Review

A Research Agenda for Malaria Eradication: Health Systems and Operational Research

The malERA Consultative Group on Health Systems and Operational Research[¶][*]

Abstract: Health systems research and development is needed to support the global malaria eradication agenda. In this paper, we (the malERA Consultative Group on Health Systems and Operational Research) focus on the health systems needs of the elimination phase of malaria eradication and consider groupings of countries at different stages along the pathway to elimination. We examine the difference between the last attempt at eradication of malaria and more recent initiatives, and consider the changing health system challenges as countries make progress towards elimination. We review recent technological and theoretical developments related to health systems and the renewed commitment to strengthening health systems for universal access and greater equity. Finally, we identify a number of needs for research and development, including tools for analyzing and improving effective coverage and strengthening decision making and discuss the relevance of these needs at all levels of the health system from the community to the international level.

Introduction

The last attempt at (global) eradication of malaria, which lasted from 1955 to approximately 1969, depended on vertical operations (centrally organized activities not linked to subnational administrative levels and/or communities). These operations—largely indoor residual spraying—often bypassed health systems, because it was assumed that they could be run most efficiently with minimal collaboration with general health services, which were often poorly developed in endemic areas. In the later phases of the first eradication era, it became clear that some form of chemotherapy was needed to reduce transmission, and that good surveillance was essential for achieving and maintaining malaria-free status in a given area. Increased attention was then given to integration with existing health services and to using malaria eradication strategically to build rudimentary health services in remote areas [1,2].

Here, we examine the health systems research and development that is necessary to support a global malaria eradication agenda. We do not address broader macroeconomic and health system development needs, even though addressing them would be beneficial to all agendas. We focus on the elimination phase of the eradication agenda and considers groupings of countries at different stages along the pathway to elimination.

On the basis of previous experiences with malaria and other diseases for which eradication has been attempted, we use standard definitions for control, elimination, and eradication throughout this article (Box 1) [3]. Importantly, these definitions emphasize the need for continued interventions for both malaria control and elimination.

Review articles synthesize in narrative form the best available evidence on a topic.

The Health System

In 2000, The World Health Organization (WHO) articulated a comprehensive definition of health systems that is now widely adopted. A health system "consists of all organizations, people and actions whose primary intent is to promote, restore or maintain health" [4] with goals of "improving health and health equity in ways that are responsive, financially fair and make the best, or most efficient, use of available resources." In 2007, WHO developed a conceptual framework comprising six "health system building blocks" that has also been widely adopted (Box 2) [5].

This framework has now been further elaborated [6] to include the role of people, not just at the centre of the system as mediators and beneficiaries, but as key actors in driving the system itself. Thus, the framework includes the participation of people as individuals and in civil society organizations and stakeholder networks, which influence each of the building blocks. Placing people and their institutions at the centre of this framework emphasizes WHO's renewed commitment to the principles and values of primary health care—fairness, social justice, participation, and intersectoral collaboration (see Figure 1).

Currently, three revolutions are under way that will transform health systems: the biotechnology revolution, the communications and information technology revolution, and the systems thinking. Systems thinking is a holistic approach to analysis that focuses on the emergent behaviour of complex systems. It analyzes how a system's constituent parts interrelate and how systems work over time and within the context of larger systems. Applied to problem solving, systems thinking addresses the dynamic, mainly nonlinear linkages, interactions, and behaviours among the elements of the entire system. Systems thinking as developed and used for other complex systems is now being applied in health systems [7] and is essential for understanding what works, for whom, to what extent, and under what circumstances. It also helps predict and mitigate possible unintended consequences of particular actions and to exploit synergies from concerted action in the system.

Figure 1. Health system building blocks [7]. Image credit: Fusión Creativa.
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The promotion and application of systems thinking will be very timely as the malaria eradication agenda develops.

Health Systems for Malaria Control, Elimination, and Eradication

The Global Malaria Action Plan (GMAP) was launched in 2008 by the Roll Back Malaria partnership against a background of greatly increased investment in research and development for malaria-control technologies since 1999 and extraordinary increases in funding for malaria control through national and global financing mechanisms since 2002 [8]. The GMAP includes three phases. The first phase—scaling-up for impact—aims to rapidly reach universal coverage for all populations at risk with locally appropriate malaria-

control interventions, supported by strengthened health systems. The second phase—sustained control—aims to prevent the resurgence of malaria by maintaining universal intervention coverage until countries enter the elimination stage. In the final phase—elimination and eradication—it is estimated that more than 20 lower burden countries around the world will be poised to eliminate malaria.

There is currently a broad global consensus on malaria-control strategies, and almost all malaria-endemic countries now have national malaria programmes in line with GMAP. Malaria indicators (both for coverage and health impact) are moving in the right direction in many countries [9]. However, progress in most endemic countries is slower than it could be, given the available financial resources. Among the main reasons for the suboptimal pace are constraints to the delivery of essential malaria interventions at effective coverage levels and quality to populations in need [9–11]. There is no doubt that success in moving towards eradication will be heavily dependent on health systems [12,13].

Some of the health system challenges in a country facing a huge malaria burden and in a country on the brink of phasing out the disease are similar, but such countries also pose different health system challenges. For example, quality case management is needed in all phases. In contrast to most other diseases for which elimination is being considered, the symptoms of malaria are nonspecific. Furthermore, treatment needs to start soon after symptoms appear both to prevent the development of severe disease and death and, particularly in areas where malaria prevalence is low, to help reduce transmission. The capacity to diagnose and provide early and effective treatment is therefore needed wherever there is a malaria risk. Achieving this capacity requires quality coverage of general health services and is an important systemic challenge for any antimalaria programme.

By contrast, although survey data can be useful for gauging progress in highly endemic areas, disease surveillance becomes increasingly important as the disease burden is lowered. Highly sensitive and dynamic surveillance becomes the crucial element in the pre-elimination phase and after [14]. Again, this capacity can only be achieved by a solid articulation between a specialized programme and functional general health services.

Finally, although the integration (or at least coordination) of malaria vector control and other preventive interventions with other health programmes can be synergistic and efficient in many settings, such integration becomes less efficient as progress makes malaria an increasingly focal and epidemic disease. Thus, malaria preventive interventions can sometimes be managed independently from general

health services but these operations nevertheless depend on fundamental health system elements such as policy and governance, human resources, financing, supplies, and monitoring.

Much progress has been made in recent years towards understanding health systems better and the importance of strengthening them. The result is that global health initiatives are providing increased funding for national health systems to accelerate progress on universal access to essential health interventions, including malaria interventions. New initiatives such as the Task Force on Innovative Financing for Health Systems [15], and initiatives from the Global Fund to Fight Aids, Tuberculosis and Malaria (GFATM), Global Alliance for Vaccines and Immunization (GAVI), WHO, World Bank Joint Platform for Health Systems Strengthening, and President Obama's Global Health Initiative are evidence of the growing momentum in favour of health system strengthening. At the same time, there is also an increased emphasis on health systems research. During the last attempt at malaria eradication, research, including health systems research, was neglected because it was assumed that rapid, uniform spraying operations would lead to eradication. More recent successful malaria disease and control programmes have been notable for including research as a critical element [2,11,16].

Health Systems Effectiveness

As an original approach to understanding health system impediments to sustaining malaria interventions at coverage levels sufficient to reduce malaria morbidity and mortality to very low levels, and to achieve and maintain malaria-free status, we introduce the concept of health systems effectiveness. We used this concept and a framework for analyzing constraints to scale-up (see below) as "stepping stones" during our development of a health systems research and development agenda.

Malaria control and elimination depend in equal measure on high-performance health systems that can deliver malaria interventions at high and equitable levels of quality and with effective coverage. In this context, effective coverage goes beyond the usual notion of population access to include provider compliant delivery, patient adherence, and individual benefit from the intervention [17]. Effective coverage requires the concerted strength of all the health system building blocks. When effective coverage levels are inadequate or inequitable, the reasons are nearly always interacting failures across the building blocks. To pinpoint where

system interventions and strengthening will be effective and efficient, programme managers need to be able to diagnose those problems and their determinants and interactions.

Figure 2 provides a graphical representation of the systems effectiveness framework and shows how an initially high intervention efficacy translates into low effectiveness in the real world because of system-specific issues of suboptimal intervention access, inadequate programme targeting because of diagnostic shortcomings, incomplete provider compliance, and client adherence.

District health system observatories are being established in Burkina Faso, Ghana, Mozambique, and Tanzania to determine their respective health systems' effectiveness in delivering artemisinin-based combination therapies (ACTs) [18], and research projects are starting to use the health systems effectiveness framework to analyze the determinants of coverage [19]. However, the results of these research projects have yet to be translated into strategically targeted health system–strengthening interventions and programme corrections.

A final stepping stone we used to develop the research agenda outlined in this paper is the framework for analyzing constraints to scale-up, developed for the Commission for Macroeconomics and Health [20]. This framework illustrates how barriers to expanding coverage of essential health services operate at all levels of the health system, from communities and households, through to cross-sectoral and sociopolitical levels, and thus suggests that interventions to address these barriers may need to operate at multiple levels.

Towards a Systems Research and Development Agenda

The health systems research and development agenda that our group has developed derives from the ideas and concepts discussed above and proposes the creation of a set of tools for applying the systems effectiveness framework for malaria elimination and control in different health system settings. The agenda is organized both across health system levels (community, facility, district, national, regional/global, and intersectoral; more details of these levels are given later) and health system building blocks (see Box 2), but, importantly it also takes account of "country groupings." These groupings are relevant to the phases defined in the GMAP and we discuss them here in some detail before presenting our research and development agenda in full.
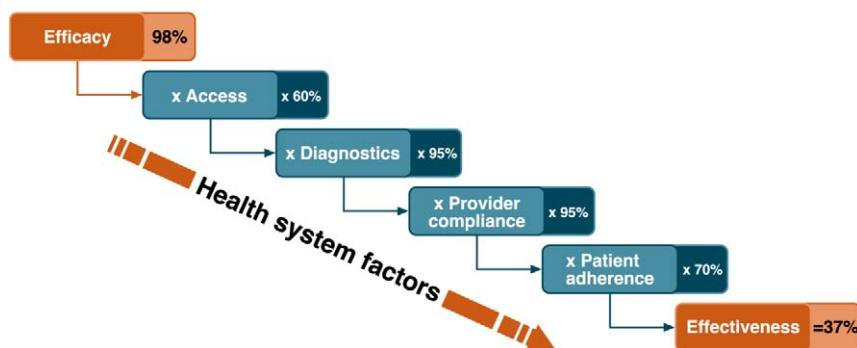
Figure 2. Graphical representation of the systems effectiveness framework. How interventions lose traction in health systems: example of artemisinin-based combination therapy (ACT) antimalarial treatment in Rufiji Demographic Surveillance Area Tanzania in 2006. Source: INDEPTH INESS Project. Systems Effectiveness Module, Swiss Tropical and Public Health Institute with data from Ifakara Health Institute and US Centers for Disease Control and Prevention based on [45–47]. Image credit: Fusión Creativa.
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We suggest that the following grouping of countries is used to identify the most relevant health system research agendas for individual countries.

Group 1 includes countries where most of the population lives in areas where malaria elimination is considered impossible with existing tools. Currently, most of these countries are scaling up malaria-control efforts and some are entering the sustained control phase. This group includes most countries of sub-Saharan Africa and Papua New Guinea. In these countries, which have large areas with very intense malaria transmission, it is generally assumed that malaria elimination will only be possible though the large-scale application of new tools, which are still to be developed. Most likely such new tools will need to be applied in combination with existing ones, and the health system requirements for the effective delivery of these tools will probably be similar to those of current malaria-control interventions. Therefore, although undertaking systems research from the perspective of elimination is likely to be unproductive in group 1 countries, addressing current health system constraints on malaria control will almost certainly prove crucial for any future elimination efforts.

Group 2 includes countries with focal malaria, where a large part of the population lives in malaria-free areas, and where research aimed at health system strengthening is likely to play a crucial role in interrupting transmission in many of the existing foci. Many of these countries have diverse and complex health system challenges. This group includes most of the malaria-endemic countries in South and Central America, middle South Asia, and Southeast Asia. In sub-Saharan Africa, it includes southern Africa, the Horn, and the northern part of Sudan. It corresponds closely to the GMAP group designated as "control: low contribution to global deaths" [9], but includes additional countries such as Bangladesh, India, Indonesia, and Nepal.

Group 3 includes countries that are elimination ready. This group is almost identical to the "pre-elimination and elimination" countries in the World Malaria Report [9] and includes Argentina, Mexico, most of the countries of the Middle East and Central Asia, Central China, and possibly Sri Lanka, Vanuatu, and the Solomon Islands. In these countries, health system issues are generally not a crucial impediment to elimination, not necessarily because the health systems are exceptionally strong but often because the country's malaria problem has always been relatively easy to tackle with existing technologies due to intrinsic biologic (e.g., vectorial capacity or efficiency) or socioeconomic and development (e.g., improved housing) factors. However, review of the road to elimination in these countries with the identification of crucial health system determinants could provide valuable lessons, so international collaborations/global initiatives should focus on learning from past experiences rather than undertaking direct support or capacity strengthening.

This grouping of countries is intended to be specific to the malaria eradication health systems research agenda. A comprehensive listing of countries by these groupings has been avoided because many countries have areas belonging to more than one of these categories; this heterogeneity by itself presents policy and implementation challenges. Furthermore, the boundaries between groups are imprecise, and some countries could move from one group to another within few years.

What Goals and Needs Should the malERA Health Systems Research and Development Agenda Include?

From our discussions, we propose that the malERA health systems research and development agenda should consider the critical/transformational and conditional/situation goals and needs described in detail in Table 1. Some of these goals and needs are also partly covered in other papers in this series. For example, the need for tools to reduce unacceptably and avoidably low effective coverage of essential malaria interventions and malaria surveillance is also partly covered by the Monitoring and Evaluation and Surveillance malERA consultative group [21], the need for decision support tools to remove policy decision uncertainty for when to commit to transitioning from control to elimination is also covered in part by the malERA Consultative Groups on Modeling and Cross-Cutting Issues [22,23], and the need for a tool to determine the kind and mix of integrated interventions that are cost-effective in differing epidemiologic and health system contexts is covered in part by the malERA Consultative Group on Modeling [22].

What Research Questions Must Be Asked to Satisfy Health Systems Needs and Goals?

The research questions that emerge from this above analysis are presented in Table 2 in a matrix of health system levels and health system building blocks. Below, we discuss these questions in greater detail arranged by health system organizational level. As in Table 2, when no country grouping is specified, the discussion refers to both group 1 and group 2 countries.

Community Level

Past experience indicates that fixed health facilities cannot reach all those in need, and that extending the reach of services is essential to achieve universal and equitable coverage with interventions for malaria and other diseases. Community health workers (CHWs) and home management of fevers (which has been well documented in Africa) offer possible approaches. Several examples of CHW initiatives are emerging from countries as varied as India, Sri Lanka, Ethiopia, and Uganda [24,25]. More needs to be done to capture and share the experience gained from these programmes, and to ensure that opportunities are taken to evaluate the effectiveness of different approaches to designing and implementing CHW programmes.

A range of community-level factors affects the ability of health systems to reach the population effectively, particularly groups that are located far from formal health facilities and/or are mobile. Some of these factors reflect the conventional barriers to access—financial, physical/geographic, and social [26], but a better understanding is needed of how community-level factors influence use in particular settings, and how they can be addressed in the context of malaria-control and elimination measures.

In the past, some community health programmes failed because they did not recognize the need to compensate CHWs for time spent delivering services, and because they were not sufficiently linked into and supported by the health systems' "higher" levels [27,28]. There is a rich literature on CHW systems that should be exploited, but given rapid changes—such as the greatly improved levels of education and the proliferation of private providers in many areas—continued experimentation with different approaches is needed to sustain CHW performance and motivation, including different forms of health facility support (for example, supervision). Better ways of integrating CHWs' results into health information and surveillance systems and ensuring that they receive information from these systems also need investigating. Furthermore, as malaria transmission falls and countries enter the elimination phase, it will become critical that malaria surveillance systems improve their coverage to include data from whichever services are used by people at risk [21]. Finally, diagnostic and

Table 1. Categorization of the malERA health systems research goals and approaches.

Categories	Goals/Problems	Means/Approaches	Cross-Cutting	Stage of Elimination/Eradication
Critical/transformational	Reduce unacceptable and avoidably low effective coverage of essential malaria interventions.	Develop/validate toolkit for owning, analyzing, and responding to system-level bottlenecks in intervention delivery and use.	Yes, drugs, vaccines, vector control, diagnostics.	Scaling-up, sustained control, preelimination, and elimination.
	Harness a community of health systems analysts into the malaria elimination community.	Assess other models of global disease elimination enterprises to develop an optimal approach to an appropriately widened community.	Yes.	Scaling-up, sustained control, preelimination and elimination, prevention of reintroduction
	Understand how and facilitate strengthening of health systems by disease-specific global health initiatives in malaria.	Assist global health initiatives to apply systems science to guide health system strengthening investments.	Yes, concerns all agendas.	Scaling-up, sustained control, preelimination, and elimination.
Conditional/situational	Facilitate policy decision uncertainty for when to commit to transitioning from control to elimination phase and understand how disease-specific global health investments in malaria strengthen health systems and facilitate it.	Develop systems dynamic modeling, tools and case studies to understand determinants for elimination go-no/go policy decisions.	Yes, concerns all agendas.	Scaling-up, sustained control and preelimination, elimination.
	Determine whether the kind and mix of integrated interventions are cost-effective in differing epidemiologic and health system contexts.	Develop system dynamic modeling and respective tools as well as case studies to assess synergies.	Yes, drugs, vaccines, vector control.	Control, preelimination, elimination.
Increased emphasis	Communicate determinants of successful regional and inter-country collaboration for disease elimination	Critical review and analysis.	No.	Elimination.
	Major increase in community and district engagement and ownership of the malaria-control and elimination agenda.	Develop means to engage communities more effectively in case management, vector control, and surveillance.	Yes, drugs, vaccines, vector control, surveillance.	Control, preelimination, elimination.

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other tools for use at the community level that are implemented as part of integrated strategies for managing illness, such as the Integrated Management of Childhood Illness (IMCI) and Integrated Management of Adult and Adolescent Illness (IMAI) strategies, have the potential to create quantum leaps in service and need to be adapted through research to the changing malaria epidemiological context. Unfortunately, few, if any, of these strategies are being systematically promoted in malaria risk areas in category 2 countries.

Facility Level

The health facility is the main point of contact with the health system for many people with fever, although private and informal providers are also important in many settings. It is also the focal point for collection, and ideally, use of data gathered through routine health management information systems. Many health systems face the challenge of ensuring that health workers are present in health facilities, have the required training and

knowledge, are equipped with the relevant drugs and other supplies, and are motivated to use these resources to provide high-quality and responsive care that follows national policies and standards.

New research is needed on how best to improve health worker performance [29,30]. A range of potential policy interventions has been suggested, including the traditional approaches of training and supervision, performance-based pay, bottom-up approaches using community accountability structures, and interventions addressing the mindset of health workers [31]. Other than training, the evidence about what works best and in what contexts is very limited, and deserves urgent attention.

Critically, interventions to improve health worker performance need to recognize the interconnectedness of the different health system building blocks. The design of pay-for-performance schemes, for example, involves questions of how best to govern such arrangements and the role of the community in these schemes, what the form and level of payments to health workers

Table 2. Matrix of health systems research and development needs.

Level/Building Block	Governance	Human Resources	Financing	Information[a]	Service Delivery, Medicines, and Technology
Community level	How can lay boards (community leader councils) strengthen local health service delivery? (Group 1 countries)	What is the role of CHWs and private sector providers in treatment of malaria and nonmalaria fevers, and in what settings are they crucial?	What are the main financial (and other) barriers to health services use and how can these be overcome?	What is the best approach to community-based monitoring of malaria and other communicable diseases building on existing and past efforts?	How can the community components of integrated approaches (IMCI and IMAI) be strengthened and adapted to different epidemiological and system settings?
	What is the role of communities in active efforts at transmission reduction (as opposed to reducing morbidity and mortality from malaria)?	How can they be incentivized and integrated with the health system to support and sustain their performance?	—	How can health information systems include information from and to CHWs? (Group 1 countries)	—
Facility level	Tools for assessing illicit payment for services	What are the most effective and appropriate methods for monitoring health worker performance?	—	How can modeling and evaluation innovations for malaria eradication strengthen health systems?	Development of IMCI and IMAI updated with new diagnostic tools and adapted to the malaria elimination context
	—	What types of financial and nonfinancial incentives can best support and sustain improved health worker performance?	—	Tools for assessing local coverage, quality, and equity to apply to systems effectiveness framework	Development of appropriate multidisease diagnostic tools
	—	—	—	—	Tools for drugs and supplies stock management
District level	What model(s) for district management of malaria-control programmes are effective in achieving and maintaining near zero malaria burden en route to elimination?	What are the appropriate organization and management, skill mix, human resource structure, and enabling factors to support effective service delivery?	Tools for developing efficient decentralized decision making and administration	How do we engage private providers and capture their data?	How can private provider involvement in case management, surveillance and vector control be harnessed?
	—	—	—	How can district managers be supported to use the systems effectiveness framework and tools to remove bottlenecks in service delivery?	How can data for decision-making skills be taught such that responses to resurgences in malaria burden are swiftly responded to? [17] Tools for systems effectiveness framework
National level	What investment and tools will ensure the quality of governance and accountability required for malaria elimination? (Groups 2 and 3).	What experience is there of strengthening health worker motivation and performance through disease-specific programmes, especially looking at global elimination initiatives (positive synergies)?	What financial resources will be required to manage the certification process at subnational and national levels? (Groups 2 and 3).	What experience is there of strengthening health management information systems through disease-specific programmes, especially looking at global elimination initiatives (positive synergies)?	What is the cost-effectiveness of different delivery modes in different national/ subnational settings (e.g., community strategy versus facility, integrated curative services versus specialized, integrated vector management) malaria vector control; operations research on effect of scale on optimal organizational structures?

Table 2. Cont.

Level/Building Block	Governance	Human Resources	Financing	Information[a]	Service Delivery, Medicines, and Technology
	What governance structures are required to manage the elimination certification process?	—	What financing mechanisms are optimal at the national level to ensure a predictable and sustained flow of resources for malaria elimination? (Group 2)	—	What experience is there of strengthening service delivery and logistics/distribution chains through disease-specific programmes, especially looking at global elimination initiatives (positive synergies)?
	What experience is there of strengthening health system governance through disease-specific programmes, especially looking at global elimination initiatives (positive synergies).	—	—	—	—
	Tools to identify and evaluate possible interventions required in health system governance	—	—	—	—
Regional and global level	What are the determinants of successful intercountry collaboration on shared public health targets?	Tools: development of better regional training	—	—	What are the strengths and weaknesses of current malaria surveillance and case-management practices in endemic countries belonging to group 2?
Intersectoral level	Does the formulation of time-specific malaria elimination targets strengthen the participation of public and private stakeholders?	—	What are the macroeconomic benefits of malaria elimination? (Group 3)	—	What are the local geographic, economic, ecological, cultural determinants of malaria, and community and health system response? Includes operations research on service provision for mobile and marginalized populations
	—	—	—	—	What architecture and dynamics of complex intersectoral intervention strategies are required to achieve a major, sustainable, and cost-effective city-wide impact on persistent urban malaria?

Group 1, countries that are scaling up and entering the sustained control phase, where most of the population lives in areas where malaria elimination is considered impossible with existing tools; group 2, countries with focal malaria, where a large part of the population lives in malaria-free areas, and where health systems strengthening could play a crucial role in interrupting transmission in many but not necessarily all of the existing foci. These are often countries with very diverse and complex health systems challenges; group 3, elimination-ready countries. When a group of countries is not indicated, the text applies to group 1 and group 2 countries alike.
[a]Responsibility for these issues shared with malERA Monitoring, Evaluation, and Surveillance group.
IMAI, integrated management of adult and adolescent illness; IMCI, integrated management of childhood illness.
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should be, and the source of funding, how to use the health information system to measure performance, how to ensure that complementary inputs such as training and supplies are coordinated and sustained, and how to avoid the risk that incentives may distort targets and divert attention from nontargeted services. Research on health worker performance should be multidisciplin-

ary, therefore, and needs to recognize the complexity of possible interventions.

Research that focuses on developing new tools for assessing coverage, quality, and equity at the facility level that can be used to monitor health facility performance and analyze system effectiveness is also needed. Such tools are essential to identify

bottlenecks that may impede malaria elimination efforts. In the context of malaria elimination activities, the development of surveillance systems and the development of ways to monitor their performance require highest attention.

In some settings, a significant amount of treatment seeking for fever takes place outside public sector facilities, through private health providers, pharmacies, and shops. The engagement of such providers has mainly been done in limited malaria intervention projects rather than in programmes, and most of the literature concerns the pre-artemisinin-based combination therapy–rapid diagnostic test (ACT-RDT) era [32]. More research is therefore needed on approaches to quality assurance that will ensure that these facilities/providers adhere to guidelines [33], and are covered by systems for gathering surveillance data.

District Level

The district is the initial coordination hub for delivering services and commodities to people (through health facilities and community programmes). The district is therefore the focal point for priority setting, resource allocation, financial administration, supply chain management, accountability for health worker performance, engagement of the private sector, surveillance and response, and monitoring, evaluation, and information management.

Some of the critical bottlenecks in malaria-control operations currently stem from weaknesses at the district level for the above operations. These bottlenecks result in inequitable or irrational financial distribution, frequent stock-outs, poor-quality services, and inefficient disease-control operations. The enhancement of district-level system operations will therefore contribute significantly to reducing effectiveness losses for interventions, and increase the cost-effectiveness of programmes. Although there has been substantial investment in district-strengthening approaches and tools, these have not been as productive as they could be for a variety of reasons, such as insufficient decentralization and lack of information feedback. Innovations in information, communication, and decision-support tools (biometrics, bar coding, mobile phones and texting, computerized logistics systems, server-based data systems, among others) have the potential to improve district health systems in a cost-effective manner.

The systems challenges at the district level are common to group 1 and 2 countries. However, in group 1 countries they may be almost universal in rural areas, whereas in group 2 countries, systems challenges may only be considerable in the most malaria-endemic areas where deep poverty, difficult terrain, and various social barriers converge. Thus, district-strengthening efforts need to be more targeted in group 2 than in group 1 countries. Furthermore, in group 1 countries, the primary challenge is to enable the health system to achieve universal coverage of malaria-control interventions and to optimize their use (thereby reducing effectiveness losses), whereas in group 2 countries and in group 1 countries where the malaria burden has decreased, the challenge at the district level is increasingly to enable the system to respond to the technical demands of elimination. This challenge requires a greater focus on real-time information management and response and so, in these settings, research data that is relevant to developing decision-making skills will be critical.

National Level

Ultimately, the decision to embark on malaria elimination rests at the national level even if malaria elimination applies to only a region of the country. Such decisions must be based on operational and technical feasibility, as well as regional economic and political considerations [34].

Group 2 countries are more likely to have had some historical or more recent regional experiences with malaria elimination, and may see elimination as a "completeness exercise" or as an entry point to strengthening the systems response to address the health needs of neglected areas or population groups [35]. In some group 1 countries, elimination may be possible in specific areas. Generally, elimination targets for provinces, regions, or other administrative units that are highly developed and already close to malaria-free status may be sensible and justified from a regional viewpoint but of little importance from a national health perspective (e.g., Zanzibar in Tanzania, Goa in India). By contrast, national elimination targets—provided they are realistic—may provide strategic leverage for improving health equity at the national level.

The overriding research questions at the national level must be directed towards defining the best possible arrangements for governance, structural and functional organization between the system and malaria-specific programmes, and must be directed towards determining the implications of malaria elimination for cross-border political dialogue and arrangements with neighbouring countries. Models for financial sustainability also need to be established. These issues will be relevant in group 1, 2, and 3 countries, and through all the phases of disease control, elimination, certification, and prevention of reintroduction. An analytical review of past elimination programmes for other diseases—both successes and failures—with these questions in mind would be helpful. A recently published review provides useful information on interactions between global health initiatives and country health systems [36], but there are obvious differences between initiatives for reducing major disease burdens and elimination activities, which aim at small burdens.

Regional/Global Level

WHO recently revised its guidelines on malaria elimination and certification, emphasizing the need for regional intercountry collaboration [37]. In recent years, cross-border collaboration for malaria control has been inefficient in contrast to, for example, collaboration on polio elimination. Therefore, experiences from these successful intercountry collaborations and malaria-control initiatives should be mapped to provide a better evidence base for strengthening the intercountry collaboration needed to achieve national elimination targets.

An issue that will and should be addressed is subnational elimination. While any country is free to certify any area as malaria-free, WHO needs data on the achievement and maintenance of subnational areas of malaria elimination to develop guidance so that countries are spared the embarrassment of declaring an area malaria-free only to have transmission be detected soon after.

In addition, the current malaria surveillance and case-management practices of a sample of countries should be investigated and mapped by health systems research groups that are external to and independent of the malaria-control/elimination programme (see [21]).

Intersectoral Collaboration

The engagement of sectors other than health is sometimes but not always important for malaria control and elimination. The importance of intersectoral collaboration is determined by the extent to which other sectors are responsible for causing a local malaria problem through environmental change or population movement, and by whether a particular sector, such as education, plays a crucial role in achieving elimination. There is an extensive literature on the influence of development projects on malaria

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Box 3. Summary of the Research and Development Agenda for Health Systems and Operational Research

Overarching issue: Development and validation of a tool kit for the national and subnational level, comparable to rapid assessment procedures, allowing (i) effectiveness decay analysis for identifying bottlenecks for effective coverage of malaria interventions and (ii) decisions on the degree of integration of interventions into existing and strengthened health systems.

Priority health systems research questions:

- At the health facility level, how can health worker performance and compliance with best practice be monitored, enhanced, and sustained?
- At the district level, what are the factors impeding greater application of existing tools and approaches to district health system strengthening including surveillance?
- At the national level, what experience is there of strengthening health system components using disease-specific programmes?
- At the regional/global level, what are the strengths and weaknesses of current malaria surveillance and patient management practices in malaria-endemic countries and what are the likely determinants of success of inter-country collaboration for disease elimination?

These research questions need to be defined locally but are of relevance to all programmes engaged in control or elimination

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(e.g., [38]) and on integrating health considerations in programme planning (e.g., [39,40]). Serious difficulties can be expected where population movements related to natural and man-made disasters and conflict occur, in situations where "spontaneous" population movements related to traditional economies (for example, nomadism, transhumance) occur, and in urban areas where a multitude of actors make it difficult to identify the most important partners, where there is often less social cohesion, and where indoor residual spraying is often not possible.

Situations such as these have proven resilient to malaria control and elimination efforts over several decades. Mobile populations that are exposed to malaria, especially in or near forested areas in Latin America and South and Southeast Asia, often belong to ethnic minority groups and are subjected to various political and economic pressures. Interdisciplinary research (geographical, ecological, economic, social) and trials of different service delivery modes have proven useful in, for example, the Amazon, Thailand, and Vietnam [41–43]. Such research is needed in many more areas to validate for local adaptations of approaches in specific settings.

Urban malaria is a specific problem on the Indian subcontinent [44] where it needs to be investigated in all its dimensions from entomology to basic human ecology, and from household and industrial politics to local, municipal, and national level politics.

Concluding Remarks

In our discussions and in this article we have identified and characterized the major health systems needs relevant to the elimination of malaria and have articulated key research questions that need to be addressed at various health systems levels. In Box 3, we present the summary of the research and development agenda for health systems and operational research that resulted from our discussions. With malaria elimination on the agenda, one important, generic question needs to be addressed through health systems research. To what extent does an explicit target of malaria elimination motivate other sectors to participate in malaria control? If research evidence shows that such an explicit target is a potent motivator of other sectors, then ministries of health might be more inclined to be highly vocal and explicit about elimination targets and about the possible consequences of not meeting these targets.

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Author Contributions

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