means to guide mHealth into this next era of maturity, with integrated solutions becoming the norm. WHO and other stakeholders will need to issue guidance to help prioritize and accelerate government mHealth adoption. Already, multiple efforts are under way to synthesize evidence, from WHO's mTERG to USAID's periodic Evidence Summits. In the future, these efforts could be guided by this framework to direct strategic investment toward key foundational layers of struggling health systems in an integrated manner. Our modified Tanahashi model facilitates a systematic approach toward constructing integrated mHealth strategies that together address multiple gaps in the pathway to UHC, improving performance in the quality, cost, and coverage necessary to provide care to all in need.

REFERENCES AND NOTES

1. J. D. Sachs, *Lancet* **380**, 944–947 (2012).
2. J. Vega, *Lancet* **381**, 179–180 (2013).
3. The UN General Assembly, *67/81 Global Health and Foreign Policy* (United Nations, New York, 2012).
4. WHO, *World Health Report: Health Systems Financing: The Path to Universal Coverage* (WHO, Geneva, Switzerland, 2010), pp. 1–128.
5. International Telecommunications Union, *The World in 2013: ICT Facts and Figures* (International Telecommunications Union, Geneva, Switzerland, 2013).
6. The Partnership for Maternal, Newborn & Child Health, *A Global Review of the Key Interventions Related to Reproductive, Maternal, Newborn and Child Health (RMNCH)* (The Partnership for Maternal, Newborn & Child Health, Geneva, Switzerland, 2011).
7. A. B. Labrique, L. Vasudevan, E. Kochi, R. Fabricant, G. Mehl, *Glob. Heal. Sci. Pract.* **1**, 160–171 (2013).
8. A. Labrique, L. Vasudevan, L. W. Chang, G. Mehl, *Int. J. Med. Inform.* **82**, 467–469 (2013).
9. T. Tanahashi, *Bull. World Health Organ.* **56**, 295–303 (1978).
10. United Nations Children's Fund, Reaching Universal Health Coverage through District Health System Strengthening: Using a Modified Tanahashi Model Sub-Nationally to Attain Equitable and Effective Coverage (United Nations, New York, 2013).
11. World Health Organization, in *Meeting on Health Sector Contributions to Strengthening Civil Registration and Vital Statistics Systems*, WHO, Ed. (WHO, Geneva, Switzerland, 2013), pp. 1–15.
12. Uganda Registration Services Bureau, Mobile Vital Records System, available at www.mobilevrs.co.ug/home.php.
13. J. Barrington, O. Wereko-Brobby, P. Ward, W. Mwafongo, S. Kungulwe, *Malar. J.* **9**, 298 (2010).
14. L. W. Chang *et al*., *AIDS Behav.* **15**, 1776–1784 (2011).
15. D. H. Peters *et al*., *Ann. N. Y. Acad. Sci.* **1136**, 161–171 (2008).
16. J. Campbell *et al*., *Bull. World Health Organ.* **91**, 853–863 (2013).
17. Department of Health, Western Cape Government, Western Cape Government Patient Complaints Line to Roll Out Across the Province (2013), available at www.westerncape.gov.za/node/9263.
18. B. Derenzi *et al*., *WORLD* **2012**, 753–762 (2008).
19. M. H. Mwanahamuntu *et al*., *PLOS Med.* **8**, e1001032 (2011).
20. N. Corby, *Using Mobile Finance to Reimburse Sexual and Reproductive Health Vouchers in Madagascar* (Marie Stopes International, London, 2012).

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PERSPECTIVE

How to transform the practice of engineering to meet global health needs

Deb Niemeier,[1] Harry Gombachika,[2] Rebecca Richards-Kortum[3]*

More of the world's population has access to cell phones than to basic sanitation facilities, a gap that can only be closed if the engineering and international aid communities adopt new approaches to design for scarcity and scalability.

Engineers have known how to produce safe drinking water and how to build toilets and roads in developing countries for more than 100 years. Yet, global access to such technologies is far from uniform. Approximately 768 million people do not have access to safe drinking water; 2.5 billion lack basic sanitation, and 1 billion practice open defecation (*1*). More than 50% of people who have no access to water and sanitation live in middle-income countries (*1*). Use of these technologies can mean the difference between life and death; diarrheal illness, 90% of which is related to inadequate access to clean water and sanitation, kills more children under 5 than AIDS, malaria, and measles combined (*2*).

Why is it so difficult to translate technologies that have improved public health in wealthy countries into solutions that equitably improve lives around the world? It is primarily because these solutions were developed to satisfy constraints of high-resource settings. In many cases, they cannot be easily adapted to work in low-resource settings; they are too expensive or rely on infrastructure or expertise that does not exist. For example, a recent survey of anesthetists in Uganda reported that only 20% had a constant supply of electricity for the equipment necessary for basic surgery (*3*). Between 2005 and 2011, the President's Emergency Plan for AIDS Relief (PEPFAR) invested over $1 billion to strengthen clinical laboratories to improve HIV/AIDS care, primarily in sub-Saharan Africa (*4*); yet maintenance and repair of the necessary laboratory equipment, designed for high-resource settings, is a continued challenge across PEPFAR countries (*4*), where intermittent power can render equipment unusable, and there is limited in-house technical support to repair medical equipment (*5*). If we are to resolve global inequities in access to innovations that improve health, we must adopt new approaches to engineering design that reflect the unique needs and constraints of low-resource settings.

[1]Department of Civil and Environmental Engineering, University of California, Davis, CA 95616, USA. [2]Electrical Engineering Department, The Malawi Polytechnic, University of Malawi, Chichiri, Blantyre, Malawi. [3]Department of Bioengineering, Rice University, Houston, TX 77005, USA. ***Corresponding author. E-mail: rkortum@rice.edu**

Design for scarcity

Engineers design new technologies to meet societal needs in the face of economic constraints; in contrast, frugal design—designing through the lens of scarcity—begins first with the assumption that material and human infrastructure are limited and not systematically integrated. These resource and infrastructure limitations dictate the constraints that frugal designs must satisfy but may also lead to reuse or repurposing of available commodities in ways that are not anticipated. For example, early efforts to scale up provision of injectable vaccines in low-resource settings led to a wave of unsafe injections, where disposable syringes were reused. It has been estimated that as many as 30% of injections in low-resource settings are unsafe because of reuse of syringes (*6*); this practice continued despite efforts to educate practitioners about the dangers of reusing disposable syringes. A "cultural resistance to waste" drove continued reuse of syringes, "regardless of training, advocacy, and regulatory factors" (*7*).

Next, it's important to engage users early. Projects pursued from the perspective of adapting high-resource design principles to low-resource settings without firm evidence of user need beg the question of adoption and can lead to one-off projects that are scaled on the basis of donor priority without evidence that they improve outcomes. For example, the nongovernmental organization (NGO) PlayPumps (Fig. 1) was initially heralded for its ability to use children's play on a merry-go-round to provide a much-needed community service: pumping of water to a community storage tank. With relatively little target community feedback, the U.S. government and other donors committed $16 million to scale up the implementation, and PEPFAR announced a plan to raise an additional $44 million. However, it quickly became apparent to users that, not only were the spare parts and technical expertise required to fix the PlayPump difficult to find, but also that the 27 hours of playtime needed to meet the required minimum daily water requirement was simply infeasible (*8*). In the end, the community users preferred the efficiency and reliability of traditional hand pumps.

Finally, there are numerous design trade-offs to be made in developing and scaling frugal technologies; rigorous experimentation is required to understand which features are most important to support positive impact at scale. For example, the rapid growth in global access to cell phones provides an opportunity to use mobile phone technology to improve health in low-resource settings. Yet, despite more than 500 pilot studies of mobile technologies for health (mHealth), there is still not sufficient programmatic evidence to inform scale-up (*9*). In most pilot studies, investigators treat the mHealth application as a "black box" and examine the effects of using or not using the intervention. As a result, there are no data to indicate which individual mHealth features might be most effective. There is an important need for multifactorial pilot study designs that identify and empirically test a range of features that might contribute to variation for a particular application (*9*).

Design for scalability

Although successful frugal design begins with constraints that are dictated by scarcity, it must also integrate this perspective with a systems-level approach centered on how new designs can be successfully implemented, scaled, and sustained. The frugal design cycle begins with a user-centric focus that accounts for the available infrastructure and economic resources. Scale-up requires evidence of efficacy at the community and national levels. Whereas aid from the international community can help jump-start efforts to scale up a project or program, business development and private sector partnerships are required to sustain implementation. Ensuring long-term access to new health technologies requires a coordinated architecture that integrates efforts to make new technologies affordable, makes certain the technologies are available where they are needed, and facilitates adoption of the technologies within health systems (*10*).

Developing a compelling value proposition requires both data to support the health benefit of a new technology and identification of a paying customer—a significant challenge within the context of the world's poorest health systems. Yet, there are examples of success. Unsafe injection practices have been dramatically reduced by developing new injection technologies that cannot be reused. One example is Uniject, a blister pack prefilled with the proper dose of vaccine and connected to a needle via a one-way valve that prevents the device from being refilled and reused (*11*). By eliminating the need to properly fill a syringe, Uniject simplifies injection practices for users like midwives and community health workers in rural communities. Tests of the device to deliver the hepatitis B vaccine to newborns in Indonesia showed that use of a prefilled device simplified logistics of vaccine delivery immediately after birth by midwives, reduced vaccine wastage, and was preferred by midwives and mothers (*6*).

The role of the international and business communities was central to the development and scale-up of Uniject. Indeed, the technology was developed in response to a 1987 meeting convened by the World Health Organization (WHO) to highlight the challenges of unsafe injection practices. With support from the U.S. Agency for International Development (USAID), the NGO PATH worked to improve technology originally developed by Merck. Merck transferred its intellectual property rights to PATH, which licensed the technology to Horizon Medical and went into pilot production of the Uniject device. On the basis of the positive results of early implementation trials, the Uniject technology was licensed to Becton Dickinson & Company (BD) in 1996 (*11*). BD invested $25 million to establish a dedicated manufacturing line for empty Uniject packages in Singapore and $10 million to launch the product on the global market; today, vaccine manufacturers buy empty Uniject containers and prefill them for global distribution (*11*). Since 2000, millions of doses of hepatitis B and tetanus vaccines have been delivered with Uniject, and efforts are under way to use Uniject to expand access to injectable contraceptives in low-resource settings (*12*). Through a partnership with Biodel, Uniject is now being developed for emergency delivery of liquid glucagon to treat severe hypoglycemia, where a simple, portable solution is of particular importance for first responders or parents of children with diabetes.

> ***"If we are to resolve global inequities in access to innovations that improve health, we must adopt new approaches to engineering design that reflect the unique needs and constraints of low-resource settings."***

Yet, the technology still faces the challenge of articulating an effective value proposition for purchasers in health systems, who are often evaluated on the basis of their ability to maximize the number of lots of vaccine they can purchase with a fixed sum. The incremental cost to deliver prefilled vaccine in Uniject packaging is approximately $0.06 higher per immunized child than with disposable syringes (*11*). Although Uniject packaging is more costly than disposable syringes, its use for newborn hepatitis B vaccination saves money when one takes into account reductions in vaccine wastage and costs of home visits. Nonetheless, critical gatekeepers often resist suggestions to purchase Uniject because of higher initial costs (*11*).

Template for success

Design simple solutions

Sometimes inexpensive, nontechnical solutions are best. Roughly 1.3 million people die annually in road traffic accidents, 90% of whom live in low- and middle-income countries. The number of deaths due to road traffic accidents is anticipated to double by 2030, rising to the third leading cause of global mortality; most of this increase will occur in low- and middle-income countries, where the number of motor vehicles is projected to increase sixfold without improvements in road infrastructure or traffic safety (*2*). Modifying driver behavior is an inexpensive alternative to building better road systems. For example, in an experiment aimed at examining the influence of social pressure on driver safety in Kenyan minibuses, signs were posted in half of a fleet of vans encouraging passengers to collectively speak out about unsafe driving practices (*13*). When compared with the control group, passengers riding in vans with signs filed about one-third as many insurance claims, and injury and fatality claims dropped nearly 50%. Behavior as a frugal design solution is low cost and easily adapted to different contexts, which makes it highly scalable.

Don't overlook traditional solutions

Investments to eradicate malaria have resulted in dramatic reductions in mortality, as much as 42% globally since 2000, with child mortality rates in Africa dropping by nearly 54% during the same time period (*14*). But with this has come increasing resistance to antimalarial medicines and heavily used insecticides such as pyrethoids. With the likelihood that new drugs are still many years out, environmental management could emerge as a key means of vector control. In the early 20th century, engineers worked with malaria control personnel to manage the mosquito population through environmental design features, many of which still show efficacy. For example, mosquito-proofing houses and better water management and irrigation methods have been highly successful at helping to reduce the incidence of malaria (*15*). This low-cost approach to governance, combining simple water resource management together with public education, can be successfully applied globally. In places like California, outreach is now emphasizing environmental controls: the elimination of standing water and using biological control measures (e.g., mosquito larvae–consuming fish) (*16*).

Think long-term, while solving short-term

Point-of-use water treatment with chlorine is widely considered one of the most effective strategies for providing safe drinking water in water-scarce settings (*17*). As much as a 29% reduction in diarrheal illness in children was seen with point-of-use chlorine treatment compared with traditional disinfection methods, a protective effect that was nearly universal across populations and conditions in short-term trials. But with rapidly increasing urbanization, it might be more efficient to begin to extend design innovation to technologies that increase the production of potable water through reuse, which would also help to address water scarcity. In Windhoek, Namibia, highly treated reclaimed water has been combined with potable water directly in the water distribution system since the late 1960s (*18*). The reclaimed water meets all drinking water standards, which makes it a viable option under both financial and water provision terms.

Fig. 1. Meeting the need. Approximately 768 million people do not have access to safe drinking water; new engineering approaches are needed to develop point-of-use technologies that meet the needs of community users and can be sustained over time. Efforts by aid organizations to scale the PlayPump (shown) failed because community users preferred the efficiency and reliability of traditional hand pumps. [Photo credit: German Chauluka]

Engage students in frugal design

Students must be educated to become successful practitioners of frugal design from a systems perspective (*19*). Curricular reforms are even more crucial in low-resource settings where a lack of engineering capacity and infrastructure severely limits economic development (*20*) and where knowledge of contextual constraints is paramount to the success of frugal designs. Sub-Saharan Africa suffers a chronic lack of indigenous engineering capacity: In the early 2000s, the number of engineers emigrating annually from South Africa matched the number of engineers graduating (*21*). Where available, tertiary education in engineering has not received anywhere near the investment required to keep pace with the developed world. Learning foci are too theoretical, based on outdated curricula, and not relevant to local needs. The teaching and learning approaches that emphasize rote memorization stunt students' potential to be innovative. Faculty lack resources for providing lab experiences and salaries are often so low that many take on additional jobs. Students who graduate from such programs face notable levels of unemployment, most likely because they graduate without needed skills and experience to be employable. Over $130 million has been invested to strengthen medical school education through the Medical Education Partnership Initiative by the U.S. National Institutes of Health, with a focus on developing human capacity, retaining faculty and graduates, and developing regionally relevant research programs (*4*); similar investments are critical if tertiary engineering education is to develop sufficient and relevant engineering capacity in the region. To fully leverage such investments, preuniversity science and math education must also be strengthened.

Design for context

Sustained implementation of a new frugal technology that performs well compared with technologies designed for higher-resource settings requires successful navigation of a number of contextual and political challenges. The explosive global growth in the availability of mobile phone technology illustrates the kind of success that is possible when the value proposition of a new technology is clear at all levels—users were willing to pay for inexpensive handsets and airtime; communities where electricity was not widely available established charging banks; and countries and the private sector invested in both the necessary private and public infrastructure to establish a network of base stations, powered by diesel generators where reliable electricity was not available (*22*). Today, 6 billion of the world's 7 billion people have access to a mobile phone, whereas only 4.5 billion have access to a latrine or toilet (*23*).

Why do more people have access to mobile phones than toilets? In part, it is more difficult to overcome the implementation challenges for technologies that require substantial investment in public infrastructure. The infrastructure to provide clean water and sanitation in developed countries requires robust vertical governance, from national to local levels. In most low-resource settings, local governments have insufficient capital to build community-level infrastructure and even less human capital for long-term maintenance. Resource constraints exist in every setting, but the nature and type of constraints in developing countries requires rethinking traditional processes. For example, the traditional design cycle for public infrastructure projects may require adjustment. Civil engineers are currently trained to optimize a design, then bid the project and accept the low bid. An alternative approach where the design engineer and end-user participate directly in a design process with feedback that is aimed at lowering the end-user costs could help designers maintain perspective about context and yield innovation that is more frugal in nature.

Adoption is facilitated when end-users see a direct personal benefit associated with purchase of a new technology. Access to mobile phones increased profits for fishermen in India and market participation for farmers in Uganda (*22*). In contrast, the benefits of health or sanitation technologies may not be as apparent to end-users. The public sector, which is usually charged with promoting such technologies, is not good at market research.

Finally, adoption is facilitated in competitive markets that can drive down the price of technology services; market liberalization was associated with a 90% drop in average mobile phone call prices and an increase in traffic volumes (*22*). In the global health care industry, two recent trends may help to accelerate the implementation of promising technologies. First, rapidly expanding health care markets in emerging economies are drawing the interest of multinational corporations (*3*). Inflation-adjusted biomedical research and development expenditures increased in India and China by 6.7% and 32.8% per year, respectively, from 2007 to 2012; in contrast, expenditures in the United States, Canada, and Europe decreased over the same period (*24*). Likewise, an increase in accountable care organizations may drive investment in resource-saving technologies in the United States.

Conclusion

We are not the first to suggest a transition to frugal design—a number of recent "grand challenges" design efforts have engaged the technology development community in frugal design efforts. Efforts like The Gates Foundation's Reinvent the Toilet Challenge reflect the kind of integrative thinking that must occur at the beginning of a design initiative; support is being directed toward strategies to create a next-generation toilet that can not only manage waste but also harvest water and energy resources. The toilet will also need to operate without the usual infrastructure, be financially sustainable, and be valued by users. Although such competitions highlight important challenges, funders often solicit solutions with a high degree of technical innovation. An unintended consequence of this premium on innovation can be to complicate downstream implementation efforts. It is time for the engineering and international aid communities to adopt approaches that can improve global health in ways that can be sustained.

REFERENCES AND NOTES

1. The Lancet, *Lancet* **383**, 1359 (2014).
2. Centers for Disease Control and Prevention, *MMWR Morb. Mortal. Wkly. Rep.* **60**, 814–818 (2011).
3. P. Howitt *et al.*, *Lancet* **380**, 507–535 (2012).
4. Institute of Medicine, *Evaluation of PEPFAR* (National Academies Press, Washington, DC, 2013).
5. P. Baldinger, W. Ratterman, "Powering health: Options for improving energy services at health facilities in Ethiopia" (USAID, Washington, DC, 2008).
6. A. Sutanto, I. M. Suarnawa, C. M. Nelson, T. Stewart, T. I. Soewarso, *Bull. World Health Organ.* **77**, 119–126 (1999).
7. J. S. Lloyd, J. B. Milstien, *Bull. World Health Organ.* **77**, 1001–1007 (1999).
8. L. Freschi, in *AIDWATCH*, 19 February 2010; http://aidwatchers.com/2010/02/some-ngos-can-adjust-to-failure-the-playpumps-story/.
9. M. Tomlinson, M. J. Rotheram-Borus, L. Swartz, A. C. Tsai, *PLOS Med.* **10**, e1001382 (2013).
10. L. J. Frost, M. R. Reich, *Access: How do Good Health Technologies Get to Poor People in Poor Countries?* (Harvard Center for Population and Development Studies, Cambridge, MA, 2008).
11. PATH, The Uniject Device (2005); www.path.org/projects/uniject.php.
12. C. B. Polis *et al.*, *Contraception* **89**, 385–395 (2014).
13. J. Habyarimana, W. Jack, *J. Public Econ.* **95**, 1438–1446 (2011).
14. World Health Organization (Geneva), www.who.int/en.
15. J. Keiser, B. H. Singer, J. Utzinger, *Lancet Infect. Dis.* **5**, 695–708 (2005).
16. A. Thier, *J. Urban Health* **78**, 372–381 (2001).
17. B. F. Arnold, J. M. Colford Jr., *Am. J. Trop. Med. Hyg.* **76**, 354–364 (2007).
18. L. Tchobanoglous, H. Leverenz, M. H. Nellor, J. Crook, *Direct Potable Reuse: A Path Forward* (Water Reuse Research Foundation, Alexandria, VA, 2011).
19. R. Richards-Kortum, L. V. Gray, M. Oden, *Science* **336**, 430–431 (2012).
20. K. Stuart, E. Soulsby, *J. R. Soc. Med.* **104**, 401–404 (2011).
21. P. Matthews, L. Ryan-Collins, J. Wells, H. Sillem, H. Wright, *Engineers for Africa: Identifying Engineering Capacity Needs in Sub-Saharan Africa* (Royal Academy of Engineering, London, 2012).
22. J. Aker, I. Mbiti, *J. Econ. Perspect.* **24**, 207–232 (2010).
23. UN News Centre (UN News Service, 2013).
24. J. Chakma, G. H. Sun, J. D. Steinberg, S. M. Sammut, R. Jagsi, *N. Engl. J. Med.* **370**, 3–6 (2014).

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PERSPECTIVE

Strengthening the evidence base for health programming in humanitarian crises

A. Ager,[1] G. Burnham,[2] F. Checchi,[3] M. Gayer,[4] R. F. Grais,[5]* M. Henkens,[6] M. B. F. Massaquoi,[7] R. Nandy,[8] C. Navarro-Colorado,[9] P. Spiegel[10]

Given the growing scale and complexity of responses to humanitarian crises, it is important to develop a stronger evidence base for health interventions in such contexts. Humanitarian crises present unique challenges to rigorous and effective research, but there are substantial opportunities for scientific advance. Studies need to focus where the translation of evidence from noncrisis scenarios is not viable and on ethical ways of determining what happens in the absence of an intervention. Robust methodologies suited to crisis settings have to be developed and used to assess interventions with potential for delivery at scale. Strengthening research capacity in the low- to middle-income countries that are vulnerable to crises is also crucial.

Health interventions in humanitarian crises—situations where disasters or conflicts constitute a critical threat to the health, safety, security, or well-being of a population—are an important focus within the broader field of global health. Such crises affect increasingly large numbers of people worldwide (*1*). There have been notable advances in programming, specifically in immunization and treatment of acute malnutrition, over the past 20 years. However, despite the increasing professionalization and standardization of humanitarian work (*2*), there is a consensus that the evidence base for much current practice remains weak (*3*, *4*).

It is not coincidental that the evidence base for health programming is frail in crisis conditions that cause high mortality and morbidity. Such health care contexts also present many challenges to scientifically rigorous research. Prime among these challenges is the acute vulnerability of populations (*5*), which requires prompt intervention rather than exploration of the comparative benefits and limitations of alternative approaches. In the face of acute needs and against a typical backdrop of limited funding, poor security, and shortages in human resources and logistics, simply providing immediate minimal standards of health services becomes an overriding concern. The space for research—particularly that involving experimental interventions or randomization or, more generally, offering different standards of care within the same population—dramatically shrinks (*6*, *7*). Acutely vulnerable populations have a compromised capacity to give meaningful informed consent. Refusing study participation may be seen as rejecting vital medical assistance (*8*, *9*).

The rapid response required in humanitarian crises contributes to an unpredictable programming environment. Although many health risks in the aftermath of disasters or conflict are predictable and minimum standards for response and best-practice interventions have already been established, health needs can evolve rapidly, and adaptable program strategies are required. Political sensitivities and security concerns may also have a substantial influence on the timing, coverage, and delivery of health interventions (*10*). Different sectorial interventions that affect health (including provision of shelter, water and sanitation, food security, livelihoods, nutrition, and vaccination) may be introduced with limited coordination and varying population coverage (*11*). This makes identification of comparison or control groups and attribution of outcomes to any single intervention methodologically challenging.

Difficulties in coordination are not only cross-sectoral but also reflect the more general complexity of multiple intervening actors and initiatives that characterize humanitarian responses. A population will typically receive services through a complex web of national and local governmental institutions, local civil society partners, United Nations agencies, nongovernmental organizations, and, in some emergencies, foreign

[1]Mailman School of Public Health, Columbia University, 722 West 168th Street, New York, NY 10032, USA. [2]Bloomberg School of Public Health, Johns Hopkins University, 615 North Wolfe Street, no. 5041, Baltimore, MD 21205, USA. [3]Save the Children UK, 1 St John's Lane, London EC1M 4AR, UK. [4]World Health Organization, Avenue Appia 20, 1211 Geneva 27, Switzerland. [5]Epicentre, 55 Rue Crozatier, 75012 Paris, France. [6]Médecins Sans Frontières International, Rue Dupré 94/Dupréstraat 94, 1090 Brussels, Belgium. [7]Clinton Health Access Initiative, Monrovia, Liberia. [8]UNICEF, Wisma Metropolitan II, lantai 10, Jalan Jenderal Sudirman kavling 31, Jakarta 12920, Indonesia. [9]Division of Global Health Protection, Centers for Disease Control and Prevention, 1600 Clifton Road, Atlanta, GA 30333, USA. [10]United Nations High Commissioner for Refugees (UNHCR), Case Postale 2500, CH-1211 Genève 2 Dépôt, Geneva, Switzerland.
*Corresponding author. E-mail: rebecca.grais@epicentre.msf.org