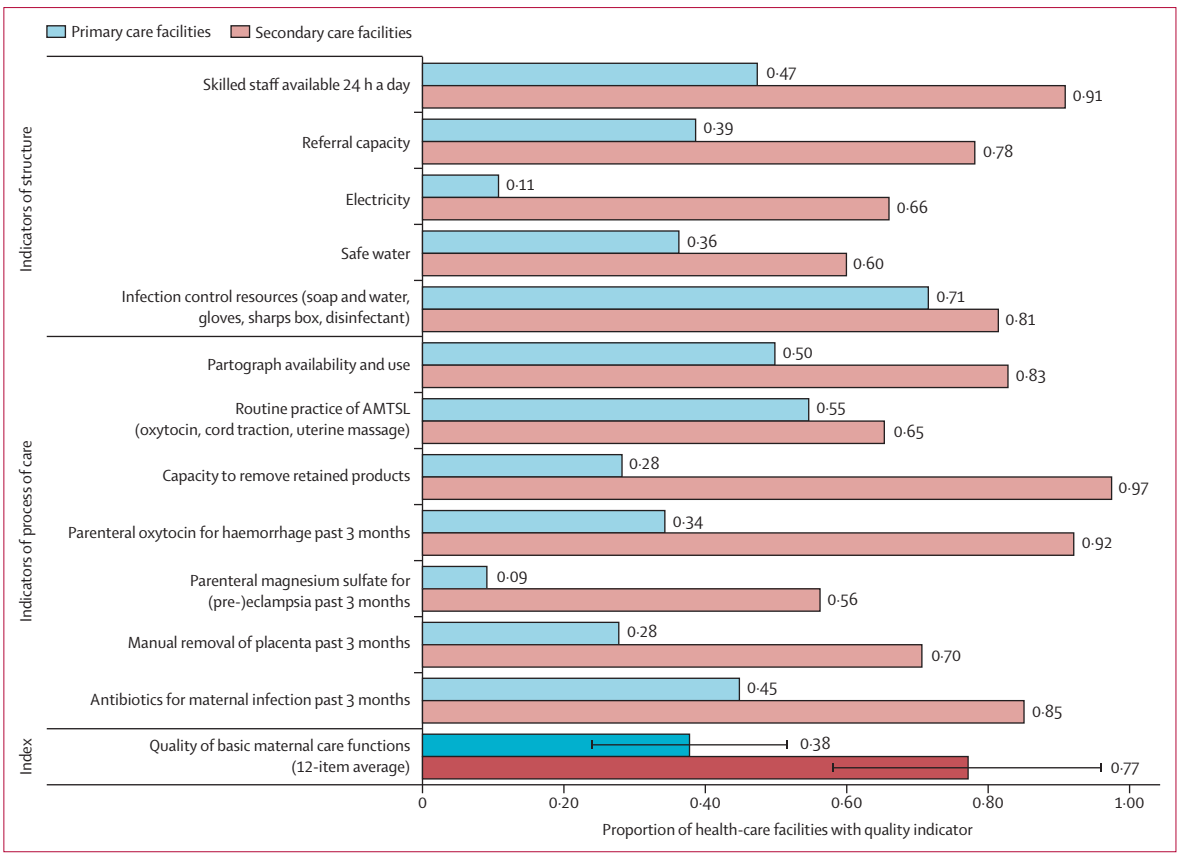


Figure 1: **Quality of basic maternal care functions in primary and secondary care facilities**
Data are unweighted. Bars show SD values. Removal of retained products indicates facility capacity for this procedure; all other basic emergency indicators reflect facility report of this procedure in past 3 months. Quality of basic maternal care index calculated as the mean of the 12 preceding items within each of five datasets with missing items imputed (see appendix for full item definitions). AMTSL=active management of third stage of labour.

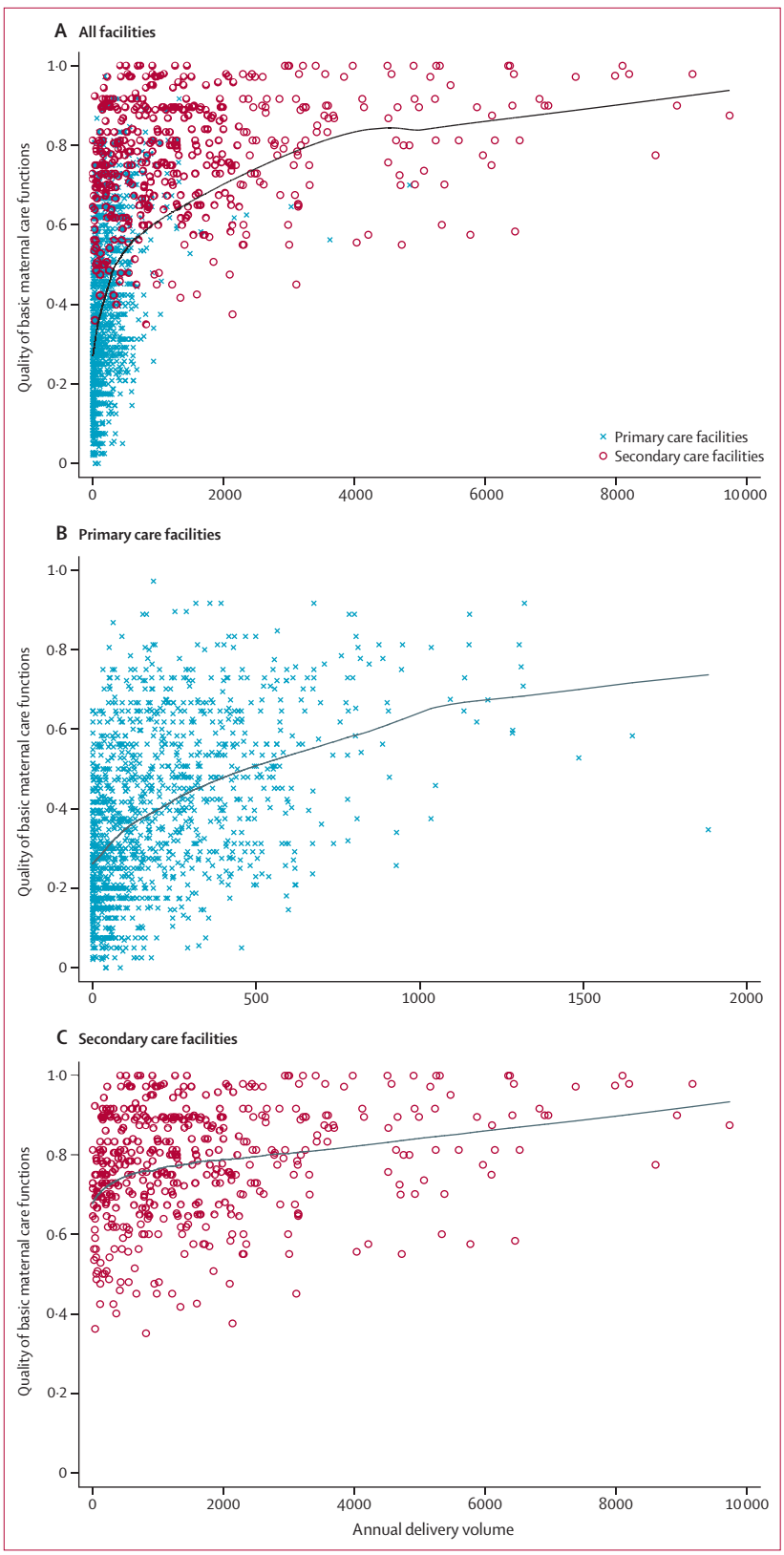
to 276 965 (44%) facility births in our sample. Secondary care facilities were more likely to be privately managed, to be able to provide ART services, and to have more staff per bed than were primary care facilities (table 2). Delivery volume for all health-care facilities was low, with a mean volume of at about one birth per day, and a median 121 births per year (IQR 45–328). Primary care facilities had a median 101 births per year (IQR 41–260), which is substantially lower than the secondary care facilities median of 973 births per year (354–1977). 32% of all deliveries and 68% of deliveries in primary care facilities were in facilities with fewer than 500 annual deliveries.

Overall quality of basic maternal care function scores on our 12-item index were low (mean 0·42 [SD 0·24]), with poorer quality in primary care facilities (0·38 [0·19]) than in secondary care settings (0·77 [0·14]). Index scores for primary care facilities were lower than secondary care facilities on all 12 indicators, with the largest difference in essential infrastructure (provision of electricity available in 162 [11%] primary care facilities *vs* 134 [66%] secondary care facilities) and basic emergency procedures (reported administering magnesium sulfate in the past 3 months in 137 [9%] primary care *vs* 114 [56%] secondary care facilities; figure 1). Similar to primary care settings, secondary care facilities often did not have basic infrastructure. Most secondary care facilities practised only two of three evidence-based procedures for AMTSL (figure 1).

254 (17%) primary care facilities did not undertake any emergency procedures in the past 3 months before the SPA survey; only 7·4% did at least four basic emergency procedures compared with 70·1% of secondary care facilities (data not shown).

Figure 2 shows the relationship between annual delivery volume and quality of basic maternal care in the observed data. The quality of maternal care index score was low and highly variable in the health-care facilities with low volumes of deliveries (<500 births), most of which were primary care facilities. In both types of health-care facilities and all countries, quality of maternal care increased as birth volume increased, with diminishing gains at high-volume facilities.

In primary care facilities, quality of basic maternal care was significantly lower in facilities with fewer than 500 deliveries per year than in those with more than



500 deliveries per year (table 3). The difference was most striking for primary care facilities with fewer than one delivery per week (≤52 births per year), with the estimated difference in quality of basic maternal care between these facilities and those with more than 500 births per year of –0·22 (95% CI –0·26 to –0·19) in the adjusted model (table 3). Differences in quality diminished in magnitude but remained significant as birth volume increased. Higher quality of care was also significantly associated with the facility being private, having an ART service, and having more staff per bed for primary care facilities, although these associations were weaker than that of low delivery volume (table 3). Quality scores were significantly higher in Kenya than all other countries.

Similar patterns were also true in secondary care facilities, in which the estimated difference in quality was largest between health-care facilities with fewer than 500 births and those with more than 4000 births per year at –0·17 (95% CI –0·21 to –0·12; table 3). The difference was not significant for facilities between 2501 and 4000 births per year versus those with more than 4000 births per year. Higher quality of care was significantly associated with private facilities and those with ART available. Assumption checks for these linear models are in the appendix. The distribution of residuals was approximately normal; we adjusted for observed hetero-scedasticity in residuals (as noted in the primary care facility model) with robust standard errors. Alternative model specifications (log of volume and cubic spline) did not alter the basic findings so we elected to present the linear model for ease of interpretation.

Additional sensitivity analyses of the main results showed that the association between delivery volume and quality of basic maternal care functions did not change under new specifications (appendix). Finally, we explored the potential effect on the regression results of excluding the 127 facilities with missing data on facility birth volume. Most facilities with missing data were primary care facilities (122 [96%] of 127 were clinics or dispensaries), had small numbers of clinical staff and maternity beds, and had very low index scores for quality of care. Inclusion of these observations would magnify the difference in quality between primary and

Figure 2: **Association of quality of basic maternal care functions and annual delivery volume**

Annual delivery volume and facility quality for observed (unweighted) sample with loess smoother (running least squares) line shown for all health-care facilities (A; n=1704), primary care facilities (B; n=1245), and secondary care facilities (C; n=455). For the purposes of description, we calculated the quality of basic maternal care functions for each facility as the mean quality score for all the five datasets, with missing items imputed. Primary care facilities (those without caesarean section capacity) are shown up to 2000 deliveries per year (five facilities excluded); secondary care facilities and all facilities are truncated at 10 000 deliveries per year (11 facilities excluded) to show the region of the plots with most facilities and the greatest degree of change in quality. The shape of the fitted line is not affected by these exclusions. The full plot without truncation and country-specific plots are in the appendix.

secondary care facilities and probably also the association between volume of births per year and quality of basic maternal care.

Discussion

Using nationally representative data from health facility surveys in five sub-Saharan African countries, we found that nearly 90% of health-care facilities providing obstetric care do not have the capacity to do caesarean sections and that these primary care facilities deliver 44% of all facility births. Overall, 85% of delivery facilities (accounting for 32% of births) reported fewer than 500 births per year. By comparison, in high-income countries, caesarean section capacity is generally required of delivery facilities (with exceptions for birth centres located near hospitals and health-care facilities in remote locations) and regionalisation of obstetric care has meant that few babies are born in low-volume facilities. In Finland[34] less than 2% of births per year occur in health-care facilities with fewer than 500 births delivered per year, which is similar in England (<5% of births per year)[35] and in the USA (<8% of births per year).[36] Similarly, in Australia, a large and sparsely populated country, less than 16% of births occurred in health-care facilities with fewer than 500 births per year.[16,37]

We found very low quality of delivery care across the study facilities, particularly in primary care facilities with a low delivery volume. Primary care facilities had a mean score of 0·38 out of 1 on the basic maternal care quality index. This score indicates crucial deficiencies in staffing, infrastructure, referral systems, and routine and emergency care practices. Less than half of facilities scoring near the mean value (range 0·367–0·389) had a skilled provider available 24 h per day or had the capacity to refer women to higher level facilities if needed. These findings are consistent with individual studies[38–41] documenting weak infrastructure, staffing, and emergency care capacity in low-income countries, and particularly in primary care clinics. This performance is of concern given that the quality index was constructed from indicators of basic equipment and processes that should reflect a minimum level of safe evidence-based care. The quality index excludes more advanced measures of processes of care (eg, correct performance of signal functions) and other key dimensions (eg, interpersonal quality of care), although increasing evidence attests to frequent disrespect and mistreatment of women during delivery.[42,43]

We noted a strong association between delivery volume and obstetric care quality, with an absolute difference of more than 20% in adjusted analyses between the lowest delivery volume in primary care facilities (<52 births per year) and those delivering more than 500 births per year. However, the secondary care facilities with the lowest birth volume had higher quality index score than primary care facilities with the highest volume of births, suggesting that a high birth volume cannot compensate for absence of surgical capacity and associated competencies. Additional factors associated with quality of care provided included private ownership, skilled staff per bed (in primary facilities), and the presence of HIV treatment programmes in the health-care facility. ART programmes, typically funded by external donors, are positively associated with some aspects of maternal care quality in other studies, which is probably through improved health information systems (eg, laboratories and recording patient's health) and staff training.[18] Secondary care facilities with any delivery volume appeared better equipped to provide timely and

	Model 1: OLS unadjusted (β [95% CI])	p value	Model 2*: OLS adjusted (β [95% CI]‡)	p value
Primary care facilities	(n=1250)	..	(n=1246)	..
Delivery volume (per year)				
≤52	−0·27 (−0·30 to −0·23)	<0·0001	−0·22 (−0·26 to −0·19)	<0·0001
53–183	−0·18 (−0·22 to −0·15)	<0·0001	−0·12 (−0·16 to −0·09)	<0·0001
184–365	−0·11 (−0·15 to −0·07)	<0·0001	−0·06 (−0·10 to −0·03)	0·001
366–500	−0·08 (−0·13 to −0·04)	0·0003	−0·05 (−0·09 to −0·01)	0·01
>500	0 (reference)	..	0 (reference)	..
Private facility	..	..	0·04 (0·02 to 0·07)	<0·0001
Skilled staff per bed (log value)	..	..	0·05 (0·03 to 0·07)	<0·0001
ART facility	..	..	0·08 (0·05 to 0·10)	<0·0001
Country				
Kenya	..	..	0 (reference)	..
Namibia	..	..	−0·07 (−0·10 to −0·04)	<0·0001
Rwanda	..	..	−0·14 (−0·17 to −0·11)	<0·0001
Tanzania	..	..	−0·22 (−0·25 to −0·19)	<0·0001
Uganda	..	..	−0·10 (−0·13 to −0·07)	<0·0001
Intercept	0·57 (0·54 to 0·60)	..	0·57 (0·53 to 0·62)	..
Secondary care facilities	(n=465)	..	(n=464†)	..
Delivery volume (per year)				
≤500	−0·11 (−0·15 to −0·07)	<0·0001	−0·17 (−0·21 to −0·12)	<0·0001
501–1500	−0·06 (−0·10 to −0·02)	0·003	−0·09 (−0·13 to −0·05)	<0·0001
1501–2500	−0·07 (−0·11 to −0·03)	0·001	−0·07 (−0·11 to −0·04)	<0·0001
2501–4000	−0·02 (−0·06 to 0·03)	0·44	−0·03 (−0·07 to 0·005)	0·087
>4000	0 (reference)		0 (reference)	..
Private facility	..	..	0·06 (0·03 to 0·08)	<0·0001
Skilled staff per bed (log value)	..	..	0·01 (−0·01 to 0·03)	0·26
ART facility	..	..	0·06 (0·03 to 0·10)	0·001
Country				
Kenya	..	..	0 (reference)	..
Namibia	..	..	−0·08 (−0·12 to −0·03)	0·002
Rwanda	..	..	−0·07 (−0·10 to −0·03)	0·0001
Tanzania	..	..	−0·17 (−0·21 to −0·14)	<0·0001
Uganda	..	..	−0·10 (−0·13 to −0·07)	<0·0001
Intercept	0·83 (0·79 to 0·91)	..	0·85 (0·79 to 0·91)	..

OLS=ordinary least squares. ART=antiretroviral therapy. *Model 2 is adjusted for the confounders shown. †Smaller number of health-care facilities for adjusted model reflects missing data in skilled staff per bed (n=4) and ART service (n=1).

Table 3: **Unadjusted and adjusted regression models of quality of basic maternal care functions index and delivery volume**

competent care to women with intrapartum complications than were primary care facilities.

How many births are too few for a primary care facility to guarantee basic quality of obstetric care? Our analysis of the quality–volume curve suggests that quality is very low in primary care facilities with fewer than 500 births per year. However, even primary care facilities with higher birth volumes exhibit low quality of these basic functions, calling into question the ability of primary care facilities to consistently provide safe maternal care. Even for facilities with strong staff and inputs, the relatively low frequency of obstetric and newborn baby complications makes maintenance of adequate clinical skills difficult.[44] Complications are unpredictable, challenging the notion of a low-risk delivery. In the USA, women are extensively monitored during pregnancy, but up to 30% of women considered low risk develop an unexpected complication during or after delivery.[45] A robust infrastructure and competent and alert staff are needed to deal with the sudden complications that can turn a natural event such as childbirth into a medical emergency.

Although emergency referral has been proposed as an option to deal with complications arising at primary care facilities, in practice the long distances to facilities, unpaved roads which might flood during rain, dysfunctional emergency transport, and slow recognition of complications mean that timely referral is not feasible in many situations.[46,47] For women who are referred once in labour, inadequate first-line treatment and travel delays can lead to poor clinical outcomes.[48,49] However, some referral systems are more effective than others. Research on best practices in emergency referral in resource-constrained and geographically challenging settings is much needed. Quality improvement efforts at primary care facilities might target effective referral as a priority.

Our study had several limitations. First, it would have been ideal to also assess case fatality rates or maternal mortality ratios as an outcome measure of quality (along with casemix information to permit comparison), but these data are not collected in the SPA. Other studies[10,50,51] have identified strong associations between facility inputs and processes and maternal outcome measures, including high case fatality in low-resource health facilities, persistently high maternal mortality for women who live near health facilities, and excessive in-facility maternal mortality ratios (861 deaths per 100 000 livebirths)—which were associated with low facility resources. Second, our index does not include all elements of maternal care quality. Although we included measures of basic referral capacity, we were unable to assess the effectiveness of referral, because data for frequency and speed of referral or clinical outcomes for referred women were not available. Similarly, we have data on staffing at health-care facilities, but we do not have data for provider skill or competence in obstetric care. These measures would be an important area for future work in view of the substantial variance in skill that has been found in providers labelled as "skilled birth attendants".[52] As previously noted, another important element of quality outside the scope of our analysis is respectful treatment during delivery—disrespect and abuse are distressingly common and might dissuade women from seeking care. Although future, more comprehensive assessments of quality will yield important insights, our index provides an initial systematic assessment of the minimum requirements of health facilities that provide obstetric care, a quality floor.

Third, the seven process-of-care indicators for the quality index were self-reported; these were mainly obstetric signal functions. Self-report is standard methodology for collection of data on signal functions, but these items might be subject to recall or other response bias that would skew our measure higher. The remaining five structure items were obtained through direct observation by survey personnel. Fourth, missing data on quality indicators required imputation of some quality indicators; however, supplementary analysis replacing missing indicators with extreme values (0 and 1) showed that these missing data did not affect our main findings. Fifth, a missing data element that could not be imputed was urban or rural location of the health-care facility, which could affect the association between volume and quality if facilities with low volume of births in urban areas differ in terms of quality of care from those in rural settings. Finally, our results might be applicable to countries with similar health contexts and systems but should not be generalised beyond these settings.

To our knowledge this is the first study to use standardised, nationally representative health system data from several African countries to systematically assess the quality of basic care available to mothers delivering in a range of health-care facilities. Future prospective studies are needed to build on this research. Determinants of quality need to be further investigated. Our data suggest that some primary care facilities were able to deliver much higher quality care than others; factors such as management and accountability at the facility, district, and national levels, and other potential determinants of quality, bear additional scrutiny. In view of the international attention to maternal mortality and the focus on facility-based deliveries, these initial findings should help to galvanise intensive research to measure and improve the quality of obstetric health care. Development of new measurement approaches and indicators that capture a more complete picture of quality and are feasible to apply nationally is a crucial first step.

This study adds to a nascent body of scientific literature identifying major quality gaps in provision of basic maternal health care that impede reduction of maternal and newborn mortality.[53,54] One of the most prominent examples is the Janani Suraksha Yojana (JSY) programme in India, which provided a cash incentive for women to deliver in health-care facilities and covered about 9·5 million women per year, making it the largest

conditional cash transfer programme in the world.[55] The JSY programme had an impressive effect on rates of facility delivery—up to 50% increases in some jurisdictions in 1 year—but had, at best, modest effects on neonatal mortality and no effect on maternal mortality.[55–57] Studies in similar settings have identified weak obstetric knowledge, effort, and management of obstetric complications by facility health workers as well as poor infrastructure as obstacles to reducing maternal and newborn mortality.[4,10,56,58–60] Taken together, these findings from our and other studies challenge the current global health framework that prioritises expansion of coverage of facility delivery without the same level of attention to the assessment and improvement of facility quality.

In view of funding and provider constraints, what are the next steps to improve the quality of maternal care in low-income countries? In the short term, countries should undertake a careful review of quality of primary care facilities that do most deliveries to ensure these meet minimum expectations of effective function. They should also examine the functionality and speed of referral under prevailing conditions rather than assumed practice. If facilities with low volumes of births are found to be without the personnel, equipment, and skills needed to ensure safe delivery, countries need to assess the feasibility and costs of strengthening many small facilities versus expanding and improving higher level facilities; existing use and preferences should also be used to inform this assessment. Geospatial analysis can assist with identification of areas where such regionalisation of births could occur. Research from Tanzania showed that reducing the number of first-level facilities in some areas with high facility density would have minimal effect on geographical access to care.[61] New research, including detailed scenario analysis and cost-effectiveness studies, will be needed to inform local decisions. Any regionalisation efforts must be accompanied by new investments in transportation, referral systems, and financial incentives and other assistance to permit women in rural areas (including those with low income), to access quality care.[62–66] Quality of care in high-volume facilities has to be measured and not just assumed to be adequate. Specific attention must be paid to issues of overcrowding, overuse of medical interventions not based on evidence, quality of surgical care, and the potential for disrespectful care in high-volume settings.[67,68]

Several lower-income countries have experimented with promoting delivery in higher-volume settings, such as maternity care units or birth centres near hospitals.[69,70] Such approaches might be increasingly feasible in some settings with the expansion of road networks, rapid urbanisation, and changes in preference for hospital care by women.[71,72] However, this approach means that the number of facilities with capability to do caesarean sections might also need to increase in most low-income countries, potentially beyond WHO's recommendation of one facility with caesarean section capacity per 500 000 people.[54,73] The Lancet's Commission on Global Surgery[74,75] called for a major expansion of facilities with surgical capacity to reduce maternal and newborn mortality in low-income countries. Any expansion must include careful measurement of surgical safety.[76] Such an expansion will require substantial additional investment that might be difficult in countries with low economic growth. Complementary approaches to improve quality of care that could be explored are more intensive pre-service and in-service training of health workers, better and more supportive supervision by highly skilled staff (eg, nurses or supervisors), effective in-service training (eg, use of clinical drills), results-based financing, accreditation for the high-quality clinics, use of checklists, maternal and perinatal audits, and continuous quality improvement efforts.[77] Maternity waiting homes might play a part for populations that are distant from the health system, although this approach has not been conclusively shown to reduce mortality.[78,79] Finally, strengthening of coverage and quality of antenatal and early postnatal care at primary care clinics is crucial to reduce newborn mortality.[4]

A pivot from coverage to quality is needed for LMICs to reach the SDG targets for maternal and newborn mortality and for health systems to meet their obligations to the population to provide safe and effective services. Countries will need to identify the most feasible policy and programme options to accomplish the targets, given their population needs, health systems, geographies, and fiscal resources. In support, policy makers and global funders need to invest resources to monitor and improve the quality of care in health facilities caring for pregnant women. Researchers must prioritise quality measurement and investigation of modifiable determinants of quality to ensure that these new efforts deliver on the promise of better health for women and newborn babies worldwide.

Contributors

MEK initially conceived the analysis. MEK and HHL drafted the manuscript. HHL led the data analysis. All authors contributed to manuscript conception, data analysis, and critical revision of the manuscript.

Declaration of interests

We declare no competing interests.

Acknowledgments

We thank Anna Gage for assistance in data management and data analysis and thank Ipek Gurol-Urganci and Jonathan Snowden for providing data on facility delivery volume in high-income countries.

References

1 UN Development Program. Sustainable Development Goals. Geneva: United Nations, 2015.

2 Alkema L, Chou D, Hogan D, et al, on behalf of the United Nations Maternal Mortality Estimation Inter-Agency Group collaborators technical advisory group. Global, regional, and national levels and trends in maternal mortality between 1990 and 2015, with scenario-based projections to 2030: a systematic analysis by the UN Maternal Mortality Estimation Inter-Agency Group. *Lancet* 2016; **387:** 462–74.

3 Kassebaum NJ, Bertozzi-Villa A, Coggeshall MS, et al. Global, regional, and national levels and causes of maternal mortality during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014; **384:** 980–1004.

4 Souza JP, Gülmezoglu AM, Vogel J, et al. Moving beyond essential interventions for reduction of maternal mortality (the WHO Multicountry Survey on Maternal and Newborn Health): a cross-sectional study. *Lancet* 2013; **381:** 1747–55.

5 Fink G, Ross R, Hill K. Institutional deliveries weakly associated with improved neonatal survival in developing countries: evidence from 192 Demographic and Health Surveys. *Int J Epidemiol* 2015; published online July 30. DOI:10.1093/ije/dyv115.

6 Bhutta ZA, Das JK, Bahl R, et al. Can available interventions end preventable deaths in mothers, newborn babies, and stillbirths, and at what cost? *Lancet* 2014; **384:** 347–70.

7 Hanson C, Ronsmans C, Penfold S, et al. Health system support for childbirth care in Southern Tanzania: results from a health facility census. *BMC Res Notes* 2013; **6:** 435.

8 Kruk ME, Hermosilla S, Larson E, Mbaruku GM. Bypassing primary care clinics for childbirth: a cross-sectional study in the Pwani region, United Republic of Tanzania. *Bull World Health Organ* 2014; **92:** 246–53.

9 Chaturvedi S, Randive B, Diwan V, De Costa A. Quality of obstetric referral services in India's JSY cash transfer programme for institutional births: a study from Madhya Pradesh province. *PLoS One* 2014; **9:** e96773.

10 Hanson C, Cox J, Mbaruku G, et al. Maternal mortality and distance to facility-based obstetric care in rural southern Tanzania: a secondary analysis of cross-sectional census data in 226 000 households. *Lancet Glob Health* 2015; **3:** e387–95.

11 Gabrysch S, Campbell OM. Still too far to walk: literature review of the determinants of delivery service use. *BMC Pregnancy Childbirth* 2009; **9:** 34.

12 Nesbitt RC, Lohela TJ, Manu A, et al. Quality along the continuum: a health facility assessment of intrapartum and postnatal care in Ghana. *PLoS One* 2013; **8:** e81–89.

13 Kendall T, Langer A. Critical maternal health knowledge gaps in low- and middle-income countries for the post-2015 era. *Reprod Health* 2015; **12:** 55.

14 Straneo M, Fogliati P, Azzimonti G, Mangi S, Kisika F. Where do the rural poor deliver when high coverage of health facility delivery is achieved? Findings from a community and hospital survey in Tanzania. *PLoS One* 2014; **9:** e113995.

15 Janakiraman V, Lazar J, Joynt KE, Jha AK. Hospital volume, provider volume, and complications after childbirth in US hospitals. *Obstet Gynecol* 2011; **118:** 521–27.

16 Kyser KL, Lu X, Santillan DA, et al. The association between hospital obstetrical volume and maternal postpartum complications. *Am J Obstet Gynecol* 2012; **207:** 42 e1–17.

17 Hein HA. Regionalized perinatal care in North America. *Semin Neonatol* 2004; **9:** 111–16.

18 Kruk ME, Jakubowski A, Rabkin M, et al. Association between HIV programs and quality of maternal health inputs and processes in Kenya. *Am J Public Health* 2015; **105:** S207–10.

19 Gabrysch S, Civitelli G, Edmond KM, et al. New signal functions to measure the ability of health facilities to provide routine and emergency newborn care. *PLoS Med* 2012; **9:** e1001340.

20 Tripathi V, Stanton C, Strobino D, Bartlett L. Development and validation of an index to measure the quality of facility-based labor and delivery care processes in sub-Saharan Africa. *PLoS One* 2015; **10:** e0129491.

21 Renfrew MJ, McFadden A, Bastos MH, et al. Midwifery and quality care: findings from a new evidence-informed framework for maternal and newborn care. *Lancet* 2014; **384:** 1129–45.

22 Bilimoria KY. Facilitating quality improvement: pushing the pendulum back toward process measures. *JAMA* 2015; **314:** 1333–34.

23 WHO, UNFPA, UNICEF, Mailman School of Public Health. Monitoring emergency obstetric care: a handbook. Geneva: World Health Organization, 2009.

24 Honaker J, King G, Blackwell M. Amelia II: a program for missing data. 2011. *J Stat Softw* 2011; **45:** 1–47.

25 World Bank. World development indicators. Washington, DC: World Bank, 2014.

26 Graham M, Hale SA, Stephens M. Geographies of the world's knowledge. London: Convoco, 2011.

27 WHO. Global health observatory data repository. Geneva: World Health Organization, 2015.

28 Kenya National Bureau of Statistics, ICF Macro. Kenya demographic and health survey 2008–2009. Calverton Maryland: Kenya National Bureau of Statistics, ICF Macro, 2010.

29 Namibia Ministry of Health and Social Services, ICF International. The Namibia demographic and health survey 2013. Windboek: USAID, 2014.

30 National Institute of Statistics of Rwanda, Rwandan Ministry of Health, ICF International. Rwanda demographic and health survey 2010. Calverton, Maryland: National Institute of Statistics of Rwanda, Rwandan Ministry of Health, ICF International, 2012.

31 National Bureau of Statistics, ICF Macro. Tanzania demographic and health survey 2010. Dar es Salaam: National Bureau of Statistics, ICF Macro, 2011.

32 Uganda Bureau of Statistics, ICF International. Uganda demographic and health survey 2011. Kampala: Uganda Bureau of Statistics, ICF International, 2012.

33 National Center for Health Statistics. Births: final data for 2013. Atlanta, GA: US Centers for Disease Control and Prevention, 2015.

34 Pyykonen A, Gissler M, Jakobsson M, Petäjä J, Tapper AM. Determining obstetric patient safety indicators: the differences in neonatal outcome measures between different-sized delivery units. *BJOG* 2014; **121:** 430–37.

35 Redshaw M, Rowe R, Schroeder L, et al. Mapping maternity care: the configuration of maternity care in England. Birthplace in England research programme. Final report part 3. Southampton; NIHR Service Delivery and Organisation programme, 2011.

36 Simpson KR. An overview of distribution of births in United States hospitals in 2008 with implications for small volume perinatal units in rural hospitals. *J Obstet Gynecol Neonatal Nurs* 2011; **40:** 432–29.

37 Tracy SK, Sullivan E, Dahlen H, Black D, Wang YA, Tracy MB. Does size matter? A population-based study of birth in lower volume maternity hospitals for low risk women. *BJOG* 2006; **113:** 86–96.

38 Hsia RY, Mbembati NA, Macfarlane S, Kruk ME. Access to emergency and surgical care in sub-Saharan Africa: the infrastructure gap. *Health Policy Plan* 2012; **27:** 234–44.

39 Hongoro C, McPake B. How to bridge the gap in human resources for health. *Lancet* 2004; **364:** 1451–56.

40 Anand S, Bärnighausen T. Human resources and health outcomes: cross-country econometric study. *Lancet* 2004; **364:** 1603–09.

41 Bailey P, Paxton A, Lobis S, Fry D. The availability of life-saving obstetric services in developing countries: an in-depth look at the signal functions for emergency obstetric care. *Int J Gynecol Obstet* 2006; **93:** 285–91.

42 Larson E, Hermosilla S, Kimweri A, Mbaruku GM, Kruk ME. Determinants of perceived quality of obstetric care in rural Tanzania: a cross-sectional study. *BMC Health Serv Res* 2014; **14:** 483.

43 Bohren MA, Vogel JP, Hunter EC, et al. The mistreatment of women during childbirth in health facilities globally: a mixed-methods systematic review. *PLoS Med* 2015; **12:** e1001847.

44 Adegoke A, Utz B, Msuya SE, van den Broek N. Skilled birth attendants: who is who? A descriptive study of definitions and roles from nine sub Saharan African countries. *PLoS One* 2012; **7:** e40220.

45 Danilack VA, Nunes AP, Phipps MG. Unexpected complications of low-risk pregnancies in the United States. *Am J Obstet Gynecol* 2015; **212:** 809 e1–6.

46 Bossyns P, Abache R, Abdoulaye MS, Miye H, Depoorter AM, Van Lerberghe W. Monitoring the referral system through benchmarking in rural Niger: an evaluation of the functional relation between health centres and the district hospital. *BMC Health Serv Res* 2006; **6:** 51.

47 Bossyns P, Van Lerberghe W. The weakest link: competence and prestige as constraints to referral by isolated nurses in rural Niger. *Hum Resour Health* 2004; **2:** 1.

48 Hirose A, Borchert M, Cox J, Alkozai A, Filippi V. Determinants of delays in travelling to an emergency obstetric care facility in Herat, Afghanistan: an analysis of cross-sectional survey data and spatial modelling. *BMC Pregnancy Childbirth* 2015; **15:** 14.

49 Assarag B, Dujardin B, Delamou A, Meski FZ, De Brouwere V. Determinants of maternal near-miss in morocco: too late, too far, too sloppy? *PLoS One* 2015; **10:** e0116675.

50 Knight HE, Self A, Kennedy SH. Why are women dying when they reach hospital on time? A systematic review of the 'third delay'. *PLoS One* 2013; **8:** e63846.

51 Montoya A, Calvert C, Filippi V. Explaining differences in maternal mortality levels in sub-Saharan African hospitals: a systematic review and meta-analysis. *Int Health* 2014; **6:** 12–22.

52 Harvey SA, Blandon YC, McCaw-Binns A, et al. Are skilled birth attendants really skilled? A measurement method, some disturbing results and a potential way forward. *Bull World Health Organ* 2007; **85:** 783–90.

53 Baker U, Peterson S, Marchant T, et al. Identifying implementation bottlenecks for maternal and newborn health interventions in rural districts of the United Republic of Tanzania. *Bull World Health Organ* 2015; **93:** 380–89.

54 Echoka E, Kombe Y, Dubourg D, et al. Existence and functionality of emergency obstetric care services at district level in Kenya: theoretical coverage versus reality. *BMC Health Serv Res* 2013; **13:** 113.

55 Lim SS, Dandona L, Hoisington JA, James SL, Hogan MC, Gakidou E. India's Janani Suraksha Yojana, a conditional cash transfer programme to increase births in health facilities: an impact evaluation. *Lancet* 2010; **375:** 2009–23.

56 Randive B, Diwan V, De Costa A. India's conditional cash transfer programme (the JSY) to promote institutional birth: is there an association between institutional birth proportion and maternal mortality? *PLoS One* 2013; **8:** e67452.

57 Paul VK. India: conditional cash transfers for in-facility deliveries. *Lancet* 2010; **375:** 1943–44.

58 Chaturvedi S, Upadhyay S, De Costa A. Competence of birth attendants at providing emergency obstetric care under India's JSY conditional cash transfer program for institutional delivery: an assessment using case vignettes in Madhya Pradesh province. *BMC Pregnancy Childbirth* 2014; **14:** 174.

59 Vogel JP, Souza JP, Mori R, et al. Maternal complications and perinatal mortality: findings of the World Health Organization Multicountry Survey on Maternal and Newborn Health. *BJOG* 2014; **121** (suppl 1)**:** 76–88.

60 Marchant T, Tilley-Gyado RD, Tessema T, et al. Adding content to contacts: measurement of high quality contacts for maternal and newborn health in Ethiopia, north east Nigeria, and Uttar Pradesh, India. *PLoS One* 2015; **10:** e0126840.

61 Fogliati P, Straneo M, Brogi C, et al. How can childbirth care for the rural poor be improved? A contribution from spatial modelling in rural Tanzania. *PLoS One* 2015; **10:** e0139460.

62 Mayora C, Ekirapa-Kiracho E, Bishai D, Peters DH, Okui O, Baine SO. Incremental cost of increasing access to maternal health care services: perspectives from a demand and supply side intervention in Eastern Uganda. *Cost Eff Resour Alloc* 2014; **12:** 14.

63 Schmidt JO, Ensor T, Hossain A, Khan S. Vouchers as demand side financing instruments for health care: a review of the Bangladesh maternal voucher scheme. *Health Policy* 2010; **96:** 98–107.

64 Obare F, Warren C, Kanya L, Abuya T, Bellows B. Community-level effect of the reproductive health vouchers program on out-of-pocket spending on family planning and safe motherhood services in Kenya. *BMC Health Serv Res* 2015; **15:** 343.

65 Alfonso YN, Bishai D, Bua J, Mutebi A, Mayora C, Ekirapa-Kiracho E. Cost-effectiveness analysis of a voucher scheme combined with obstetrical quality improvements: quasi experimental results from Uganda. *Health Policy Plan* 2015; **30:** 88–99.

66 Jamison DT, Summers LH, Alleyne G, et al. Global health 2035: a world converging within a generation. *Lancet* 2013; **382:** 1898–955.

67 Litorp H, Kidanto HL, Roost M, Abeid M, Nystrom L, Essen B. Maternal near-miss and death and their association with caesarean section complications: a cross-sectional study at a university hospital and a regional hospital in Tanzania. *BMC Pregnancy Childbirth* 2014; **14:** 244.

68 Van Lerberghe W, Matthews Z, Achadi E, et al. Country experience with strengthening of health systems and deployment of midwives in countries with high maternal mortality. *Lancet* 2014; **384:** 1215–25.

69 Moran NF, Naidoo M, Moodley J. Reducing maternal mortality on a countrywide scale: the role of emergency obstetric training. *Best Pract Res Clin Obstet Gynaecol* 2015; **29:** 1102–18.

70 Hofmeyr GJ, Mancotywa T, Silwana-Kwadjo N, Mgudlwa B, Lawrie TA, Gulmezoglu AM. Audit of a new model of birth care for women with low risk pregnancies in South Africa: the primary care onsite midwife-led birth unit (OMBU). *BMC Pregnancy Childbirth* 2014; **14:** 417.

71 UN. World urbanization prospects: the 2014 revision. New York: United Nations, 2014.

72 Kante AM, Exavery A, Phillips JF, Jackson EF. Why women bypass front-line health facility services in pursuit of obstetric care provided elsewhere: a case study in three rural districts of Tanzania. *Trop Med Int Health* 2016; **21:** 504–14.

73 Pearson L, Shoo R. Availability and use of emergency obstetric services: Kenya, Rwanda, Southern Sudan, and Uganda. *Int J Gynaecol Obstet* 2005; **88:** 208–15.

74 Meara JG, Leather AJ, Hagander L, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet* 2015; **386:** 569–624.

75 Molina G, Weiser TG, Lipsitz SR, et al. Relationship between cesarean delivery rate and maternal and neonatal mortality. *JAMA* 2015; **314:** 2263–70.

76 Arya S, Ng-Kamstra J, Meara JG, Langer A. Tracking perioperative mortality and maternal mortality: challenges and opportunities. *Lancet Glob Health* 2016; **4:** e440–41.

77 Bollinger L, Kruk ME. Innovations to expand access and improve quality of health services. In: Black R, Laxminarayan R, Temmerman M, Walker N, eds. Reproductive, maternal, newborn, and child health. Washington, DC: World Bank Group, 2016.

78 Hussein J, Kanguru L, Astin M, Munjanja S. The effectiveness of emergency obstetric referral interventions in developing country settings: a systematic review. *PLoS Med* 2012; **9:** e1001264.

79 van Lonkhuijzen L, Stekelenburg J, van Roosmalen J. Maternity waiting facilities for improving maternal and neonatal outcome in low-resource countries. *Cochrane Database Syst Rev* 2012; **10:** CD006759.