VACCINE DELIVERY RESEARCH DIGEST

UNIVERSITY OF WASHINGTON STRATEGIC ANALYSIS, RESEARCH & TRAINING (START) CENTER

REPORT TO THE BILL & MELINDA GATES FOUNDATION

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1. High resolution age-structured mapping of childhood vaccination coverage in low-and middle-income countries.
{Abstract & START Scientific Comment} {Full Article}

- An analysis of various geostatistical approaches for modelling age-structured measles vaccination coverage in children under 5 years of age in Cambodia, Nigeria, and Mozambique.

2. Indirect rotavirus vaccine effectiveness for the prevention of rotavirus hospitalization: A systematic review and meta-analysis.
{Abstract & START Scientific Comment} {Full article}

- A systematic review of indirect rotavirus vaccine effectiveness for preventing rotavirus hospitalization in children under 5 years.

3. Strategies to improve treatment coverage in community-based public health programs: A systematic review of the literature.
{Abstract & START Scientific Comment} {Full article}

- A systematic review to identify strategies for increasing coverage of community-based health programs in low-and middle-income countries.

4. The equity impact vaccines may have on averting deaths and medical impoverishment in developing countries.
{Abstract & START Scientific Comment} {Full article}

- An impact analysis to model the health economic benefits of vaccines across socioeconomic groups for ten antigens in forty-one low-and middle-income countries from 2016-2030.

5. Maternal immunization against Group B streptococcus: World Health Organization research and development technological roadmap and preferred product characteristics.
{Abstract & START Scientific Comment} {Full article}

- An overview of two World Health Organization technical documents that provide a vaccine development technology roadmap and preferred product characteristics for advancing vaccine development, guiding future research, and supporting policy decision-making for Group B streptococcus (GBS).

6. Predictors of measles vaccination coverage among children 6-59 months of age in the Democratic Republic of the Congo.
{Abstract & START Scientific Comment} {Full article}

- An analysis of measles predictors, measles vaccination coverage, and disparities in vaccination documentation for children 6-59 months in the Democratic Republic of the Congo.

7. Improving rotavirus vaccine coverage: Can newer-generation and locally produced vaccines help? {Abstract & START Scientific Comment} {Full article}

- A review of Rotarix and RotaTeq vaccine efficacy compared to newer-generation vaccines to determine vaccine protection in low-and middle-income countries.

8. Challenges and opportunities for meningococcal vaccination in the developing world. {Abstract & START Scientific Comment} {Full article}

- A literature review to assess vaccination implementation challenges for invasive meningococcal disease (IMD) globally.

9. Implementation research: reactive mass vaccination with single-dose oral cholera vaccine, Zambia. {Abstract & START Scientific Comment} {Full article}

- An analysis of the implementation and feasibility of a large-scale cholera vaccination campaign in urban Zambia.

10. The cost-effectiveness of alternative vaccination strategies for polyvalent meningococcal vaccines in Burkina Faso: A transmission dynamic modeling study. {Abstract & START Scientific Comment} {Full article}

- A mathematical transmission model to assess characteristics of meningococcal epidemics and costs associated with vaccination campaigns for polyvalent meningococcal polysaccharide (PMP) vaccines and polyvalent meningococcal conjugate (PMC) vaccines in 55 districts in Burkina Faso.

APPENDIX

DETAILS OF ARTICLES

1. High resolution age-structured mapping of childhood vaccination coverage in low-and middle-income countries.
   Utazi CE, Thorley J, Alegana VA, Ferrari MJ, Takahashi S, Metcalf CJE, et al.
   Vaccine. 2018 Mar 14;36(12):1583-1591. [Epub ahead of print]
   PubMed ID: 29454519

ABSTRACT
BACKGROUND:
The expansion of childhood vaccination programs in low-and-middle income countries has been a substantial public health success story. Indicators of the performance of intervention programmes such as coverage levels and numbers covered are typically measured through national statistics or at the scale of large regions due to survey design, administrative convenience or operational limitations. These mask heterogeneities and 'coldspots' of low coverage that may allow diseases to persist, even if overall coverage is high. Hence, to decrease inequities and accelerate progress towards disease elimination goals, fine-scale variation in coverage should be better characterized.
METHODS:
Using measles as an example, cluster-level Demographic and Health Surveys (DHS) data were used to map vaccination coverage at 1 km spatial resolution in Cambodia, Mozambique and Nigeria for varying age-group categories of children under five years, using Bayesian geostatistical techniques built on a suite of publicly available geospatial covariates and implemented via Markov Chain Monte Carlo (MCMC) methods.
RESULTS:
Measles vaccination coverage was found to be strongly predicted by just 4-5 covariates in geostatistical models, with remoteness consistently selected as a key variable. The output 1×1 km maps revealed significant heterogeneities within the three countries that were not captured using province-level summaries. Integration with population data showed that at the time of the surveys, few districts attained the 80% coverage, that is one component of the WHO Global Vaccine Action Plan 2020 targets.
CONCLUSION:
The elimination of vaccine-preventable diseases requires a strong evidence base to guide strategies and inform efficient use of limited resources. The approaches outlined here provide a route to moving beyond large area summaries of vaccination coverage that mask epidemiologically-important heterogeneities to detailed maps that capture subnational vulnerabilities. The output datasets are built on open data and methods, and in flexible format that can be aggregated to more operationally-relevant administrative unit levels.

START EDITORIAL COMMENT: This study used geostatistical approaches to model measles vaccination coverage to better predict vaccination coverage in Nigeria, Cambodia, and Mozambique. The analysis used four age intervals from the Demographic and Health Surveys (DHS) were used: <9 months, 9-11 months, 12-23 months and 24-59 months, and <59 months, and utilized a Bayesian framework to assess the geostatistical model to predict age-specific probabilities of vaccination. Results showed high predictive power of these geostatistical models including the ability to map sub-national heterogeneity

in vaccine coverage. While this modeling method proved successful in this study, scaling up this method to multi-country or global models may be challenging.

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2. Indirect rotavirus vaccine effectiveness for the prevention of rotavirus hospitalization: A systematic review and meta-analysis.
Rosettie KL, Vos T, Mokdad AH, Flaxman AD, Khalil I, Troeger C, et al.
Am J Trop Med Hyg. 2018 Feb 12. [Epub ahead of print]
PubMed ID: 29436336

ABSTRACT

Two rotavirus vaccines, RotaTeq and Rotarix, are licensed for global use; however, the protection they confer to unvaccinated individuals through indirect effects remains unknown. We systematically reviewed the literature and quantified indirect rotavirus vaccine effectiveness (VE) for preventing rotavirus hospitalization in children aged less than 5 years. From 148 identified abstracts, 14 studies met our eligibility criteria. In our main analysis using a random-effects model, indirect rotavirus VE was 48% (95% confidence interval [CI]: 39-55%). In a subgroup analysis by country income level, indirect VE was greater in high-income countries (52%; 95% CI: 43-60%) than in low- and middle-income countries (LMICs) (25%; 95% CI: 5-41%). In a sensitivity analysis using a quality-effects model, the indirect VE in LMICs was not statistically significant (25%; 95% CI: 1-44%). Our findings highlight the importance of increasing rotavirus vaccine coverage, particularly in LMICs where evidence for indirect VE is limited and rotavirus burden is high.

START EDITORIAL COMMENT: This study was a systematic review of indirect rotavirus vaccine effectiveness (VE). The primary analysis used an inverse-variance-weighted random-effects model while the sensitivity analysis used a quality-effects model. Results showed a positive, protective benefit of rotavirus vaccine (VE of 48%) against rotavirus hospitalization, especially among unvaccinated populations. Indirect vaccine efficacy was higher in countries with high vaccine coverage and efficacy was found to be higher in high-income countries compared to low- and middle-income countries. Limitations of this study included limited available studies and confounding introduced by the design of the study. However, overall findings support the introduction of national rotavirus immunization programs and efforts to increase vaccine coverage to improve the health of children in low-and middle-income countries.

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3. [Strategies to improve treatment coverage in community-based public health programs: A systematic review of the literature.](#)

ABSTRACT
BACKGROUND:
Community-based public health campaigns, such as those used in mass deworming, vitamin A supplementation and child immunization programs, provide key healthcare interventions to targeted populations at scale. However, these programs often fall short of established coverage targets. The purpose of this systematic review was to evaluate the impact of strategies used to increase treatment coverage in community-based public health campaigns.
METHODOLOGY/ PRINCIPAL FINDINGS:
We systematically searched CAB Direct, Embase, and PubMed archives for studies utilizing specific interventions to increase coverage of community-based distribution of drugs, vaccines, or other public health services. We identified 5,637 articles, from which 79 full texts were evaluated according to pre-defined inclusion and exclusion criteria. Twenty-eight articles met inclusion criteria and data were abstracted regarding strategy-specific changes in coverage from these sources. Strategies used to increase coverage included community-directed treatment (n = 6, pooled percent change in coverage: +26.2%), distributor incentives (n = 2, +25.3%), distribution along kinship networks (n = 1, +24.5%), intensified information, education, and communication activities (n = 8, +21.6%), fixed-point delivery (n = 1, +21.4%), door-to-door delivery (n = 1, +14.0%), integrated service distribution (n = 9, +12.7%), conversion from school- to community-based delivery (n = 3, +11.9%), and management by a non-governmental organization (n = 1, +5.8%).
CONCLUSIONS/SIGNIFICANCE:
Strategies that target improving community member ownership of distribution appear to have a large impact on increasing treatment coverage. However, all strategies used to increase coverage successfully did so. These results may be useful to National Ministries, programs, and implementing partners in optimizing treatment coverage in community-based public health programs.

START EDITORIAL COMMENT: In this study, a systematic review identified strategies to improve coverage of community-based health programs by collecting data on study design, location (urban or rural), targeted disease, and other relevant metrics. The review identified the following methods to increase intervention coverage: community-directed treatment; distributor incentives; distribution along kinship networks; intensified information; education; communication activities; fixed-point delivery; door-to-door delivery; integrated service distribution; conversion from school- to community-based delivery; and, management by a non-governmental organization. Overall, all strategies employed to increase coverage succeeded, but the most successful programs involved community member ownership of the intervention.

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4. [The equity impact vaccines may have on averting deaths and medical impoverishment in developing countries.](#)
Chang AY, Riumallo-Herl C, Perales NA, Clark S, Clark A, Constenla D, et al.
Health Aff (Millwood). 2018 Feb;37(2):316-324.
PubMed ID: 29401021

ABSTRACT

With social policies increasingly directed toward enhancing equity through health programs, it is important that methods for estimating the health and economic benefits of these programs by subpopulation be developed, to assess both equity concerns and the programs' total impact. We estimated the differential health impact (measured as the number of deaths averted) and household economic impact (measured as the number of cases of medical impoverishment averted) of ten antigens and their corresponding vaccines across income quintiles for forty-one low- and middle-income countries. Our analysis indicated that benefits across these vaccines would accrue predominantly in the lowest income quintiles. Policy makers should be informed about the large health and economic distributional impact that vaccines could have, and they should view vaccination policies as potentially important channels for improving health equity. Our results provide insight into the distribution of vaccine-preventable diseases and the health benefits associated with their prevention.

WEB: [10.1377/hlthaff.2017.0861](#)
IMPACT FACTOR: 4.89
CITED HALF-LIFE: 5.20

START EDITORIAL COMMENT: This study used multiple vaccines—measles, hepatitis B, human papillomavirus, yellow fever, *Hemophilus influenzae* type b, *Streptococcus pneumoniae*, rotavirus, rubella, *Neisseria meningitidis* serogroup A, and Japanese encephalitis—to assess the number of vaccine-averted deaths for each antigen, quantified the contributions of sets of risk and prognostic factors, estimated the number of cases of medical impoverishment averted, and estimated the distribution of cases and deaths by wealth quintile. The poorest population quintile accounted for the largest share of deaths averted by all vaccines, and the poorest two population quintiles accounted for over half of the deaths averted by most vaccines. This study provides evidence that vaccination is particularly beneficial for poor populations, furthering evidence for the health and economic benefits of vaccination.

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5. [Maternal immunization against Group B streptococcus: World Health Organization research and development technological roadmap and preferred product characteristics.](#)
Vekemans J, Moorthy V, Friede M, Alderson MR, Sobanjo-Ter Meulen A, Baker CJ, et al.
Vaccine. 2018 Feb 2. pii: S0264-410X(17)31359-2. [Epub ahead of print]
PubMed ID: 29398277

ABSTRACT

Group B streptococcus, found in the vagina or lower gastrointestinal tract of about 10-40% of women of reproductive age, is a leading cause of early life invasive bacterial disease, potentially amenable to prevention through maternal immunization during pregnancy. Following a consultation process with global stakeholders, the World Health Organization is herein proposing priority research and development pathways and preferred product characteristics for GBS vaccines, with the aim to facilitate and accelerate vaccine licensure, policy recommendation for wide scale use and implementation.

WEB: [10.1016/j.vaccine.2017.09.087](#)
IMPACT FACTOR: 3.41
CITED HALF-LIFE: 5.90

START EDITORIAL COMMENT: In this review, researchers present recommendations to support policy decision-making for the implementation of Group B streptococcus (GBS) products in low-and middle-income countries. Such recommendations could lead to safer and more affordable GBS vaccines, in addition to improved health outcomes for pregnant women and neonates exposed to GBS. Recommendations included: the production of high-quality research to quantify the potential public health impact of GBS vaccine; enhanced vaccine composition; long-term strain composition monitoring; high-impact one-dose regimens; and, formulations (with or without adjuvants) that prioritize safety. Cost of vaccine research, production, procurement, and delivery will prove to be of utmost importance for campaigns in many low-and middle-income countries.

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6. [Predictors of measles vaccination coverage among children 6-59 months of age in the Democratic Republic of the Congo.](#)
Ashbaugh HR, Hoff NA, Doshi RH, Alfonso VH, Gadoth A, Mukadi P, et al.
Vaccine. 2018 Jan 25;36(4):587-593.
PubMed ID: 29248265

ABSTRACT
BACKGROUND:
Measles is a significant contributor to child mortality in the Democratic Republic of the Congo (DRC), despite routine immunization programs and supplementary immunization activities (SIA). Further, national immunization coverage levels may hide disparities among certain groups of children, making effective measles control even more challenging. This study describes measles vaccination coverage and reporting methods and identifies predictors of vaccination among children participating in the 2013-2014 DRC Demographic and Health Survey (DHS).
METHODS:
We examined vaccination coverage of 6947 children aged 6-59 months. A multivariate logistic regression model was used to identify predictors of vaccination among children reporting vaccination via dated card in order to identify least reached children. We also assessed spatial distribution of vaccination report type by rural versus urban residence.
RESULTS:
Urban children with educated mothers were more likely to be vaccinated (OR = 4.1, 95% CI: 1.6, 10.7) versus children of mothers with no education, as were children in wealthier rural families (OR = 2.9, 95% CI: 1.9, 4.4). At the provincial level, urban areas more frequently reported vaccination via dated card than rural areas.
CONCLUSIONS:
Results indicate that, while the overall coverage level of 70% is too low, socioeconomic and geographic disparities also exist which could make some children even less likely to be vaccinated. Dated records of measles vaccination must be increased, and groups of children with the greatest need should be targeted. As access to routine vaccination services is limited in DRC, identifying and targeting under-reached children should be a strategic means of increasing country-wide effective measles control.

START EDITORIAL COMMENT: This study aimed to assess measles vaccination coverage, measles vaccination predictors, and discusses disparities in vaccine documentation by geographic area in the Democratic Republic of the Congo (DRC). Results of the analysis showed that while 70% (4889) of children were vaccinated, approximately 30% (2058) of children remain unvaccinated. Although vaccine disparities are exacerbated by poor data quality in regions of the DR, this study provides insight into vaccination coverage and predictors. Increased focus on targeting disadvantaged and difficult to reach children (particularly in conflict areas), increased data quality, and enhanced vaccination coverage could be implemented to improve measles-related vaccination programs in the DRC.

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7. [Improving rotavirus vaccine coverage: Can newer-generation and locally produced vaccines help?](#)
Deen J, Lopez AL, Kanungo S, Wang XY, Anh DD, Tapia M, et al.
Hum Vaccin Immunother. 2018 Feb 1;14(2):495-499.
PubMed ID: 29135339

ABSTRACT

There are two internationally available WHO-prequalified oral rotavirus vaccines (Rotarix and RotaTeq), two rotavirus vaccines licensed in India (Rotavac and Rotasiil), one in China (Lanzhou lamb rotavirus vaccine) and one in Vietnam (Rotavin-M1), and several candidates in development. Rotavirus vaccination has been rolled out in Latin American countries and is beginning to be deployed in sub-Saharan African countries but middle- and low-income Asian countries have lagged behind in rotavirus vaccine introduction. We provide a mini-review of the leading newer-generation rotavirus vaccines and compare them with Rotarix and RotaTeq. We discuss how the development and future availability of newer-generation rotavirus vaccines that address the programmatic needs of poorer countries may help scale-up rotavirus vaccination where it is needed.

START EDITORIAL COMMENT: Rotarix and RotaTeq are two of several rotavirus vaccines currently available in low-and middle-income countries. This study aimed to provide a comparison of existing, newer-generation rotavirus vaccines, such as Lanzhou Lamb rotavirus vaccine (LLR) and Rotavin-M1 rotavirus vaccine, to Rotarix and RotaTeq in India, China, and Vietnam (Table 1). Although LLR and Rotavin-M1 have been deployed in China and Vietnam, respectively, LLR has not been confirmed in a placebo-controlled Phase III clinical trial and Rotavin-M1 is only available in the private market and has not been subject to effectiveness studies. Further vaccine research is underway to develop other candidate rotavirus vaccines (e.g. RV3-BB, BRV-TV, and P2-VP8 subunit rotavirus vaccine) globally. Whether current or newly developed vaccines are implemented, many opportunities exist to improve vaccine rollout, cost-effectiveness, and availability in many low-and middle-income countries.

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8. [Challenges and opportunities for meningococcal vaccination in the developing world.](#)
   Heffernan A, Barber E, Cook NA, Gomaa AI, Harley YX, Jones CR, et al.
   Open Forum Infect Dis. 2017 Nov 17;5(1):ofx252.
   PubMed ID: 29354656

ABSTRACT

Meningococcal disease continues to be a lif- threatening infection with high morbidity and mortality even in appropriately treated patients. Meningococcal vaccination plays a major role in the control of the disease; however, implementing vaccination remains problematic in the developing world. The objective of this review is to identify the challenges facing the use of meningococcal vaccines in the developing world in order to discuss the opportunities and available solutions to improve immunization in these countries. Inadequate epidemiologic information necessary to implement vaccination and financial challenges predominate. Multiple measures are needed to achieve the successful implementation of meningococcal conjugate vaccination programs that protect against circulating serogroups in developing countries including enhanced surveillance systems, financial support and aid through grants, product development partnerships that are the end result of effective collaboration and communication between different interdependent stakeholders to develop affordable vaccines, and demonstration of the cost-effectiveness of new meningococcal vaccines.

WEB: [10.1080/21645515.2018.1434463](#)
IMPACT FACTOR: 0
CITED HALF-LIFE: NA

START EDITORIAL COMMENT: Invasive meningococcal disease (IMD) is the most common infectious cause of childhood death with impacts that vary based on age group and geographic region. Current challenges to immunization programs include lack of adequate epidemiology and surveillance data, unfavorable vaccine prioritization, and vaccine unaffordability, among other systematic and implementation barriers. These barriers are magnified in low resource and low income countries. Opportunities such as vaccine product development partnerships and funding strategies provide fertile ground for redefining immunization programs.

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9. [Implementation research: reactive mass vaccination with single-dose oral cholera vaccine, Zambia.](#)
Poncin M, Zulu G, Voute C, Ferreras E, Muleya CM, Malama K, et al.
Bull World Health Organ. 2018 Feb 1;96(2):86-93.
PubMed ID: 29403111

ABSTRACT
Objective:
To describe the implementation and feasibility of an innovative mass vaccination strategy - based on single-dose oral cholera vaccine - to curb a cholera epidemic in a large urban setting.
Method:
In April 2016, in the early stages of a cholera outbreak in Lusaka, Zambia, the health ministry collaborated with Médecins Sans Frontières and the World Health Organization in organizing a mass vaccination campaign, based on single-dose oral cholera vaccine. Over a period of 17 days, partners mobilized 1700 health ministry staff and community volunteers for community sensitization, social mobilization and vaccination activities in 10 townships. On each day, doses of vaccine were delivered to vaccination sites and administrative coverage was estimated.
Findings:
Overall, vaccination teams administered 424 100 doses of vaccine to an estimated target population of 578 043, resulting in an estimated administrative coverage of 73.4%. After the campaign, few cholera cases were reported and there was no evidence of the disease spreading within the vaccinated areas. The total cost of the campaign - 2.31 United States dollars (US$) per dose - included the relatively low cost of local delivery - US$ 0.41 per dose.
Conclusion:
We found that an early and large-scale targeted reactive campaign using a single-dose oral vaccine, organized in response to a cholera epidemic within a large city, to be feasible and appeared effective. While cholera vaccines remain in short supply, the maximization of the number of vaccines in response to a cholera epidemic, by the use of just one dose per member of an at-risk community, should be considered.

START EDITORIAL COMMENT: This study evaluated the feasibility and effectiveness of an oral cholera vaccine campaign conducted in response to annual cholera epidemics in Lusaka, Zambia between 2003 and 2011. Vaccination strategies included immunization programs, social mobilization, and cold-chain management supported by volunteers, environmental health technicians, and local and national health workers. The vaccination team administered roughly 420,000 vaccine doses at a cost of $0.4 per dose with a vaccine wastage of less than 0.01%. This study demonstrates a successful method for mass, single-dose cholera vaccination administered to at-risk individuals, which may be applicable to other low-and-middle income countries given the continuing global shortage of oral cholera vaccines.

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10. [The cost-effectiveness of alternative vaccination strategies for polyvalent meningococcal vaccines in Burkina Faso: A transmission dynamic modeling study](#).

ABSTRACT

BACKGROUND:
The introduction of a conjugate vaccine for serogroup A Neisseria meningitidis has dramatically reduced disease in the African meningitis belt. In this context, important questions remain about the performance of different vaccine policies that target remaining serogroups. Here, we estimate the health impact and cost associated with several alternative vaccination policies in Burkina Faso.
METHODS AND FINDINGS:
We developed and calibrated a mathematical model of meningococcal transmission to project the disability-adjusted life years (DALYs) averted and costs associated with the current Base policy (serogroup A conjugate vaccination at 9 months, as part of the Expanded Program on Immunization [EPI], plus district-specific reactive vaccination campaigns using polyvalent meningococcal polysaccharide [PMP] vaccine in response to outbreaks) and three alternative policies: (1) Base Prime: novel polyvalent meningococcal conjugate (PMC) vaccine replaces the serogroup A conjugate in EPI and is also used in reactive campaigns; (2) Prevention 1: PMC used in EPI and in a nationwide catch-up campaign for 1-18-year-olds; and (3) Prevention 2: Prevention 1, except the nationwide campaign includes individuals up to 29 years old. Over a 30-year simulation period, Prevention 2 would avert 78% of the meningococcal cases (95% prediction interval: 63%-90%) expected under the Base policy if serogroup A is not replaced by remaining serogroups after elimination, and would avert 87% (77%-93%) of meningococcal cases if complete strain replacement occurs. Compared to the Base policy and at the PMC vaccine price of US$4 per dose, strategies that use PMC vaccine (i.e., Base Prime and Preventions 1 and 2) are expected to be cost saving if strain replacement occurs, and would cost US$51 (-US$236, US$490), US$188 (-US$97, US$626), and US$246 (-US$53, US$703) per DALY averted, respectively, if strain replacement does not occur. An important potential limitation of our study is the simplifying assumption that all circulating meningococcal serogroups can be aggregated into a single group; while this assumption is critical for model tractability, it would compromise the insights derived from our model if the effectiveness of the vaccine differs markedly between serogroups or if there are complex between-serogroup interactions that influence the frequency and magnitude of future meningitis epidemics.
CONCLUSIONS:
Our results suggest that a vaccination strategy that includes a catch-up nationwide immunization campaign in young adults with a PMC vaccine and the addition of this new vaccine into EPI is cost-effective and would avert a substantial portion of meningococcal cases expected under the current World Health Organization-recommended strategy of reactive vaccination. This analysis is limited to Burkina Faso and assumes that polyvalent vaccines offer equal protection against all meningococcal serogroups; further studies are needed to evaluate the robustness of this assumption and applicability for other countries in the meningitis belt.

START EDITORIAL COMMENT: Most effective meningitis vaccination campaigns using MenAfriVac vaccine are especially important for countries within the meningitis belt in sub-Saharan Africa. Researchers developed a stochastic compartmental model and a gravity model to capture key characteristics and patterns of meningococcal epidemics in Burkina Faso. Results of a 30-year simulation show an annual average of 5,412 meningococcal cases with strain replacement and 1,642 meningococcal cases without strain replacement. While PMC vaccination strategies reduce the number of annual meningitis cases, they do not eliminate or decrease the likelihood of meningitis outbreaks. Cost-effectiveness of vaccination strategies (Table 3) varies depending on strain-replacement scenarios, however Base Prime, Prevention 1 strategy, and Prevention 2 strategy had a larger incremental benefit. While this study is specific to Burkina Faso, additional research is necessary to confirm generalizability of the results.

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(((((vaccine[tiab] OR vaccines[tiab] OR vaccination[tiab] OR immunization[tiab] OR immunisation[tiab] OR vaccine[mesh] OR immunization[mesh]) AND (logistics[tiab] OR supply[tiab] OR "supply chain"[tiab] OR implementation[tiab] OR expenditures[tiab] OR financing[tiab] OR economics[tiab] OR "Cost effectiveness"[tiab] OR coverage[tiab] OR attitudes[tiab] OR belief[tiab] OR beliefs[tiab] OR refusal[tiab] OR "Procurement"[tiab] OR timeliness[tiab] OR systems[tiab])) OR ("vaccine delivery"[tiab])) NOT ("in vitro"[tiab] OR "immune response"[tiab] OR gene[tiab] OR chemistry[tiab] OR genotox*[tiab] OR sequencing[tiab] OR nanoparticle*[tiab] OR bacteriophage[tiab] OR exome[tiab] OR exogenous[tiab] OR electropor*[tiab] OR "systems biology"[tiab] OR "animal model"[tiab] OR cattle[tiab] OR sheep[tiab] OR goat[tiab] OR rat[tiab] OR pig[tiab] OR mice[tiab] OR mouse[tiab] OR murine[tiab] OR porcine[tiab] OR ovine[tiab] OR rodent[tiab] OR fish[tiab])) AND (English[LA]) ("2018/1/15"[PDAT] : "2018/2/14"[PDAT]))

* February 30, 2017, this search of English language articles published between January 15, 2017 and February 14, 2017 and indexed by the US National Library of Medicine resulted in 268 unique manuscripts.