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Preventing the re-establishment of malaria during the COVID-19 pandemic in Sri Lanka: implications for health security

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Abstract

Background The COVID-19 pandemic—with its first reported case in Sri Lanka in March 2020—had the potential to impact the risk of re-establishing malaria, a disease which was eliminated from Sri Lanka in 2012. Post-elimination, the country remains highly vulnerable to a return of malaria on account of high vector mosquito densities and the inflow of imported malaria cases.

Methods Parallels between COVID-19 and malaria after its elimination as health security threats were drawn, and the many ways in which the COVID-19 pandemic impacted the prevention of re-establishment of malaria programmes in the country in 2020 were examined. The implications of this experience for global health security are analysed.

Results In 2020, imported malaria cases were fewer than in the previous 3 years, due to restrictions on international travel. Yet, a high level of malaria case and entomological surveillance was sustained through surveillance strategies modified to focus on quarantine centers, in response to the pandemic. As a result, more imported malaria cases were detected by active case detection than by passive surveillance. Some of the operational shifts adopted by the Anti Malaria Campaign were moving rapidly into functioning as an intersectoral player by reinforcing its collaborations with the Ministries of Aviation and Defense, switching to the use of online communication systems, and integrating and synergizing its field activities with the COVID-19 control programme.

Conclusions The experience highlights the need for disease control programmes to be agile, flexible and responsive, and underscores the importance of maintaining even a lean focal programme for diseases such as malaria after they have been eliminated. Sustaining public health leadership and robust technological capacities in communication and data management were paramount in preventing the disruption of the malaria prevention programme during the pandemic and sustaining the malaria-free status of the country.

Keywords Malaria, Prevention of re-establishment, COVID-19, Sri Lanka, Health security

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Background

Sri Lanka eliminated malaria, reporting the last case of indigenous malaria in 2012, and received certification by the World Health Organization (WHO) in 2016 [1]. Due to the high prevalence of malaria vectors in the country and a steady inflow of imported malaria cases, the country remains at a very high risk of malaria being re-established [2]. Therefore, a rigorous programme to prevent the re-establishment of malaria is being conducted by the Anti Malaria Campaign (AMC), which is a special programme within the Ministry of Health. Post-elimination, Sri Lanka has remained free of indigenous malaria except for a case of introduced malaria (infection transmitted locally from an imported case) in 2018 [3] and a case of transfusion-induced-malaria in 2021 [4].

In 2020, the COVID-19 pandemic caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) and its devastating impact worldwide raised acute awareness of the need for enhanced global health security. Only two decades ago, malaria in Sri Lanka was a major part of the unfinished agenda of infectious disease elimination, but now, after its elimination in 2012, it is a disease at risk of being re-established through importation. Thus, the Prevention of Re-establishment (PoR) of malaria programme is itself reliant on effective health security [5]. It constitutes a parallel example to COVID-19 in the current global discussions on health security [6]. Furthermore, the COVID-19 pandemic also had the potential to impact on the PoR programme for malaria in Sri Lanka in many and diverse ways. Restriction of human movement due to country and area lockdowns and curfews being imposed from time to time; the possibility of having human and financial resources moved away from malaria for COVID-19 control; and the potential of the global pandemic to interfere with procurement of essential commodities were some of the ways in which the malaria PoR programme could have been compromised [7]. However, the COVID-19 pandemic may have also led to a reduction in risk of malaria importation to the country on account of airport closures and restrictions on the arrival of people to the country, which is the principal route of population movement and parasite introduction.

This paper addresses how these complex processes played out, and the resulting impact of the COVID-19 pandemic on the malaria PoR programme in Sri Lanka. It reports on how innovation and adaptation on the part of the AMC and its Regional Malaria Offices (RMOs) kept the country malaria-free amidst the pandemic despite importation of malaria. It also analyses the elements of health security essential to deal with global health threats based on Sri Lanka's experience with COVID-19 and malaria.

Methods

COVID-19 surveillance data

COVID-19 data were obtained from the Ministry of Health, Sri Lanka. All reported cases in Sri Lanka during the period of the study, March to December 2020, were based on reported COVID-19 cases.

Malaria data

Malaria data from January 2017–December 2020 were sourced from the databases of the AMC, which record confirmed malaria cases and the mode and place of detection. The details of the AMC's operations, including district level data and the collaborations of the AMC with other sectors and departments within other ministries were captured in the AMC records which are updated every month over time.

Malaria case surveillance

A cornerstone of the PoR strategy in Sri Lanka is case and entomological surveillance and response. Case surveillance is based on three strategies: passive case detection (PCD), reactive case detection (RACD) and proactive case detection (PACD) [8]. PCD is the detection of cases when patients present on their own accord to the health care system with symptoms suggestive of malaria and are screened for malaria by the attending health worker. RACD is the screening of high-risk individuals and groups prompted by an index case (e.g., those living in the same neighborhood or travel companions of an index case of malaria). PACD is defined as the screening of known high-risk groups, unrelated to an index case of malaria.

Entomological surveillance for malaria

As an integral component of the PoR strategy, the AMC routinely conducts several entomological surveillance operations as follows: (1) at pre-determined sentinel sites, (2) by way of proactive surveillance operations at selected sites deemed to be at high risk, and (3) reactive surveillance when a case of malaria is detected, in areas surrounding the residence of and places inhabited by the patient [9].

Results

The COVID-19 epidemic in Sri Lanka

The COVID-19 epidemic in Sri Lanka which began in March 2020 was well controlled until end-September of that year. With the exception of three clusters which led to spikes of cases in April, May and July, all of which were effectively controlled, the daily incidence of new cases of COVID-19 was kept well below 100 in the population of 21 million (Fig. 1) [10]. This was achieved through testing, stringent contact tracing and quarantining, implemented

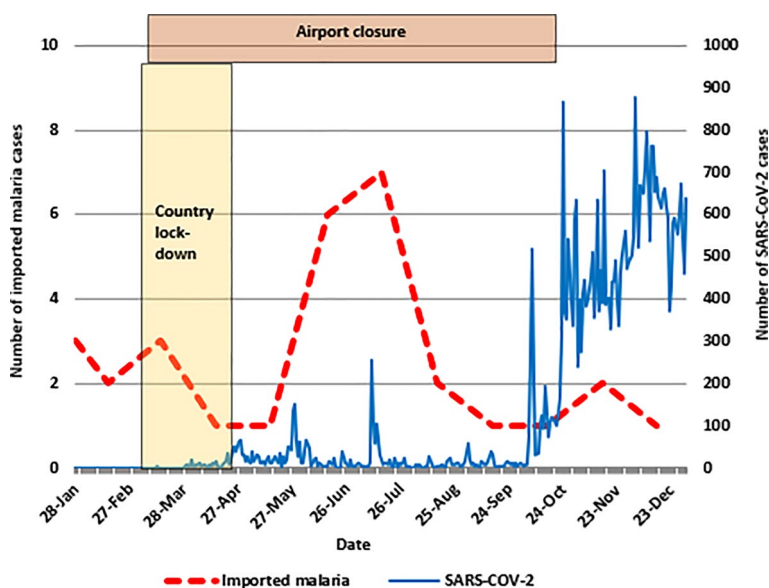


Fig. 1 Imported malaria and COVID-19 incidence, 2020

through a close collaboration between the Ministries of Health and Defense, combined with the mandatory wearing of face masks, social distancing and strict personal hygiene, which remained enforced throughout 2020 [11]. A countrywide lockdown was imposed on 20th March and lasted until 27th April when it was lifted in some of the COVID-19-free districts, but in others the lockdown continued until 4th May 2020 [11]. The two international airports in the country were closed for incoming flights from 17th March 2020 except for flights bringing Sri Lankan nationals who had been stranded overseas [12]. The airport remained closed for regular international traffic up to about middle of October after which limited travel was permitted for organized tourism—an experiment in which a “bubble” concept was applied to small groups of tourists who were allowed to enter the country for a controlled passage of tours under strict surveillance [13]. Although organized tourism was not a success, the airports were opened for normal traffic in January 2021.

Until September 2020, as much as a third of COVID-19 cases were reported among arrivals to the country from overseas, both foreigners and Sri Lankan repatriates. At the end of September 2020, a large outbreak of COVID-19 among factory workers saw the beginning of a rapid and sustained increase of cases, which was less responsive to the rigorous control measures that were being applied [10]. The COVID-19 epidemic worsened in early October 2020, leading to case numbers doubling every month during the last 3 months of the year and peaking at a daily incidence of over 600 cases per day and remained so up to the end of the study period

(Fig. 1). As of 31st December 2020, a total of 42,702 cases of COVID-19 were reported from 1,250,417 real-time PCR tests. During the last 3 months of the year, 95% of reported COVID-19 cases were in resident Sri Lankan nationals, indicating massive community spread [10].

Only thirteen deaths due to COVID-19 were reported up to 14th October 2020. However, since then, in the face of the heightened epidemic, COVID-19 deaths as well as the case fatality rate began to increase. A total of 199 COVID-19 deaths were reported through the end of December 2020.

Malaria during the COVID-19 pandemic in 2020

All malaria cases reported in 2020 were imported, as they were in almost all previous years since malaria was eliminated in 2012. The number of imported malaria cases was lower in 2020 than in previous years, at 30 total cases compared to the 3-year period 2017–2019, when 57, 48 and 53 cases, respectively, were reported (Table 1).

The number of overseas arrivals in the country in 2020 (1.1 million) was reduced to about a fifth of that of the three previous years 2017–2019 (average 5.1 million per year) (Table 1). Of the arrivals in 2020, at least 5790 (0.52%) were known to have arrived from malaria endemic countries, and 95% of those who came from malaria endemic countries were Sri Lankan nationals who returned home due to the COVID-19 pandemic.

Although imported malaria case numbers fluctuated monthly over the past few years (2017–2019) there has been a general trend of higher cases during the first and last few months of the year, corresponding to the peak of

Table 1 Imported malaria cases 2017–2020

Year	Number of arrivals by air	Number of imported malaria cases	Proportion (%) of imported malaria cases	
			From Africa/India ^a	Sri Lankan nationals
2017	4,970,549	57	56/37	68
2018	5,409,587	47	62/36	70
2019	4,930,455	53	59/34	83
Pre-covid average	5,103,530	52	59/36	74
2020	1,124,393	30	73/17	87

^a This column does not add up to 100 because there were cases acquired in other continents/countries

travel for holidays and return of Sri Lankans employed overseas (Fig. 2). This trend was not evident in 2020; instead, a spike of cases was seen in June and July, corresponding to the peak in repatriation of Sri Lankans living overseas owing to the COVID-19 pandemic (Fig. 2).

Findings on malaria PoR operations during the COVID-19 epidemic

Malaria case surveillance

From the beginning of the COVID-19 epidemic, working arrangements were made between the AMC and the Ministries of Defence, Airports and Aviation, and Foreign Affairs which coordinated the arrival of passengers, including repatriates, to the country and arranged for quarantine and COVID-19 testing. Screening incoming travelers from malaria endemic countries while they were in quarantine centers was made possible through a well-coordinated arrangement between many sectors: the military operations center, which was in charge of repatriation, informed the AMC of all incoming flights and their passenger lists, where they were coming from and when they were arriving, as well as the location of the centers where incoming passengers were to be quarantined. The AMC then informed the RMOs of the relevant districts to which passengers would be transferred to quarantine centers, providing them with passenger lists well in advance. Thereafter, the RMOs arranged the screening of those passengers arriving from malaria endemic countries whilst in quarantine in their district.

From March 2020 onwards, the screening of all persons arriving in the country from malaria endemic countries was performed routinely on day 10 of quarantine, irrespective of their having symptoms or not. The collection

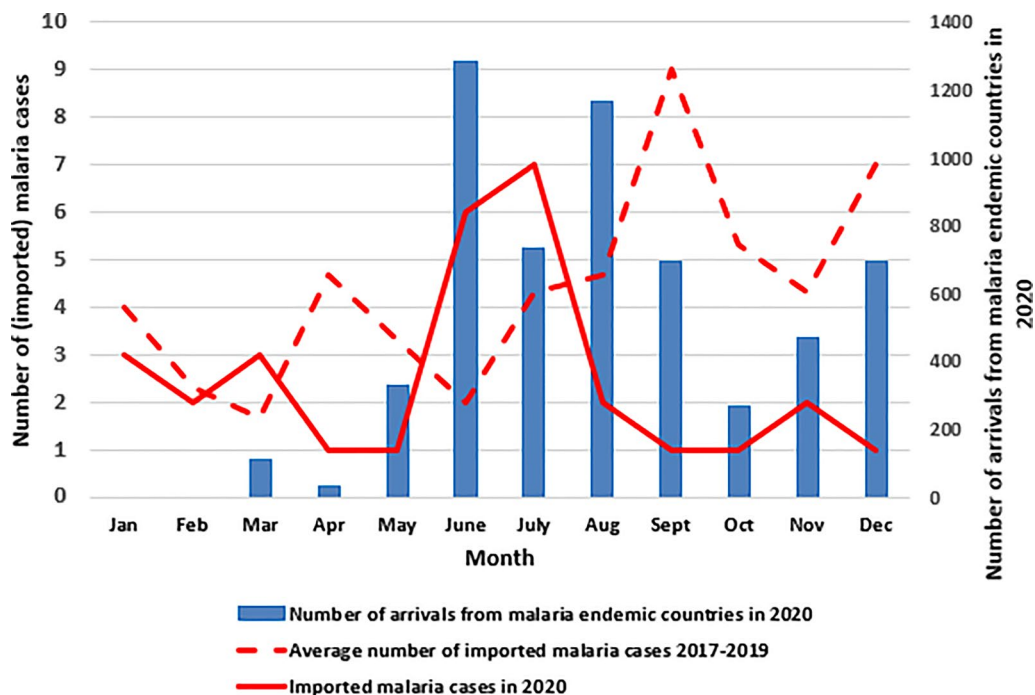


Fig. 2 Imported malaria incidence before (2017–2019) and during the COVID-19 pandemic (2020) in relation to arrivals from malaria endemic countries in 2020

of blood samples for malaria microscopy was synchronized with that for COVID-19 testing by working closely with the appropriate unit within the Ministry of Health. If any person developed fever whilst in quarantine (s) he was promptly screened for malaria in co-ordination with the COVID-19 testing programme. After the 14-day quarantine period, when people returned to their residences, they were all screened for malaria at 3, 6 and 12 months after arrival regardless of symptoms, and were advised to report to the nearest hospital (where microscopy facilities were available) if they developed symptoms of malaria.

Eighty percent of those who returned from malaria endemic countries in 2020 (n=4609) were screened for malaria within a week following their arrival. This included screening of 173 Air Force personnel returning from United Nations Peacekeeping Missions in the Central African Republic and South Sudan. The total

number of blood smears screened for malaria by all three case surveillance strategies in 2020 (n=383,922) was significantly lower than in the previous 3 years (average 691,700) (Table 2).

In 2020, 63% of imported malaria cases were detected by PCD, 33% by PACD and 3.3% of cases by RACD. In previous years, a vast majority of cases were detected by PCD: 98%, 100% and 89% of cases in 2017, 2018 and 2019, respectively. Over the same 3-year period, PACD and RACD contributed very little to the detection of imported malaria cases, with, on average, 1.9% and 2.5% of malaria cases detected by PACD and RACD, respectively [8]. Of the 30 imported malaria cases diagnosed and treated during 2020, a third (n=10; 33%) were detected through screening of arrivals from malaria endemic countries while they were in quarantine centers by PACD.

The proportions of blood smears collected for screening by the different case detection strategies did not change much in 2020 compared to previous years (Table 2; Fig. 3). Therefore, the yield of positives from PACD was very much higher in 2020 compared to that in previous years.

The ways in which malaria operations and the work of the AMC were modified during the COVID-19 epidemic and adapted to the new conditions and restrictions, and their implications and impact are summarized in Table 3.

Malaria case management

The malaria case management procedures were also adapted to the new conditions imposed by the COVID-19 epidemic. In Sri Lanka, all confirmed malaria cases are routinely managed as in-ward hospital patients [14]. In 2020, malaria patients were admitted and managed in isolated hospital wards until a concomitant COVID-19

Table 2 Outcomes of case surveillance strategies 2017–2020

Year		No. of blood smears by each case surveillance strategy			
		PCD ^a	RACD ^b	PACD ^c	Total
2017	Positive	56	1	0	57
	Examined	289,495	3085	373,745	666,325
2018	Positive	48	0	0	48
	Examined	298,072	10,509	375,045	683,626
2019	Positive	47	3	3	53
	Examined	352,313	22,248	350,588	725,149
2020	Positive	19	1	10	30
	Examined	209,418	7869	166,635	383,922

^a PCD refers to passive case detection

^b RACD refers to reactive case detection

^c PACD refers to proactive case detection

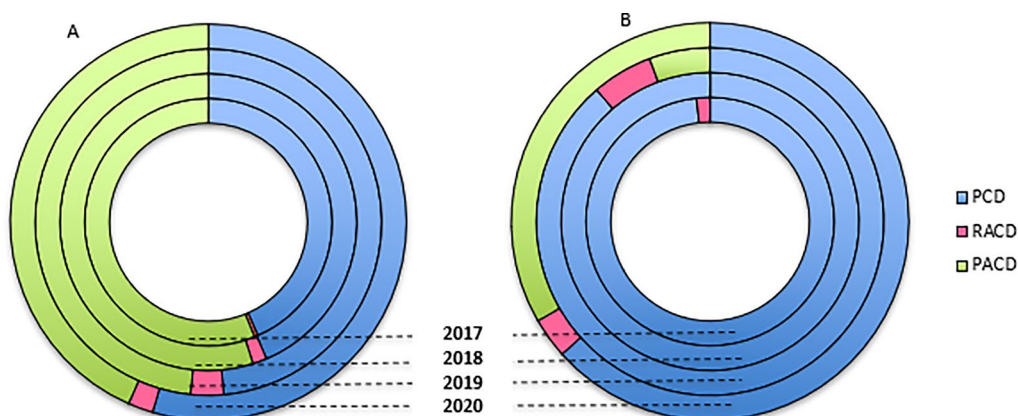


Fig. 3 Proportion of **A** blood films/examined microscopically and **B** malaria cases detected, by each of the case surveillance strategies by year

Table 3 How AMC's plan of action was affected

Activity	How modified	Reasons	Impact
Active case detection	Proactive case surveillance shifted focus markedly from resident high-risk populations to screening of persons arriving from overseas while being in quarantine centres.	Inability of staff to conduct population screening due to lockdown of areas. The at-risk population for imported malaria were new arrivals from endemic countries now captive in quarantine centres.	Although the total number of malaria screenings were reduced, active case detection (both proactive and reactive) was, overall, not compromised. The yield of detection was higher from PACD and RACD due to screening being more focused.
Passive case detection	The proportion of malaria patients detected through PCD dropped to 63% compared to over 89–100% in previous years.	Due to patients not seeking or delaying seeking healthcare for fever. A true reduction in the incidence of malaria infections on account of reduced numbers entering the country. Most infections being detected by PACD in quarantine centres.	PCD services were somewhat compromised, but this would not have led to delays in diagnosis or failure to diagnose imported malaria because active case detection substituted for PCD.
Case management of diagnosed patients	Continued unchanged, with patient management and follow-up performed as usual adhering to COVID-19 guidelines.	The health system and the AMC continued to function under new conditions.	No adverse impact.
Entomological surveillance	Routine entomological surveillance at sentinel sites greatly reduced. Entomological screening around quarantine centres was newly introduced. Reactive entomological screening continued. Conducted as required.	The total number of entomological operations were reduced due to restricted movement of staff during area or country lockdowns.	Difficult to assess, but absence of local transmission during 2020 testifies to entomology surveillance and response being adequate.
Vector control in relation to malaria cases			Difficult to assess, but absence of local transmission during 2020 testifies to entomology surveillance and response being adequate.
Regular AMC review meetings with RMOs	Monthly review meetings of the AMC, RMOs and partners continued without interruption, shifting from in-person to virtual meetings. Co-ordination of PoR activities worldwide moved to using online communication apps.	Travel of RMOs to Colombo was restricted. Social distancing rules discouraged in-person meetings.	Under the circumstances, co-ordination of work was satisfactory.
AMC supervision visits to the districts	Greatly reduced. However, several new electronic platforms were created for data sharing, including dashboards for presenting data in all areas of PoR activities.	Travel restrictions and social distancing requirements precluded in-person meetings. Time spent on travel was used to develop several new, very effective data sharing platforms.	May have had a negative impact on quality of services due to reduced supervisory visits. Improved data sharing mechanisms were a positive development.
Training programmes	Microscopy training, national competency assessments for microscopy, and other training programmes reduced significantly in number. A new outbreak response simulation exercise was conducted for all staff, moving the venue to an area which was not affected by COVID-19.	Inability to conduct in-person training programmes due to social distancing rules, but some were conducted as distance programmes online.	Quality of services may have been affected. However, absence of local transmission suggests no adverse impact.
AMC mid-term external review	Conducted as planned with an international consultant through virtual means and local members of the team conducting the review as planned.	Due to restrictions on international travel, and in-country movement.	Mid-term external review may have been of poorer quality and its impact may have been less than previous reviews.

Table 3 (continued)

Activity	How modified	Reasons	Impact
Budget allocation to AMC	No changes were made to the AMC budget.	Funding of COVID-19 control was not at the expense of the malaria PoR programme.	No change in funding status. In fact, the AMC fund utilization was higher.
Human resources	No major change in human resource strength of AMC or the Provincial Ministries of Health over and above the routine transfers of staff. AMC staff were not deployed for COVID-19 control except for a few short-term temporary deployments for COVID-19 activities (e.g., PCR testing in airports).	AMC being a specialized unit within the MoH, and the fact that malaria PoR is given priority.	No adverse impact.
Intersectoral coordination and collaboration	Effective collaboration with the Ministry of Defence, Airports and Aviation Authority and with other Departments within the MoH greatly increased.	Because most of the malaria PoR operations had to depend on coordinated approaches on incoming arrivals to the country.	Major positive impact on account of successfully detecting and responding to imported malaria cases.

infection was excluded in the patient. They were screened daily to monitor the malaria blood infection in response to treatment using EDTA blood samples. Patient management was reviewed online by the AMC with regional (district) teams on the ground.

In 2020, all malaria patients were followed up as routinely done in previous years—i.e., microscopy screening on days 7, 14, 21, 28 and 42 for all species, and additionally once a month for 12 months for *Plasmodium vivax* and *Plasmodium ovale* infections [15]. All blood screenings for malaria were conducted strictly in accordance with the guidelines for case management of the AMC [14] and conforming to the safety guidelines for the COVID-19 epidemic [7].

Entomological surveillance

In 2020, entomological surveillance operations were affected by the COVID-19 epidemic owing to restrictions imposed on human movement during area lockdowns and also community resistance to the presence of healthcare workers visiting the area. In total, there were fewer entomological surveillance operations performed in 2020 (n=1184) compared to the previous year 2019 (n=2039) (Fig. 4). The relative proportions of the different types of surveillance operations remained the same as the previous year (Fig. 5). One major change in 2020 was, however, that the proactive surveillance operations were rapidly moved to the areas surrounding the quarantine centers which (a) housed passengers arriving from malaria endemic countries, and (b) were located in previously malaria endemic regions of the country. This was based on the assumption that quarantine centers were the most likely places to locate malaria infected persons and that previously malarious areas were most receptive to malaria transmission [16]. In previous years, site selection for proactive entomological surveillance operations was based on geographical areas in which high-risk individuals, such as foreign labourers and other returnees from overseas resided [9].

Training, supervision, advocacy and advisory mechanisms

Every year, the AMC conducts several training programmes for its own technical and field staff and for technical staff of other institutions such as the private health sector and the military. These events were greatly reduced in number owing to the COVID-19 pandemic control guidelines issued by the Ministry of Health. Of 15 microscopy training events for Public Health Laboratory Technicians scheduled in 2020, only six were conducted. Of 10 such programmes scheduled for the private health sector free-of-charge in 2020, only two were conducted. The External Competency Assessments for malaria microscopy conducted within

the WHO Southeast Asia Regional Office's validation programme had to be postponed to 2021. Several of the training programmes conducted in 2020 were carried out as distance-programmes online. Routine supervisory visits by AMC and RMO staff to the various hospitals and field sites throughout 2020 were cancelled owing to travel restrictions.

A new event—a simulation exercise on malaria outbreak response—was carried out for staff in 2020 by the AMC in collaboration with the Disaster Management Unit of the Ministry of Health. The event was held in a venue in a previously malaria endemic district which was not, at the time, affected by COVID-19.

To ensure that malaria is not a forgotten disease, particularly by the medical profession, several advocacy events are conducted every year as part of AMC's communications programmes. These include visits to Government hospitals in the provinces, making presentations at clinical meetings, and events organized by the Medical Associations. These activities were minimized in 2020. Instead, tele-messaging using Short Message Service through a telecommunications network, was increasingly used as a means of communication with clinicians.

Communication groups were created using internet-based messaging apps, such as WhatsApp, to exchange vital information on most activities in real time among AMC headquarters staff and RMOs, including members of the Technical Support Group (a group of independent experts advising the AMC) [17]. Monthly review meetings of the AMC with all RMOs and meetings of the Case Review Committee (a group of experts that reviews all malaria cases diagnosed by the AMC in the previous month) were conducted without interruption using cloud-based video conferencing systems.

During country- and district-level lockdowns, the AMC had to work with less than the full cadre of staff because travel was restricted. A roster system was introduced for staff, providing transport for them to come to work and to carry out field work. Staff were provided with personal protective equipment as appropriate, and all work was carried out according to the COVID-19 control guidelines provided by the Ministry of Health [18, 19].

AMC developed interim guidelines for surveillance operations in 2020 in accordance with preventive and precautionary measures for COVID-19 and consistent with the country's COVID-19 control guidelines [16, 20, 21]. When working conditions became very restricted, such as during the months of April and May when the entire country was in lockdown, the AMC prioritized essential work and ensured that commodities—medicines, diagnostics and vector control supplies—were provided to all districts and service delivery points.

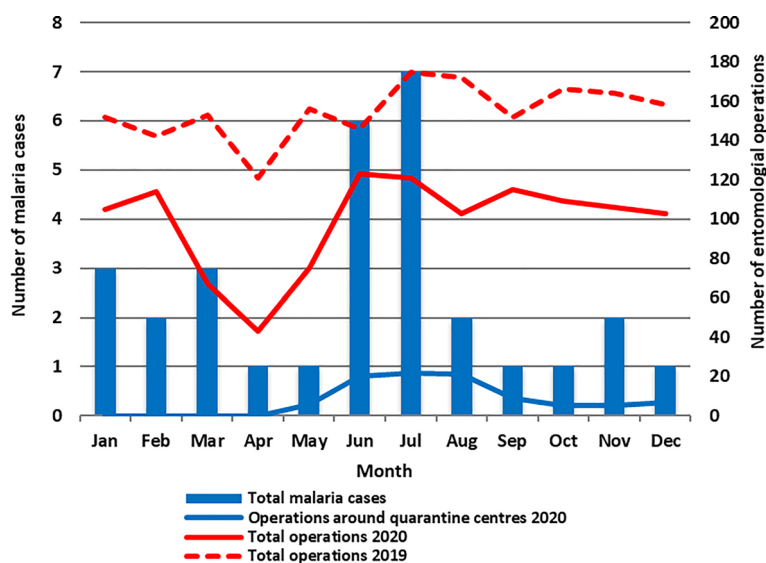


Fig. 4 Entomological surveillance operations in 2019 and 2020 in relation to number of malaria cases in 2020

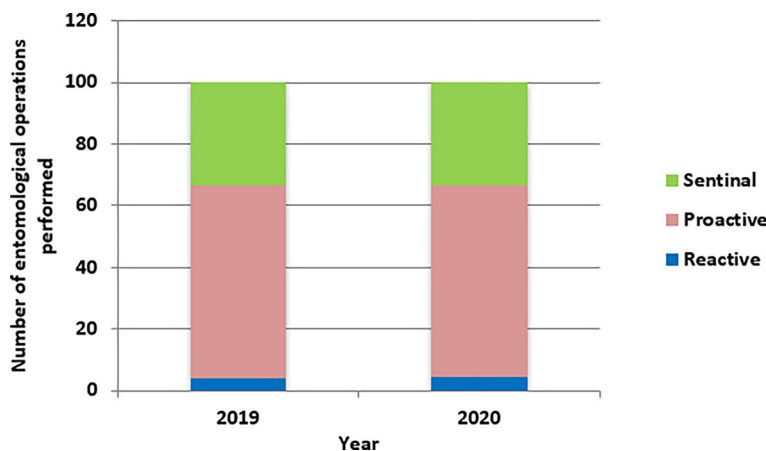


Fig. 5 Entomological surveillance operations performed by the 3 strategies—reactive, proactive and sentinel surveillance in 2019 and 2020

Intersectoral co-ordination for malaria surveillance

With the onset of the COVID-19 epidemic in 2020, the malaria PoR programme was conducted with even stronger links to its inter-sectoral collaborators than in previous years [22]. The Sri Lanka Army, Airforce and Navy were in charge of implementing several components of the COVID-19 control programme, from the arrival of travelers into the country and their screening for COVID-19 to quarantining [19, 23]. The AMC rapidly sought synergies with the military’s work and with the Airports and Aviation Services for screening and follow up of people arriving from malaria endemic countries in a seamless manner.

Budgetary implications and procurement of commodities

The approved budget allocations for the AMC Headquarters were not changed during the course of 2020. Utilization of funds was reduced initially, but over the entire year budget utilization increased compared to the previous year. This was due to funds being transferred to regions (districts) to implement activities in the latter part of 2020.

Although the ease and speed of procurement of commodities and supplies was severely affected during the pandemic, the delays did not affect the AMC very much because it had buffer stocks of almost all commodities—antimalarial medicines, rapid diagnostic tests,

reagents for microscopy and chemical insecticides—to last through the pandemic. When stocks of the rarely-used second-line medicine (dihydroartemisinin–piperaquine) were running low, the small quantity required was sent by WHO. During the period of the study, and throughout the pandemic, the malaria PoR programme experienced no stockouts.

Discussion

Commonalities between malaria and COVID-19 control programmes

For Sri Lanka, malaria and COVID-19 share some important features: both are febrile diseases with overseas travel as a major risk factor. Whilst the source of malaria in Sri Lanka today is entirely overseas, COVID-19 started out as imported infections before local transmission was established. Yet, importation remained as a very important factor for introducing different, possibly more virulent variants of the virus. Therefore, both malaria and COVID-19 required surveillance of persons arriving from overseas. Thirdly, a key strategy for the control of both diseases was active case surveillance and contact screening. Fourthly, programmes for the control of both diseases were heavily dependent on strong inter-sectoral cooperation and collaboration involving several sectors beyond health. The AMC was quick to identify these common and overlapping areas of intervention and sought synergies with the control of the COVID-19 epidemic in order to effectively deal with malaria PoR amidst the disruptions caused by the former.

Adaptation and innovation within the PoR programme

The success of the malaria PoR programme rests on rigorous surveillance—both case and entomological surveillance—and rapid response as principal components of the strategy [24]. Due to the COVID-19 pandemic and its consequences, some aspects of the malaria PoR action plans which were being rigorously implemented by the AMC had to be either scaled down, modified or even abandoned (Table 3). The COVID-19 pandemic also led the AMC to introduce and adopt several new and innovative strategies, mechanisms and activities to face the new realities whilst keeping the country free of malaria transmission.

On the one hand, arrivals to the country, which were the only sources of malaria infections to Sri Lanka, were reduced by 78% in 2020 compared to the average over the previous 3 years. Yet, case surveillance was not only maintained but further strengthened compared to previous years. The AMC took advantage of the fact that passenger arrivals through airports were greatly controlled, and that there was a policy of testing for COVID-19 on arrival and mandatory quarantine for 14 days thereafter.

These procedures provided the AMC with a ‘captive’ population at risk, which could be more easily screened for malaria through PACD at quarantine centers. In contrast, in previous years, the AMC could proactively screen only a very small proportion of those arriving in the country from malaria endemic parts of the world, mostly military groups returning from UN Peacekeeping Missions.

Apart from these groups, prior to 2020, most arrivals from malaria endemic countries could move freely in the community anywhere in the country until they developed symptoms of malaria and sought healthcare on their own. Therefore, whilst the PCD surveillance strategy detected most (89–100%) imported malaria infections in previous years [8], in 2020, PCD detected only 63% of malaria infections reported. In contrast, the proportion of malaria cases detected by PACD increased significantly, from 0 to 1.9% in previous years to 33% in 2020.

RACD was conducted in relation to every case of malaria detected as in previous years [3, 4]. The total number of blood samples examined for malaria in 2020 was just over half (56%) of the average number screened during the past 3 years. Rather than attributing this reduction to a compromised case surveillance programme, it is postulated that this was because there were fewer people at risk of malaria; fewer arrivals from overseas owing to travel restrictions; and screening being more targeted to capture high-risk groups in quarantine centres which was able to capture the cases before they presented in the community, thus, requiring less screening for malaria in the community.

Overall, the shift in case detection yields from different strategies is a testament to the AMC’s agile and responsive PoR programme, which was quick to change strategy and its modus operandi soon after the COVID-19 epidemic began.

On the other hand, by severely restricting human movement and activity owing to lockdowns and on account of individual safety concerns, the COVID-19 pandemic made several of the routine activities of the PoR programme difficult to perform (Table 3). Some were reduced in frequency, and others were cancelled, but in their place innovative new mechanisms were adopted. The AMC was quick to switch to electronic means of communication amongst its network of staff island-wide. Besides, several new ways of operating—such as depending on online platforms for data sharing and using internet-based communication apps—continued throughout the year and beyond and may have contributed to greater efficiency by reducing travel time of staff. These new and possibly more cost-effective ways of working prompted by the COVID-19 pandemic may have even greater potential in the future with development of adequate technological capacity.

Essential malaria PoR activities were sustained despite the COVID-19 pandemic whilst strictly conforming to the Government's COVID-19 control measures and guidelines. Even the Mid-Term External Review of the AMC was conducted as scheduled by a group of experts in Sri Lanka led by a foreign expert using online communication methods. What was mostly compromised, particularly during the lockdown periods, were supervisory visits by staff to districts and provinces and in-person training programmes such as those for microscopy. This may have led to deterioration in the quality of services.

Intersectoral collaboration: a critical component of both COVID-19 and malaria PoR

Already well-established intersectoral collaborations of the AMC which functioned well during and after malaria elimination [22] served the programme extremely well during the COVID-19 pandemic. Over the years, the AMC had established strong alliances and worked closely with many sectors beyond health, namely, (1) the Ministry of Defence (Sri Lanka Army, Air Force and Navy) and the Police Department, on account of their members being at high risk of importing malaria on their return from UN Peacekeeping Missions [25–28]; (2) the Airports and Aviation Ministry, for granting permission for the AMC staff to carry out activities related to malaria surveillance on arriving passengers [29]; and (3) the International Organization for Migration, which repatriates Sri Lankan nationals from India [30]. In 2020, rapid connections were re-established to screen passengers arriving from overseas for malaria at quarantine centers in complete synchrony with the testing programme for COVID-19. This entailed a high degree of coordinated efforts between the AMC, the aforementioned sectors, and Provincial authorities within the Ministry of Health as quarantine centers were located throughout the country [8]. This experience highlights the need for agility and flexibility, and rapidity in the response of health programmes as a key component of health security.

Public health component of the health system

Staff of the malaria PoR programme were not reassigned to control COVID-19 to a significant degree; thus, human resources for malaria were not compromised by the pandemic. The country rapidly deployed cadres of public health personnel to the field, from the Medical Officers of Health to the Public Health Inspectors, and called in the defence forces and the Police Department to implement a stringent COVID-19 control programme. This illustrates yet another important feature for health security, which is to have an adequately staffed public health programme operating at the most peripheral levels of the health system, which can be rapidly deployed in

health emergencies without compromising the activities of other specialized programmes.

Several senior public health officials who directed the COVID-19 control programmes when interviewed stated that they had worked in malaria endemic provinces and districts in the 1980s and 1990s and that their prior experience of malaria control served them well in planning and executing the COVID-19 response [30]. When malaria was endemic in the country, the principles used in its control were much the same as those underlying the control of the COVID-19 epidemic: screening high-risk populations, isolating/treating positives, investigating cases to locate the source of transmission, and tracing and screening of contacts. This emphasizes the point that public health cadres proficient in principles and practices of infectious disease control will be an essential component of health security systems that are equipped to respond to future pandemics.

Leadership within the AMC emerged as a critically important factor during 2020, which served as a stress test for an otherwise well run and effective malaria PoR programme. A highly motivated leadership, which inspired dedication and a high work ethic amongst the staff and those in the district malaria offices, was perhaps one of the key factors which led to uninterrupted and successful PoR activities.

Entomological surveillance operations constitute an important component of the PoR programme because the country is highly receptive to malaria due to the high prevalence of vector mosquitoes. This component was placed under stress because it entails extensive fieldwork and is difficult to perform when human movement is highly restricted. Yet, it appears that sufficient entomological surveillance and vector control operations were carried out, albeit more effectively targeted to risk-areas around quarantine centers, to keep the country free of malaria transmission despite many situations which could have led to the resumption of malaria transmission and the re-establishment of the disease.

This raises an important issue, which is often overlooked in health systems that are overly bureaucratic: prioritization of leadership training and development for health professionals. The AMC's experience in the post-elimination period in Sri Lanka also highlights the importance of maintaining a national malaria programme with dedicated staff and clear mandates, even if it has to operate through a decentralized and integrated health system in the districts. Had there been no equivalent of an AMC in the country, the malaria outcomes during the COVID-19 epidemic might have been quite different, with the general health system under pressure to deviate its resources and attention to COVID-19 control at the peril of other communicable diseases such as malaria.

The lesson for malaria endemic countries, many of which are nearing elimination, is the importance of sustaining a lean but dedicated programme for malaria to prevent re-establishment even if implementation of interventions must be integrated within the health system. The risk of fully integrating malaria services into the general health system too early without maintaining dedicated malaria leadership and expertise must be recognized when planning for health security.

Prioritizing current threats vs preserving gains achieved

This collective experience begs the question as to whether Sri Lanka's malaria PoR programme, which successfully kept the country malaria-free during the COVID-19 pandemic, was justified during an unexpected and serious health crisis. Indeed, many routine health delivery systems, such as those for non-communicable diseases, were seriously disrupted when the country was locked down and human movement was severely restricted. On balance, it appears that the malaria PoR programme was not sustained at the expense of any COVID-19 control interventions; there were adequate public health staff to implement both programmes. The important public health lesson here was the leadership, adaptation, and innovation on the part of the malaria PoR programme in aligning its implementation plans with those of the COVID-19 programme, and taking advantage of the synergies between the two programmes so that both could be successful.

Furthermore, there are many instances of the COVID-19 pandemic negatively affecting malaria control programme in South-East Asia [31]. For example, despite reporting zero indigenous malaria cases since 2017, Timor Leste experienced a localized outbreak of malaria in 2020 due to COVID-19 pandemic disruptions and had to defer planned request of WHO malaria-free certification [31]. Given that Sri Lanka nearly achieved near elimination in 1963 before programme disruptions caused a major resurgence, the public health importance of successfully maintaining PoR while effectively managing the COVID-19 pandemic cannot be overstated.

Conclusion

The COVID-19 pandemic struck an ill-prepared world of public health with alarming suddenness. It demanded rapid responses, swift changes and innovation on a scale that had not been experienced by the current generation of health professionals and planners. Sri Lanka's AMC innovatively made use of the synergies between COVID-19 and the prevention of re-establishment of malaria, recognizing both as health security threats, and took advantage of strong inter-sectoral collaboration to sustain and even maximize the effectiveness of the malaria PoR programme during

the pandemic. The experiences of Sri Lanka's malaria PoR programme in keeping the country free of malaria during the pandemic highlight several important aspects of health security which are increasingly relevant in a world likely to face similar health challenges in the future.

Abbreviations

AMC	Anti Malaria Campaign
COVID-19	Coronavirus disease 2019
PACD	Proactive case detection
PCD	Passive case detection
PoR	Prevention of reestablishment
RACD	Reactive case detection
RMO	Regional Malaria Officer
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
WHO	World Health Organization

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Author contributions

KM, DK, and RW were involved in the conceptualization and analysis. PR, KG, TF, RP and AC were involved in data curation. Funding was secured by GN and RW. Writing original draft, review and editing were done by KM, DF, RW, PR, KG, TF, GN, RP, and AC.

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Availability of data and materials

All data used for analyses are presented in the manuscript.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Review Committee of the Faculty of Medicine, University of Kelaniya, Sri Lanka (Ref. No. P/201/12/2021).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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