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Impact of a systems engineering intervention on PMTCT service delivery in Côte d'Ivoire, Kenya, Mozambique: a cluster randomized trial

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Abstract

BACKGROUND—Efficacious interventions to prevent mother-to-child HIV transmission (PMTCT) have not translated well into effective programs. Prior studies of systems engineering applications to PMTCT lacked comparison groups or randomization.

METHODS—Thirty-six health facilities in Côte d'Ivoire, Kenya, and Mozambique were randomized to usual care or a systems engineering intervention, stratified by country and volume. The intervention guided facility staff to iteratively identify and then rectify barriers to PMTCT

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implementation. Registry data quantified coverage of HIV testing during first antenatal care visit, antiretrovirals (ARVs) for HIV-positive pregnant women, and screening HIV-exposed infants (HEI) for HIV by 6–8 weeks. We compared the change between baseline (January 2013–January 2014) and post-intervention (January–March 2015) periods using *t*-tests. All analyses were intent-to-treat.

RESULTS—ARV coverage increased 3-fold (+13.3 percentage points [95% CI: 0.5, 26.0] in intervention vs. +4.1 [−12.6, 20.7] in control facilities) and HEI screening increased 17-fold (+11.6 [−2.6, 25.7] in intervention vs. +0.7 [−12.9, 14.4] in control facilities). In pre-specified subgroup analyses, ARV coverage increased significantly in Kenya (+20.9 [−3.1, 44.9] in intervention vs. −21.2 [−52.7, 10.4] in controls; *p*=0.02). HEI screening increased significantly in Mozambique (+23.1 [10.3, 35.8] in intervention vs. +3.7 [−13.1, 20.6] in controls; *p*=0.04). HIV testing did not differ significantly between arms.

CONCLUSIONS—In this first randomized trial of systems engineering to improve PMTCT, we saw substantially larger improvements in ARV coverage and HEI screening in intervention facilities compared to controls, which were significant in pre-specified sub-groups. Systems engineering could strengthen PMTCT service delivery and protect infants from HIV.

Keywords

Health systems; Health systems performance; HIV/AIDS; Maternal health services; PMTCT; Systems engineering

INTRODUCTION

Translating efficacious interventions to prevent mother-to-child HIV-1 transmission (PMTCT) into effective programs has been slow and uneven. In sub-Saharan Africa, despite high antenatal care (ANC) utilization,¹ bottlenecks occur at each step of the PMTCT cascade, from HIV testing of pregnant women, to uptake of antiretrovirals (ARVs) or combination antiretroviral therapy (cART), to screening HIV-exposed infants (HEI) with HIV polymerase chain reaction (PCR) testing, to adoption and maintenance of appropriate infant feeding.^{2–4} Facility-level barriers include human resources shortages,⁵ lack of service integration,^{3,5,6} lack of ongoing mentoring,⁷ and poor patient-provider interactions.⁵ Though vertical transmission rates of <1% have been achieved in high-income countries,⁸ actual rates in sub-Saharan Africa are estimated to be several times higher.^{9–11}

The PMTCT cascade is uniquely complex. First, it encompasses more than two years and crosses multiple biological phases for women and infants. Second, women and infants must navigate multiple sectors, from antenatal care, to maternity, postpartum care, and finally integration into long-term HIV care. Each transition between services is an opportunity for patients to be lost to follow-up. Finally, completion of the sequential steps in the PMTCT cascade is conditional upon completion of previous steps; therefore, even modest inefficiencies across individual services compound one another.

The advent of lifelong cART for all pregnant or breastfeeding HIV-positive women, termed Option B+, has theoretical logistical advantages, as clinicians prescribe a uniform, fixed dose combination regimen without prior CD4 testing.¹² The three countries in which this

randomized trial was conducted have each implemented Option B (in which cART is given for the duration of pregnancy and breastfeeding) or B+. Côte d'Ivoire adopted Option B in November 2012, and gradually rolled it out during 2013.¹³ Mozambique implemented Option B+ in June 2013.⁷ Kenya introduced Option B+ at research sites in 2011, and adopted it as national policy in 2014.¹⁴

However, Option B/B+ also presents new obstacles.¹⁵ A sizable proportion of women – who may feel healthy – refuse or default from cART^{4,16,17} or receive no ARVs at all,¹⁸ putting them at risk of increased MTCT. Data on long-term retention and adherence are as yet lacking. In addition, Option B/B+ has not addressed – and may even worsen, if women are more likely to default from care – the urgent need for PMTCT programs to improve HEI screening as part of a “child-centric” approach.¹⁹ Increasing HEI screening promotes long term engagement in care and prompt recognition and treatment of infant HIV infection,¹⁹ but also could promote family planning and other services for mothers, which are utilized by only a fraction of women at 2 months postpartum.²⁰

Systems engineering is a multidisciplinary approach to optimize complex processes.²¹ Value stream mapping and quality improvement (QI) are systems engineering tools which seek to maximize value while minimizing waste, and have been successfully applied to health care.²² QI has been applied to increase maternal HIV status documentation in the U.S.,²³ cotrimoxazole prophylaxis among adult HIV patients in Uganda, Mozambique, Namibia, and Haiti,²⁴ uptake of early infant diagnosis of HIV in rural Mozambique,²⁵ and decrease turn-around time for HEI screening test results in Tanzania.²⁶ QI has proven feasible to apply to PMTCT programs in South Africa^{27–29} and Zambia,³⁰ though previous PMTCT-focused QI interventions in sub-Saharan Africa have lacked a comparison group^{27,28} or were non-randomized.³⁰ None have evaluated QI to improve PMTCT services in the era of Option B+, though one other randomized QI intervention is ongoing in Nigeria.³¹

We sought to quantify the effectiveness of a package of systems engineering tools, including QI, to improve PMTCT services in sub-Saharan Africa, as measured by its impact on three key steps in the PMTCT cascade: HIV testing coverage during first ANC visit, ARV coverage among HIV-positive pregnant women, and screening infants exposed to HIV.

METHODS

Details of the study design of this pragmatic, two-arm, longitudinal cluster-randomized trial have been published elsewhere, including eligibility criteria, locations, HIV prevalence, and other characteristics of study facilities.³² Briefly, we randomized 36 health facilities 1:1 to either the study intervention or usual care, stratified by country and volume of first antenatal care visits (ANC1), to test whether our package of systems engineering tools could improve PMTCT service delivery at the facility (i.e., cluster) level. Option B/B+ rollout at study facilities began in March 2013 and continued throughout the study (see Table, Supplemental Digital Content 1, listing roll-out dates at each facility).

Study intervention

The Systems Analysis and Improvement Approach (SAIA) study intervention was a 5-step, iterative package of systems analysis and improvement tools developed using multiple systems engineering techniques, including continuous quality improvement (CQI). Full details of the study intervention, protocols, and tools are available at <http://www.healthallianceinternational.org/wp-content/uploads/2016/02/SAIA-Study-Tools.pdf>. The first two steps helped facility staff understand barriers to PMTCT service delivery in their health facility using decision support tools. Staff used the Excel-based PMTCT Cascade Analysis Tool (PCAT)³³ to quantify drop-offs along the cascade and identify the number of additional mother-infant pairs who would complete the cascade if drop-off at each individual step were eliminated, holding all other steps constant (Step 1). Then, staff mapped patient flow through PMTCT services across sectors at their facility and identified which specific step to adapt, within one service element of the cascade (Step 2). The final three steps utilized CQI methodology. Staff developed and implemented a “microintervention” to mitigate bottlenecks in the cascade (Step 3). Next, they updated the PCAT and assessed the impact of the microintervention on drop-offs (Step 4). Finally, staff would either modify the initial microintervention, or implement a new one if it had been successful. Steps 1–4 were then repeated in an iterative cycle (Step 5).

After a 4-day workshop at each intervention facility to orient staff to the intervention’s purpose and methods, including how to select metrics to assess the impact of microinterventions, follow-up visits were conducted weekly for 4 weeks, biweekly for the next 8 weeks, and thereafter monthly or as determined by facility and study staff. Implementation barriers were addressed by interviewing both leadership and frontline health workers at follow-up visits. Impacts of microinterventions were evaluated monthly via the PCAT, though staff often collected additional data (e.g., total time for ANC1 visit) to assess impacts in real time. The implementation period was initially 6 months, but was extended to 9 months (February–November 2014) due to recognition that more time was essential for facility staff to become proficient at systems improvement and see the impact of multiple, incremental improvements in service delivery. Staff did not implement the intervention during December 2014, as services are reduced or suspended during December due to staff absences for the holidays.

Primary Outcomes

The primary outcomes were: the proportions of (1) pregnant women tested for HIV during ANC1, (2) HIV-positive pregnant women receiving ARVs, (3) HIV-exposed infants (HEI) screened for HIV with PCR test by 6–8 weeks of age. These outcomes reflect key steps across the PMTCT cascade (see Figure, Supplemental Digital Content 2, showing outcomes within the cascade), and have been previously validated as measures of performance.³⁴ All primary outcomes applied to the cluster level. We estimated the denominator for the last outcome, HEI screening, with a weighted average using the distribution of the gestational ages at ANC1 visits at each facility and the number of ANC1 visits in previous months (see Document, Supplemental Digital Content 3, for details of primary outcome definitions). Outcomes were calculated using monthly data from facility registries; outcomes greater than 100% were capped at 100%. Data collection began in January 2014. Data from 2013 were

collected retrospectively; all other data were collected prospectively. Data were double-collected on site by two trained abstractors. Any differences between abstractors were re-reviewed on-site until they reached consensus.

Statistical Analysis

For each outcome, we tested whether the change between the baseline period's mean (January 2013–January 2014) and post-intervention period's mean (January–March 2015) differed between study arms using a two-sided *t*-test. Specifically, for each facility, we subtracted the baseline mean from the post-intervention mean. Then, the resulting 18 values in control facilities were compared to the 18 values in intervention facilities using a *t*-test. We also conducted one pre-specified sub-group analysis: stratification by country. No other sub-group analyses were conducted. We did not adjust for covariates, as the intervention was randomized. We did not need to account for clustering, as the unit of randomization and the unit of analysis were each at the cluster (i.e., facility) level.³⁵ All analyses were intent-to-treat.

The ethics review boards of the Ministries of Health in Mozambique and Côte d'Ivoire, and of Kenyatta National Hospital in Nairobi, Kenya each approved the study. The study was reviewed by the Institutional Review Board at the University of Washington, and qualified for federal exempt status, category 2. All procedures were conducted in accordance with the Helsinki Declaration of 1975, as revised in 2000. All analyses were completed using Stata version 13.1 (College Station, Texas).

RESULTS

Thirty-six facilities were randomized. One high-volume facility in Kenya (facility AA) randomized to the intervention declined to participate despite repeated attempts to engage staff. Primary outcomes data from this site were included in the analysis. Two facilities in Kenya (one low-volume intervention, one low-volume control) were excluded due to an ongoing World Health Organization-sponsored QI intervention, which overlapped sufficiently with our own to warrant the facilities' replacement. In Côte d'Ivoire, two facilities (one high-volume intervention, one low-volume control) were excluded due to the absence of on-site delivery or postpartum care, which precluded gathering primary outcomes data. These four facilities were replaced with similar-volume sites that were randomly selected from the remaining eligible facilities in each country. There were no significant differences between study arms in experience offering PMTCT, volume, staffing levels, or infrastructure (Table 1).

Over the nine-month intervention period, the 17 facilities that implemented the SAIA intervention tested 158 microinterventions (range: 4 – 31). On average, each facility tested 9.3 microinterventions, or approximately one per month. Microinterventions focused on one of five categories: reorganizing services, strengthening existing norms, educating patients, improving health worker communication (within the facility or with outside laboratories), and improving routine data quality (see Table, Supplemental Digital Content 4, for the distribution of microintervention types). Most microinterventions were modest alterations to reorganize existing services (36%), such as sending new ANC patients to the lab for blood

draw before they queued to see the nurse, or to strengthen existing norms (30%), such as conducting trainings for health workers on Option B+. Among the three primary outcomes, a similar proportion of microinterventions targeted ARV coverage (27%), HEI screening (26%), and other aspects of PMTCT services not captured by the primary outcomes ([28%], e.g., HIV testing during subsequent ANC visits or at the time of delivery, procuring stethoscopes for exclusive use in maternal and child health sectors, etc.). A smaller proportion targeted testing coverage (18%), as baseline coverage of testing was already high and the PCAT suggested that improving other aspects of the cascade would be more effective.

Patient volume and HIV prevalence varied substantially across study sites and countries (see Table, Supplemental Digital Content 5, for raw numbers used to calculate primary outcomes). For example, the mean volume of ANC1 visits during the 13-month baseline period per facility was 1,078 in Côte d'Ivoire, compared to 2,034 in Kenya and 2,089 in Mozambique.

Secular events

In Kenya, facilities were subject to the nationwide shortage of HIV test kits in mid-2014. However, this period was included in neither baseline nor endline periods. Two control facilities in Kenya (facilities K and L) were located in coastal areas near the Kenya-Somalia border that were unfortunately subject to violence beginning in the spring of 2014.³⁶ All three primary outcomes declined in these facilities, most dramatically for ARV coverage (−65% and −44%). For safety reasons, study staff could not return to collect data directly from these facilities' registries; instead, data were extracted from Kenya's national health information system. In Mozambique, national elections during the last quarter of 2014 may have impacted health service delivery across sectors, though again, this period was not included in either baseline and endline periods. In Côte d'Ivoire, the ANC registry form was updated in mid-2013, which may have impacted data quality for both control and intervention sites during the baseline period.

Primary outcomes

In the overall analysis, increases in ARV coverage and HEI screening, but not HIV testing in ANC1, were substantially greater in intervention facilities compared to controls (Figure; see Figures, Supplemental Digital Content 6–8 for country-specific trend lines). HIV testing in ANC1 increased, on average, in intervention facilities from 90.5% to 95.9%, a gain of +5.3 percentage points (95% CI: −1.7, 9.0) and in control facilities from 87.8% to 93.4% (+5.5 percentage points, [−2.8, 13.8]; $p=0.97$) (Table 2). In intervention sites, ARV coverage increased from 66.4% to 77.7% (+13.3 percentage points [0.5, 26.0]), and in control sites ARV coverage increased from 64.0% to 65.9% on average (+4.1 percentage points [−12.6, 20.7]; $p=0.36$) (Table 3). The proportion of HIV-exposed infants screened for HIV increased from 34.5% to 46.1% (+11.6 percentage points [−2.6, 25.7]) in intervention sites, on average, and increased from 31.3% to 32.0% in controls, on average (+0.7 percentage points [−12.9, 14.4]; $p=0.25$) (Table 4). Though ARV provision and HEI screening declined >10% in four facilities each, mean coverage levels were not significantly lower in intervention facilities compared to controls for any outcome.

In pre-specified sub-group analyses stratified by country, notable differences emerged. For HIV testing coverage in ANC1 (Table 2), in Kenya, intervention sites improved substantially more than control sites (+9.2% vs. -0.4%, $p=0.30$). For ARV coverage (Table 3), differences between study arms in Kenya were statistically significant; intervention sites improved from 52.5% to 73.4% whereas controls sites declined from 59.7% to 38.5% ($p=0.02$). For HEI screening (Table 4), intervention sites in Mozambique improved significantly more than control sites (+23.1% vs. +3.7%; $p=0.04$).

For ANC1 testing coverage, ARV coverage, and HEI screening, 4.1%, 4.8%, and 8.9% of values were >100%, and were capped at 100%. In sensitivity analyses, there were no meaningful or significant changes in the results when values were left uncorrected.

DISCUSSION

In this first randomized, controlled trial of a package of systems engineering tools to improve PMTCT services in sub-Saharan Africa, ARV coverage among HIV-positive pregnant women and screening of HIV-exposed infants increased substantially in the overall analysis, and increased significantly in selected countries in a pre-specified subgroup analyses. HIV testing coverage during first ANC visit, near 90% at baseline, improved modestly in both arms. There was no evidence of harm. Health facilities were not required to implement only those microinterventions that could plausibly impact the study's primary outcomes, and this may have diluted our ability to measure the intervention's true impact. However, this approach was consistent with our aim to quantify the intervention's real-world effectiveness to improve the flow of mother-infant pairs through the PMTCT cascade.

HIV testing coverage in ANC1 improved similarly across study arms, which may reflect several factors. First, a smaller proportion of microinterventions targeted this step of the PMTCT cascade (18% of all microinterventions), compared to the other two primary outcomes. Further, baseline levels were high (88% in control and 91% in intervention facilities), leaving relatively little room for improvement. By the end of the study, HIV testing in ANC1 achieved near-universal coverage levels in both arms. This is encouraging, as testing is the essential first step to access PMTCT. Moreover, PMTCT programs have historically provided the largest proportion of HIV testing and counseling services for adults,⁷ and therefore represent the most common entry point into HIV care. Missing an HIV test in ANC represents a dual failure to protect the infant from HIV acquisition, and provide the mother with timely cART. This also reinforces that the PMTCT cascade magnifies inefficiencies, as each step is conditional on completing prior steps.

ARV coverage among HIV-positive women improved 3-fold more in intervention (+13.3%) than control facilities (+4.1%), though this difference was not significant. ARV coverage in Kenya improved significantly more among intervention facilities (+20.9%) compared to control facilities (-21.2%). However, the decline in the two coastal facilities near the Kenya-Somalia border may have contributed to the magnitude and significance of this difference. Facilities in Côte d'Ivoire were able to achieve 100% ARV coverage, though facilities in Côte d'Ivoire had much smaller volumes due to lower HIV prevalences.¹¹

The nearly 17-fold larger improvement in HEI screening in intervention vs. control facilities is particularly encouraging. Though not statistically significant, this promising result merits further investigation as it represents a meaningful increase in retention in longer-term care.¹⁹ Ongoing engagement in the later steps of the PMTCT cascade is critical to the success of PMTCT in general, and to Option B+ in particular, though it has been difficult to improve.³⁷ When the analysis was restricted to Mozambican facilities, where microinterventions targeted HEI screening more frequently than the other two primary outcomes, intervention facilities improved 6-fold more than control facilities (23.1% vs. 3.7%), a difference that was statistically significant. The facility in Mozambique (II) that integrated HEI screening into immunization clinics saw the largest increase, from 6.2% to 35.9%. Service integration of HEI screening into immunization clinics has previously been shown to be associated with increased uptake, younger age at screening, increased receipt of test results, and increased enrollment in HIV care.³⁸ Further, the high HIV incidence among postpartum women in Mozambique³⁹ and the higher risk of viral rebound in the first 3⁴⁰ to 6⁴¹ months postpartum highlights the importance of engaging postpartum women in ongoing care to preserve the mother's health and to prevent vertical transmission, including counseling on appropriate feeding, HEI screening, and prevention of future unplanned pregnancies.

Testing coverage levels at baseline were similar to comparable data from the most recent national reports^{9–11} and post-B+ facilities in Malawi,⁴² which verified the study methodology and representativeness of the study facilities. Comparable ARV coverage estimates were not available, as Mozambique's and Côte d'Ivoire's most recent national reports were published before Option B+ implementation. Facilities in Kenya reported lower ARV coverage (53% in intervention facilities and 60% in controls) than estimates in Kenya's 2014 national report (71% in 2013), though internal inconsistencies in this section of the report and lack of clear definitions limit its utility as a comparison point.⁹ Estimated HEI screening coverage in study clinics exceeded that in national reports, though intervention facilities in Kenya had an estimated coverage level identical to that in reported in 2013 (45%).⁹ These differences could be due to the fact that we extrapolated the denominator for HEI screening.

The study intervention has several unique advantages. Our intervention directly addresses three of the four prongs of PMTCT identified by the World Health Organization:⁴³ primary prevention of HIV infection via strengthened counseling and testing services, preventing mother-to-child transmission, and linking HIV-infected women and infants to long-term care. Many intervention facilities chose to address the fourth prong – preventing unintended pregnancies among women living with HIV – by integrating family planning services into newborn immunization and HEI screening visits. The intervention was feasible and well accepted; only one facility declined to implement it. In future publications, our group will explore facility-level factors that explain variations in the fidelity of SAIA implementation, such as leadership engagement, using qualitative data from focus group discussions with health facility staff at the study's conclusion.⁴⁴ Our intervention intrinsically incorporates context, a key consideration in implementation science:¹⁵ microinterventions were responsive to facility-specific barriers, as identified by staff themselves. While being inherently context-specific, the intervention is also applicable to diverse settings and healthcare contexts, even those beyond PMTCT. Frontline health workers are at the heart of

this intervention, and the skills they gained to develop, test, and monitor the performance of microinterventions could be useful for other staff in any healthcare sector with minimal expense and oversight. Our intervention would translate easily to adult HIV services, which will be increasingly important as early and rapid cART initiation becomes the norm.⁴⁵ Systems engineering tools are particularly appropriate for management of chronic diseases that require continuity within and/or across health sectors, such as PMTCT, but also cardiovascular disease, depression, diabetes, and others. Systems engineering could re-orient African health systems to respond more nimbly to a shifting disease landscape.

Our study has several strengths. First, this was the first randomized study to investigate the impact of systems engineering on PMTCT. Second, the study was conducted in geographically diverse countries, in western, eastern, and southern Africa, which increases generalizability. Third, the study provides pragmatic data; we tested the intervention in real-world health facilities using routinely available data from facility registries, as would likely occur should the study intervention be scaled up. Consequently, our data could easily and inexpensively be compared to data generated from future implementation. Finally, microinterventions were not artificially restricted to those that would impact the primary outcomes; rather, we encouraged staff to implement microinterventions that they thought would improve PMTCT services holistically.

This study was not without limitations. We could not follow mother-infant dyads through the PMTCT cascade or beyond it, and therefore cannot measure improvements in direct health outcomes, nor long-term retention and adherence. We had to extrapolate denominators to calculate HEI screening. However, this formula was applied uniformly across study sites and over time, and therefore should not impact our ability to analyze trends. Our power to rule out chance as an explanation for observed differences was limited by the small sample size; in essence, our study had similar power to an individually-randomized trial with 36 people. We utilized routine health facility records to collect data, which were not collected primarily for research purposes. However, routine data quality is high in Mozambique,⁴⁶ and data were double-collected directly from facility registries by two trained abstractors to maximize accuracy (except when unrest prevented travel to facilities K and L). As with any study investigating trends over time, we could not rule out the impact of secular events on our outcomes, though the randomized nature of the study strengthens the inference that the intervention itself was responsible for observed differences between study arms. Measures of fidelity to the SAIA intervention were not included in this intent-to-treat analysis, though this will be explored in the future.

To achieve the elimination of pediatric HIV, health facilities must function at near-optimal levels. Systems engineering has the potential to optimize any health service along the PMTCT cascade, while at the same time building capacity among staff to leverage these tools for other health services. This study's findings indicate that systems engineering could substantially increase the coverage of critical aspects of the PMTCT cascade, namely ARV coverage and HEI screening. However, due to limited sample size and the lack of restriction of microinterventions to those that would impact our chosen primary outcomes, the results – while substantial in overall analyses – achieved statistical significance only in sub-groups. Though seemingly contradictory, there were specific explanations for each significant sub-

group result – Mozambican facilities focused on HEI screening, and violence undermined ARV provision in Kenyan control facilities – which were tempered in the overall analysis. Future studies evaluating systems engineering applications to HIV services are urgently needed to expand our body of knowledge about these powerful tools.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure.

Mean coverage of (A) HIV testing in first antenatal care visit; (B) ARV usage among HIV-positive pregnant women, and (C) HIV PCR testing among HIV-exposed infants by 6–8 weeks of age, in 36 facilities in the SAIA trial. Dashed lines are actual means; solid lines are from linear regressions over baseline, intervention, and endline periods.

Table 1

Characteristics of health facilities randomized to intervention (n=18) and control (n=18) in the Systems Analysis and Improvement Approach (SAIA) trial.

		Control (n=18) n(%)	Intervention (n=18) n(%)	p
Year of PMTCT initiation				
	Before 2005	3 (17)	3 (17)	0.46
	2005–2008	12 (67)	9 (50)	
	After 2008	3 (17)	4 (22)	
Nurses				
	0–1	0 (0)	1 (6)	0.58
	2–4	4 (22)	5 (28)	
	5–9	6 (33)	5 (28)	
	10–19	2 (11)	4 (22)	
	20+	6 (33)	3 (17)	
Physicians				
	0	3 (17)	2 (11)	0.38
	1	5 (28)	8 (44)	
	2–9	8 (44)	4 (22)	
	10+	2 (11)	2 (11)	
Monthly ANC1 visits (quintiles) ^I				
	<65	5 (28)	2 (12)	0.56
	65–<86.9	4 (22)	3 (18)	
	86.9–<122.2	3 (17)	4 (24)	
	122.2–<185.3	2 (11)	5 (29)	
	185.3+	4 (22)	3 (18)	
Monthly ANC1 visits per nurse (quintiles) ^I				
	1.3–6.1	3 (17)	4 (22)	0.40
	6.2–10.5	5 (28)	2 (11)	
	10.6–13.9	5 (28)	2 (11)	
	14.0–22.8	2 (11)	5 (28)	
	22.9+	3 (17)	4 (22)	
Monthly ANC1 visits per physician (quintiles) ^I				
	3.1–15.2	3 (17)	2 (11)	0.22
	15.3–37.9	4 (22)	2 (11)	
	38.0–63.4	2 (11)	4 (22)	
	63.5–94.4	5 (28)	1 (6)	
	94.5+	1 (6)	5 (28)	
Air conditioning at facility		6 (33)	10 (56)	0.39
Pima CD4 machine at facility		1 (6)	2 (11)	0.83

¹Number of ANC1 visits was missing for one high-volume intervention site in Kenya.

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Table 2

Mean proportion of pregnant women tested for HIV among those presenting for first antenatal care visit at 36 health facilities in the Systems Analysis and Improvement Approach (SAIA) trial, during 13-month baseline period (January 2013–January 2014) and 3-month endline period (January–March 2015).

Country	Control (n=18)						Intervention (n=18)						p
	Facility	Baseline	Endline	Change (95% CI)	Facility	Baseline	Endline	Change (95% CI)	Facility	Baseline	Endline	Change (95% CI)	
Côte d'Ivoire	A	84.0%	100.0%	16.0%	S	91.8%	100.0%	8.2%					
	B	99.0%	100.0%	1.0%	T	92.2%	100.0%	7.8%					
	C	100.0%	100.0%	0.0%	U	96.7%	99.7%	3.0%					
	D	100.0%	99.4%	-0.6%	V	95.4%	100.0%	4.6%					
	E	55.0%	100.0%	45.0%	W	99.9%	100.0%	0.1%					
	F	68.3%	100.0%	31.7%	X	89.1%	100.0%	10.9%					
	mean	84.4%	99.9%	+15.5% (-4.6, 35.6)		94.2%	100.0%	+5.8% (-13.4, 13.8)					0.25
Kenya	G	69.8%	98.0%	28.2%	Y	90.8%	92.6%	1.8%					
	H	93.4%	99.0%	5.5%	Z	90.5%	96.3%	5.8%					
	I	92.7%	94.2%	1.5%	AA	95.2%	95.7%	0.5%					
	J	94.1%	98.8%	4.7%	BB	81.9%	98.5%	16.7%					
	K	98.6%	86.6%	-12.0%	CC	74.2%	97.6%	23.4%					
	L	77.5%	47.2%	-30.4%	DD	88.3%	95.1%	6.8%					
	mean	87.7%	87.3%	-0.4% (-20.9, 20.2)		86.8%	96.0%	+9.2% (-0.3, 18.6)					0.30
Mozambique	M	88.9%	88.7%	-0.2%	EE	84.1%	91.1%	7.0%					
	N	92.7%	87.9%	-4.7%	FF	98.5%	90.1%	-8.4%					
	O	91.2%	90.2%	-1.0%	GG	96.7%	97.5%	0.8%					
	P	92.8%	95.9%	3.0%	HH	91.8%	88.4%	-3.4%					
	Q	95.5%	97.2%	1.7%	II	76.3%	86.5%	10.2%					
	R	87.7%	97.3%	9.6%	JJ	96.5%	96.3%	-0.2%					
	mean	91.5%	92.9%	+1.4% (-3.7, 6.5)		90.6%	91.7%	+1.0% (-6.1, 8.1)					0.91
Overall mean		87.8%	93.4%	+5.5% (-2.8, 13.8)		90.5%	95.9%	+5.3% (1.7, 9.0)					0.97

Table 3

Mean proportion of HIV-positive pregnant women who received antiretroviral medications at 36 health facilities in the Systems Analysis and Improvement Approach (SAIA) trial, during 13-month baseline period (January 2013–January 2014) and 3-month endline period (January–March 2015).

Control (n=18)		Intervention (n=18)			
Country	Facility	Baseline	Endline	Change (95% CI)	p
Côte d'Ivoire	A	70.4%	100.0%	29.6%	18.4%
	B	91.7%	100.0%	8.3%	-
	C	100.0%	100.0%	0.0%	45.8%
	D ^I	100.0%	-	-	20.0%
	E	90.4%	100.0%	9.6%	1.7%
	F	52.9%	100.0%	47.1%	38.9%
	mean	84.2%	100.0%	+18.9% (-4.9, 42.7)	79.2% 100.0% +25.0% (3.1, 46.8) 0.62
Kenya	G	81.0%	96.3%	15.3%	24.3%
	H	43.2%	16.7%	-26.6%	-10.4%
	I	66.8%	57.7%	-9.1%	40.8%
	J	31.0%	33.3%	2.4%	-3.0%
	K	79.6%	14.4%	-65.2%	45.6%
	L	56.7%	12.8%	-43.9%	28.1%
	mean	59.7%	38.5%	-21.2% (-52.7, 10.4)	52.5% 73.4% +20.9% (-3.1, 44.9) 0.02
Mozambique	M	25.1%	51.5%	26.4%	-24.6%
	N	88.3%	69.6%	-18.7%	-13.8%
	O	23.2%	67.8%	44.6%	43.0%
	P	36.7%	89.8%	53.1%	1.9%
	Q	54.3%	71.9%	17.7%	-7.9%
	R	60.6%	38.8%	-21.8%	-23.4%
	mean	48.0%	64.9%	+16.9% (-16.1, 49.9)	67.6% 63.5% -4.1% (-30.5, 22.2) 0.23
Overall mean		64.0%	65.9%	+4.1% (-12.6, 20.7)	66.4% 77.7% +13.3% (0.5, 26.0) 0.36

^I0/0 for all 3 months of endline period.

Table 4

Mean proportion of HIV-exposed infants who received an HIV PCR screening test by 6 or 8 weeks of age¹ at 36 health facilities in the Systems Analysis and Improvement Approach (SAIA) trial, during 13-month baseline period (January 2013–January 2014) and 3-month endline period (January–March 2015).

Control (n=18)					Intervention (n=18)				
Country	Facility	Baseline	Endline	Change (95% CI)	Facility	Baseline	Endline	Change (95% CI)	p
Côte d'Ivoire	A	0.0%	15.1%	15.1%	S	27.4%	33.3%	5.9%	
	B	30.8%	33.3%	2.5%	T ³	-	-	-	
	C	59.3%	48.1%	-11.2%	U	59.0%	33.3%	-25.7%	
	D	40.0%	91.0%	51.0%	V	20.0%	66.7%	46.7%	
	E	67.1%	42.4%	-24.7%	W	40.0%	22.5%	-17.5%	
	F	39.1%	25.4%	-13.8%	X	33.4%	100.0%	66.6%	
mean		39.4%	42.6%	+3.2% (-25.4, 31.7)		36.0%	51.2%	+15.2% (-34.7, 65.1)	0.57
Kenya	G	44.8%	41.3%	-3.4%	Y	64.2%	59.0%	-5.2%	
	H	13.8%	54.8%	41.1%	Z	29.4%	66.7%	37.3%	
	I ²	-	-	-	AA	60.9%	39.5%	-21.3%	
	J	0.0%	0.0%	0.0%	BB	40.0%	24.0%	-16.0%	
	K	0.0%	0.0%	0.0%	CC	31.9%	8.1%	-23.8%	
	L	66.4%	0.0%	-66.4%	DD	40.4%	51.8%	11.4%	
mean		25.0%	19.2%	-5.8% (-53.6, 42.1)		44.5%	41.5%	-2.9% (-27.7, 21.8)	0.88
Mozambique	M	23.3%	31.9%	8.6%	EE	24.5%	51.9%	27.5%	
	N	43.5%	22.2%	-21.3%	FF	45.9%	58.9%	13.0%	
	O	45.0%	66.0%	21.0%	GG	15.8%	41.4%	25.5%	
	P	20.2%	23.0%	2.7%	HH	5.8%	43.9%	38.1%	
	Q	31.0%	49.6%	18.6%	II	6.2%	35.9%	29.7%	
	R	7.3%	0.0%	-7.3%	JJ	41.4%	46.1%	4.7%	
mean		28.4%	32.1%	+3.7% (-13.1, 20.6)		23.3%	46.3%	+23.1% (10.3, 35.8)	0.04
Overall mean		31.3%	32.0%	+0.7% (-12.9, 14.4)		34.5%	46.1%	+11.6% (-2.6, 25.7)	0.25

¹ By 6 weeks of age in Kenya and Mozambique, and by 8 weeks of age in Côte d'Ivoire, in accordance with country guidelines.

² Did not offer infant testing until July 2014, so baseline estimates cannot be calculated. Infant testing data were missing for endline period.

³ Projected number of HIV-exposed infants (the denominator) was n=0 for all months during baseline & endline periods.