Leveraging artificial intelligence to improve malaria epidemics' response

Potenciar a inteligência artificial para melhorar a resposta a epidemias de malária

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Resumo

À medida que se avança para a eliminação da malária, o paradigma de gestão deve mudar para abordar a deteção precoce de casos em áreas mais remotas. As áreas remotas enfrentam dificuldades adicionais na deteção e no tratamento que exigem abordagens inovadoras. A eliminação da malária precisa de tomada de decisão baseada em evidências com acesso em tempo-real aos dados de casos de malária. O esforço para a eliminação da malária criou várias bases-de-dados, frquentemente sem interoperabilidade, dificultando o uso dos dados. O acesso a alertas precoces pode promover a ação rápida dos decisores no envio de intervenções.

É necessário um sistema de informação abrangente, sustentável e integrado. Propomos uma estratégia de implementação colaborativa, combinando elementos de gamificação, Sistema de Informação Geográfica (SIG) e Inteligência Artificial para permitir alertas-precoces de deteção de risco de epidemias e apoiar o envoi de intervenções.

Estas tecnologias podem ser combinadas para reforçar a sustentabilidade da coleta de dados e a mudança comportamental dos decisores de saúde pública. O sucesso desse sistema depende principalmente de como as ações de eliminação serão melhoradas em configurações reais. A envolvência dos profissionais de saúde permite ajustar o desenho de um sistema que responda às necessidades dos profissionais.

Palavras Chave:
Eliminação da malária, inteligência artificial, implementação, informação de saúde, sistemas de apoio à decisão.

Abstract

As the world advances toward malaria elimination, the elimination management paradigm has to change to address early case detection in more local and remote areas. Remote areas face additional difficulties in both detection and treatment demanding innovative approaches. Malaria elimination needs evidence-based decision-making with real-time access to malaria-cases data. Years of endeavor towards malaria elimination have created several databases, which often lack interoperability, making the crossing of data difficult. The access to early alerts can promote decision-makers quick action in launching early interventions particularly in a low-resources settings.

Therefore, a smart, comprehensive, sustainable and integrated information system is required. We propose a collaborative-design implementation strategy, combining elements of gamification, Geographical Information System (GIS) and Artificial Intelligence (AI) to enable early-detection and risk of epidemics alerts, and to direct interventions around detected cases.

These technologies can be combined to further reinforce the sustainability of data collection and the behavioral change of public health decision-makers. The success of such a system depends mostly on how elimination actions will be improved in real settings. Therefore design-science research methodology could engage health professionals and use evidence-based knowledge in the design of an innovative system that responds to what public health professionals' real needs.

Key Words:
Malaria elimination, artificial intelligence, implementation, health information, decision-support system.

Introduction:

Malaria elimination had remarkable progress in recent years, but still far from the 2020 milestone of 40% reduction in incidence and mortality, according to WHO [1]. Therefore it is necessary to think differently towards a paradigm change.
The last World Malaria Report [1] reveals about 200 million new cases, worldwide in 2015, with an estimation of 430 thousand of life lost, mainly in the southern region of the World (90% in sub-Saharan-african countries). The global mortality rate has been decreasing but slowly, now at 29% on average, while 31% for WHO African Region [1]. The most successful malaria measures, such as the ones that increases diagnostic testing for children (reaching about 77%) and the administration of three doses, or more, of intermittent preventive treatment (IPTp) in pregnant women (31% in 2015, in African countries), or even the doubling of the use of insecticide-treated mosquito nets (ITNs), still lack in population coverage. These interventions have significantly contributed to malaria mortality reduction, especially among the more vulnerable population, the under 5 years-old children. This gave 5 years-old children a global life expectancy gain of 5% (12,3% for WHO African Region), from 2000 to 2015, with economic impact of about US$ 2040 billion (US$ 1810 billion in sub-Saharan Africa) [2].
Countries are still at different stages regarding malaria elimination. Between 2010 and 2015, the global malaria incidence rate decreased 21%, going faster in the WHO European Region (100%) and the WHO South-East Asia Region (54%) than in the WHO African Region (21%), together with the WHO Eastern Mediterranean Region (11%).
What are the factors behind this? Besides the deep asymmetries in healthcare access and socio-economic conditions (i.e. health determinants), among others, the parallel control programs and of epidemics-report systems gave rise to lack of global valuable information, an important barrier to efficiently tackle the problem and implement any quick intervention [2]. Remote areas face additional difficulties in both detection and treatment demanding innovative approaches [1].
To accomplish the sustainable development goal of ending the epidemics by 2030, measures should target the disease elimination at local and remote areas, and invest on preventive and control programs [2]. The dissemination factor could be more efficiently addressed, focusing on the elimination at the source, the reservoirs, with continued measures to prevent the re-establishment of transmission from mosquitoes to final hosts. Research and Development (R&D) allows the development of innovative prevention and control solutions to interrupt transmission and accelerate the elimination process.

As the world advances toward malaria elimination, the elimination management paradigm has to change to address early case detection in more local and remote areas. Remote areas face additional difficulties in both detection and treatment demanding innovative approaches.

The integration of health data for observatory and intervention purposes, using innovative web-based technologies is of major importance to achieve such goals. It allows the availability of evidence-based information, real-time. For example, WHO has been promoting a platform, the "District Health Information System" (DHIS2), that already centralizes health and diseases-specific data from more than 50 countries, including several ones on malaria programs [2]. However, most of the countries lack supporting organization to tackle the helath information integration's implementation. For instance, Namibia's case, which has about 67 different data sources and only 3 are integrated (including the DHIS2 system), meaning that this is still an ongoing process [3]. The lack of interoperability standards and integrative policy, the lack of qualified human resources or low levels of internet connectivity, among others, are main barriers to be overcome.
Malaria elimination needs evidence-based decision-making with real-time access to malaria cases data. Years of endeavor towards malaria elimination have created several databases. Unfortunately these database often lack interoperability making the use and the crossing of data difficult. The access to real-time alerts can promote decision-makers leadership and quick action in launching early interventions particularly in less-resources settings. The early detection in local and remote areas, and information integration for a faster response, are key.
Therefore, we aim at testing a collaborative process of design and implementation strategy, combining simple elements of gamification, Geographical Information System (GIS) and Artificial Intelligence (AI) to enable early-detection and risk of malaria epidemics alerts, and to direct interventions around detected cases. Our case will focus in a region of Angola.

Methods

A smart, comprehensive, sustainable and integrated information system is required to support this challenge. This study aims at improving malaria epidemics management through the use of artificial intelligence and other technologies power.
The collaborative design and implementation strategy combines simple elements of Gamification, Geographical Information System (GIS) and Artificial Intelligence (AI). This solution enables epidemics situations early-detection

and risk-alerts (e.g. combining actual patterns of malaria with both previous patterns and Centers for Disease Control and Prevention (CDC) heuristic-based alerts), and allowing to direct control interventions around detected cases and outbreaks. Combing both GIS/DHIS2 and AI will enable real-time forecasts, provind the possibility for helping improve malaria interventions response time, hopefully anticipating and preventing the spread of new cases. Combined together, these technologies have the potential to strengthen the sustainability of data collection processes, giving support to decision-makers and fomenting the behavior change of public health decision-makers in malaria risk management.

It is a fact that healthcare services need to be responsive to epidemics, where a prompt and effective action will make the difference. The smart malaria elimination tool can facilitate malaria elimination needs identification and support evidence-based decision-making, through real-time access to data. This will also enable the creation of bigger databases from which one can learn and improve the response procedures.

The smart-surveillance information system (SSIS) tool is designed, developed and implemented using the Design Science Research Methodology (DSRM) framework [4]. This method ensures the adjustment to the public health context. Through a collaborative and participatory process teamwork is strongly promoted (e.g. between epidemiologists and information systems experts), aiming at solving organizational problems by creating and evaluating a shared and integrated information system. It depends on the dedicated collaboration and contributions of healthcare professionals (HP), including technicians and administrative staff, as well as from top management commitment. The DSRM establishes the base for the artefact construction process following six sequential steps [5]. Together with the HP, the researchers set-up priorities, define objectives for the solution (e.g. the alerts required), pre-select important and necessary data, identifying its sources' systems, etc. The designed system will be finnaly implemented and demonstrated in the field (Bengo region, in Angola), being submitted to constant evaluation, with results communication, in form of constant profiling and reporting.

Results and discussion

The DSRM first steps ask for the understanding of the problem, identifying possible solutions. Only then, we can advance to the next steps for implementation. The benchmarking and learnt lessons with prior technology innovations are also relevant.

A Public Health Information System has started (with both problem identification and solution obejctives definition) to be developed and will be tested in Bengo – Angola. From the first step (problem identification) there were some identified difficulties to the tool implementation process. Currently malaria data still is recorded in basic text and calculation Excel sheets, and so it is feebly consolidated, only enabling the production of simple and basic graphics. There is the opportunity to address these issues altogether, with the development of a the smart-surveillance information system (SSIS), which should integrate the following functionalities:

1) (Malaria) epidemiological surveillance: suspected by confirmed cases; total severe cases by mortality;
2) Entomological features, for the vector control, as entomological inoculation index;
3) Epidemics risk alerts;
4) Logistics: medicine stock and mosquito nets control and management, including received and distributed material.

Supporting the idea of creating the SSIS system that actually address an intervention for epidemics surveillance and management, in malaria elimination programs, the solution design could benefit from previous experiences.

The Design Science Research Methodology, have been used to implement several tools in Global Health and Tropical Medicine, involving several healthcare innovation systems, such as HAITooL, OSYRISH, and ePharmaCare, among others, always under collaborative processes, following best-practices and helping to go further through optimization for each of the cases.

HAITooL is an decision-support information system to help preventing and controling hospital infections and antibiotic prescription and resistance. Implemented in two hospitals as a participatory process, each of the two teams worked together with the researchers in the design-science research process, in order to co-design and implement an effective surveillance and decision-support system, adapted to both hospitals clinical processesa and socio-cultural context [6]. As a decision-support system, HAITool uses smart algorithms to displays alerts, for example for an excessive antimicrobial therapy duration or if antimicrobial therapy is not in accordance with microbiology results, among others. The system presents an integrated views of patient, microbiology and pharmacy data, displayed in innovative layouts and graphics, allows the visualization of patient clinical evolution, antibiotic consumption trends, antibiotic resistant infections indicators and patterns. Information turns to be easy and clear for the professional use [7].

OSYRISH is a decision-supporting information system to help nurses improve hand hygiene in order to reduce healthcare-acquired infections. It includes an indoor location technology and a gamification applica-

tion applied at the nursing ward level, in order to raise awareness, at real-time, regarding hand hygiene compliance, individual behavior change and performance optimization. The gamification solution aims at collecting data from nurses procedures, provides real-time accurate feedback to the nurses (the information is shown in a screen at the nursing office). Involving nurses in the design process of aligning the combined automated monitoring systems with gamification with the nursing processes, allowed a better understanding of their needs and of the barriers facing nursing work at the ward [8].

ePharmaCare is a decision-supporting system to collaboratively manage medicine prescription and patient informations in community pharmacies linked with online patients. The systems supports an online pharmaceutical service, implemented to bring the pharmacist closer to the patient for medicine follow-up services (e.g. quick identification of adverse events or the need for a new prescription), valued by both [9]. Pharmacists' lack of time, improper time management and incurrect information systems usage skills were the main barriers for the full system adoption. Training, communication with online patients and pharmacy services reorganization are critical to ensure the correct implementation of the service [10].

The use of decision-making algorithms is essential to enable quick a proper use of the information for decision-making. In these cases, the algorithms were designed in close collaboration between researchers and healthcare professionals and leveraging evidence-based rules. The use of machine-learning is another level of smart-decision-making, which will enable the delivery of predictive models that can provide important information to help urgent decision-making. Using machine-learning generated epidemic patterns, the system will be able to combine different data and issue an early epidemics alert. The system's algorithms could integrate national and international guidelines, norms and laws, as another layer of possible analysis and guided action.

The system could provide valuable forecast capabilities and use cognitive computing to detect patterns associated with malaria epidemics (e.g. by using IBM-Watson Discovery Advisor functionalities) providing the right context to smooth quick decision-making. This capability needs to be comprehensively tested and its accuracy properly measured (and corrected if necessary). The systems requires as much as possible previous epidemics situations in order to learn and be prepared to new cases.

Information visualization models are also very important. When new technology innovations are combined, and assigning new features to a system, it allows a refining of the information, as well as a better performance is expected. Timely reporting malaria cases is key, but it is currently very fragile. It often depends on the professional's availability and motivation. Hence, healthcare people may benefit from improved working processes and extra motivation to improve the case reporting.

The use of gamification (e.g., adapting tasks into the form of a game to engage professional into improved performance) could be particularly useful to improve data entry quality since it depends on the full attention the healthcare professional. Basic gamification functionalities can be applied collaboratively with users to encourage both ownership and behavior change, improved resilience and awareness of the time-lapse from information reception to action. It even can be linked to a more transparent quality supported incentive program in a ltter stage of the implementation. In the same line, a "nudging technique" performance could help guiding the professionals throughout the prevention and control procedures, like in the OSYRISH project, to promote nurses' hand hygiene compliance self-awareness and action.

The system's approach to implementation should strengthen the availability of information, its integration process as well as the decision-makers capacity to act accordingly. The collaboration process is fundamental to establish a responsibility model so that they can address regular quality processes improvement. The HP should lead the construction of the system as they will be using it, in real-time, for decision-making, assuring it offers both safety and accurate procedures [11]. The collaborative design process enables the alignment with malaria elimination decision-making processes. It also should allow to validade the confidence in making decisions and if the system is an effective anchor to reduce malaria at the end of the day.

Machine-learning systems are still not mature but improving. The success of such a system depends on the number of previous cases and on how elimination actions will be improved in real settings (i.e. if the systems output are truly valuable to improve decision-making). The organizational aspects are critical, since the system only works if people are trainned and ready to use it. Therefore, co-designed science research methodology is a valuable to both engage health professionals and use evidence-based knowledge in the design of innovative systems that are designed to properly respond to what specific public health professionals need. Additionally, using a Lean approach, involving both management and health practitioners, it will provide the understanding wheather if the working processes are effectively delivering as promised, therefore benefiting the organization by eliminating waste directly related to information access, treatment and analysis, for example, reducing information errors or improving on quality of data presentation [12].

Conclusions

Smart public health information systems, like SSIS, are tools that will take public health into the future. It can actually address the goal of real-time epidemics surveillance and management as an intervention in elimination programs require.
Combing smart systems based on artificial intelligence and geographic information, with a well-designed set of features for better information analysis and visualization, it allows the follow-up of epidemics, screening and highlighting the priority cases and even simulating future scenarios (e.g. for training epidemiologists), based on past and actual data. Interactive layouts and basic gamification functionalities can be applied to engage and motivate users, while facilitating the adoption of the new innovative solution (because HP participated actively in developing it). A participatory process is an important driver to encourage behavior change, improved resilience and awareness of the time-lapse from information collection to action.

The system is going to be tested using IBM Watson Discovery Advisor functionalities, hopefully providing the right framework to facilitate quick decision-making and effectively reducting malaria cases.

Acknowledgements

We would like to acknowledge and thanks the valuable discussions with Prof. João Pinto and Dr. César Capinha from GHTM. We also thanks the collaboration with IBM Portugal and IBM Angola. The authors would like to thanks the support of the Global Health and Tropical Medicine research center, GHTM – UID/Multi/04413/2013. This support and the individual grants from Fundação para a Ciência e Tecnologia to Mélanie Maia are gratefully acknowledged.

Conflict of interests statement:

No conflits of interest for disclosure.

References

1. WHO. World malaria report 2016. Genève: World Health Organization; 2017.

2. UN. United Nations - The Sustainable Development Goals Report 2017. 2017.

3. Dlodlo N, Hamunyela S. The Status of Integration of Health Information Systems in Namibia. Electron J Inf Syst Eval 2017;20.

4. Peffers K, Tuunanen T, Rothenberger MA, Chatterjee S. A Design Science Research Methodology for Information Systems Research. J Manag Inf Syst 2007;24:45–77. doi:10.2753/MIS0742-1222240302.

[5. Simões AS, Maia MR, Gregório J, Lapão LV. Implementing effective antibiotic stewardship programs throughout a collaborative process between healthcare workers and researchers. Antimicrob. Resist. Infect. Control, vol. 6(Suppl 3):P310, Geneva, Switzerland: BioMed Central; 2017.

6. Simões AS, Alves DA, Gregório J, Couto I, Dias S, Póvoa P, et al. Fighting antibiotic resistance in Portuguese Hospitals: understanding antibiotic prescription behaviors to better design antibiotic stewardship programs. J Glob Antimicrob Resist 2018. doi:10.1016/j.jgar.2018.01.013.

7. Simões AS, Couto I, Toscano C, Gonçalves E, Póvoa P, Viveiros M, et al. Prevention and Control of Antimicrobial Resistant Healthcare-Associated Infections: The Microbiology Laboratory Rocks! Front Microbiol 2016;7:855. doi:10.3389/fmicb.2016.00855.

8. Marques R, Gregório J, Pinheiro F, Póvoa P, da Silva MM, Lapão LV. How can information systems provide support to nurses' hand hygiene performance? Using gamification and indoor location to improve hand hygiene awareness and reduce hospital infections. BMC Med Inform Decis Mak 2017;17. doi:10.1186/s12911-017-0410-z.

9. Gregório J, Pizarro Â, Cavaco A, Wipfli R, Lovis C, Mira da Silva M, et al. Online Pharmaceutical Care Provision: Full-Implementation of an eHealth Service Using Design Science Research. Stud Health Technol Inform 2015:261–265. doi:10.3233/978-1-61499-512-8-261.

10. Lapão LV, da Silva MM, Gregório J. Implementing an online pharmaceutical service using design science research. BMC Med Inform Decis Mak 2017;17. doi:10.1186/s12911-017-0428-2.

11. Campbell J, Dussault G, Buchan J, Pozo-Martin F, Guerra Arias M, Leone C, et al. A universal truth: no health without a workforce. Forum Report, Third Global Forum on Human Resources for Health, Recife, Brazil. Geneva: Global Health Workforce Alliance and World Health Organization.; 2013.

12. Lapão LV. Lean in the Health Management: An opportunity to improve focus on the patient, respect for professionals and quality in the health services. Acta Médica Port 2016;29:237. doi:10.20344/amp.6615.