Control of residual malaria parasite transmission

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Gerry Killeen
on behalf of Malaria Vector Control Technical Expert Group
Stereotypical African malaria vectors

- Exposure that would otherwise occur indoors that is prevented by using an LLIN
- Exposure that occurs indoors despite using an LLIN
- Exposure that occurs outdoors

An. gambiae s.l.

π_i = 0.94
π_i,n = 0.48

An. funestus s.l.

π_i = 0.97
π_i,n = 0.65

Rarieda, Kenya


Indeed, evidence from a variety of settings over the last half century indicates that residual malaria parasite transmission occurs even in the presence of well-implemented LLINs or IRS, or in other situations where LLIN use or IRS are not practical.

Such transmission is maintained due to a combination of human and vector behaviours, for example when human populations are away from houses, or when local mosquito vector species exhibit one or more behaviours that allow them to avoid the core interventions.
While the factors that can limit the effectiveness of existing interventions are indeed of vital importance and require due attention, it is unlikely that, even in the event of full and correct deployment, malaria parasite transmission would be halted across all settings.
Residual Transmission of Malaria: An Old Issue for New Approaches

Lies Durnez and Marc Coosemans

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/55925

From Wikipedia, the free encyclopedia:

• **Residual:** A remainder left over at the end of some process.

• **Residue:** Whatever remains after something else has been removed.
1. Natural or insecticide-induced behavioural avoidance of treated surfaces indoors

Figure 2. Overall mortality of free flying mosquitoes ±95% confidence interval. *Anopheles arabiensis* (white), *An. gambiae* (black) and *An funestus* (grey) species.

doi:10.1371/journal.pone.0031481.g002
2. Exposure outside of houses or sleeping spaces

**Figure 2.** Protection ‘gap’ when only indoor insecticide-based vector control measures are applied. Anophelines generally bite between 6pm and 6am. ITNs will only protect from infective bites that are acquired indoors, and during sleeping time. IRS only target mosquitoes that rest indoors. Therefore, there is a gap in protection both indoors and outdoors before and after people go to bed (A), but also for people conducting outdoor activities during the night (i.e. ‘risk behaviour’) (B).
3. Feeding upon animals

4. Resting away from indoor-treated surfaces

Figure 2 Barrier screens were constructed between village houses and potential resting and/or oviposition sites, as shown in Haleta village, Solomon Islands (A) and Mirap village, Papua New Guinea (B). Potential resting sites among the vegetation and the primary oviposition site (a brackish water swamp) can be seen to the right of the barrier screen while village houses and animal pens (seen to the left of the barrier screen) provide potential blood meals.
Main vector behaviours maintaining residual transmission

1. Reduced house entry, diversion from contact with indoor treated surfaces or nets, or early exit from houses (such behavioural avoidance often occurs naturally but may be due to insecticide-induced irritancy, repellency and/or toxicity).

2. Feeding upon humans when and where they are not protected, including indoors at times when humans are not under nets, outdoors, or when away from sprayed houses due to occupational, domestic or recreational activities.

3. Feeding upon animals in preference to humans and thereby reduced contact with indoor treated surfaces or nets.

4. Resting outdoors away from indoor treated surfaces.
Causes of persisting residual transmission

- EMERGE
- GESTATE
- FEED ON UNPROTECTED HUMANS OR ANIMALS OUTDOORS
- FEED ON UNPROTECTED HUMANS INDOORS
- NOCTURNAL HOST-SEEKING
- CREPUSCULAR HOST-SEEKING
- AVOID CONTACT WITH INSECTICIDE-TREATED SURFACES AND EXIT HOUSE IN SEARCH OF UNPROTECTED HOSTS
- SUGAR FEEDING
- OVIPOSIT

Solutions to persisting residual transmission

**NIGHT TIME**
- OVIPOSIT
- EMERGE
- NOCTURNAL HOST-SEEKING
- FEED ON UNPROTECTED HUMANS INDOORS
- AVOID CONTACT WITH INSECTICIDE-TREATED SURFACES AND EXIT HOUSE IN SEARCH OF UNPROTECTED HOSTS

**DUSK AND DAWN**
- SUGAR FEEDING
- CREPUSCULAR HOST-SEEKING
- TOXIC SUGAR BAITS

**DAY TIME**
- GESTATE

**IMPROVED METHODS FOR KILLING INSIDE HOUSES**
- IMPROVED IMPLEMENTATION MODELS FOR LARVAL SOURCE MANAGEMENT
- REPPELLENTS OR INSECTICIDAL CLOTHING/EMANATORS/DRUGS

**SUGAR FEEDING**

Protecting humans outdoors

WHILE ASLEEP

WHILE ACTIVE
Insecticide-treated livestock, attractive odor lures and sugar sources

Lancet (2001) 357: 1837

Parasites & Vectors (2010) 3: 12

PLoS One (2014) 8: e81468

Malaria Journal (2012) 9: 262
Need for new tools and strategies to address residual transmission

- National malaria control programmes must prioritise the implementation of current tools whilst improved or novel vector control interventions are under development and validation.

- Meanwhile, the focus should be to assess the following strategies for effectiveness, practicability and affordability:

  1. Exclude or deter indoor entry, feeding and resting using physical screening barriers, repellents, or insecticides with no deterrent properties;

  2. Prevent successful outdoor feeding by using insecticide-treated clothing or repellents to directly protect people;

  3. Reduce adult vector densities or transmission potential otherwise by:
     a) Outdoor attractants to lure and trap/kill mosquitoes
     b) Topical or systemic insecticides for livestock that kill mosquitoes during or after feeding, or
     c) Applying insecticides to natural sugar sources or by introducing insecticidal sugar baits.
Following the establishment of a sufficient entomological surveillance and monitoring system, national malaria control programmes may consider selectively piloting at sub-national scales promising new vector control tools in order to generate local evidence on impact and acceptability.

The deployment of new tools may be progressively adapted and expanded based on robust entomological and epidemiological surveillance and monitoring data.

Such pilot implementation will not only allow optimization of the effectiveness of such tools at national level, but will also contribute to the global evidence base required to inform the development or improvement of tools and define the conditions for their deployment.
Stratification based on behaviour-matched interventions

- Epidemiological stratification, sociological and demographic information, and entomological surveillance and monitoring data must be used to inform the implementation of existing and new vector control interventions across all settings.
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Stratification based on behaviour-matched interventions

- Culicifacies
- Fluvialis
- Nunezovari
- Stephensi
- Insecticide-treated livestock
- Vapor-phase emanator with repellency maximized
- Epiroticus
- Punctulatus
- Koliensis
- Funestus
- Gambiae
- Darlingi
- Asqualis
- Nuneztovari
- Farauti
- Stepensi
- Albinanus
- Culicifacies
- Fluviatilis
- Nunezovari
- Darlingi
- Asqualis
- Nuneztovari
- Farauti
- Stepensi
- Albinanus

Malaria Journal (2014) 13: 146
Limitations of existing data from research platforms

- Much of our knowledge on malaria vector biology and behaviour has been derived from small-scale research projects rather than longitudinal routine surveillance. This information is therefore of limited geographical scope and is often outdated.

**WHERE AND WHEN HUMANS ARE EXPOSED TO MOSQUITO BITES**

**PROPORTION OF MOSQUITO BLOOD MEALS OBTAINED FROM HUMANS**


Sinka et al. (2014) In progress
• What are the major mosquito vectors present in the country and what is the specific contribution made to malaria transmission by each of the known or suspected vector species in each ecological zone?
• What are the long-term trends in vector species composition?
• What is the insecticide susceptibility status of the known or suspected vectors?
• Are the vector control interventions being implemented in the country effective against the vectors responsible for transmitting the malaria parasites in the different epidemiological situations encountered?
• Are those interventions still effective in the face of insecticide resistance and/or changes in mosquito behaviour?
• What are the specific behaviours of the mosquito vectors that may impact on the effectiveness of insecticide-based control interventions? (e.g. do they bite indoors or outdoors? Do they feed preferentially on humans or on domestic animals, or both? Do they rest inside houses or other structures, or do they rest outdoors? At what time of night do the different vector species bite?
• How does human behaviour and changes in human behaviour affect effectiveness of interventions?
• What are the characteristics of the preferred larval habitats of each of the known or suspected vectors and what is the geographic distribution of those sites?
Remaining challenges of assessing vector behaviour
The need to assess vector response to interventions

Recommendations

- National malaria control programmes in collaboration with academic or research institutions should generate local evidence on the magnitude of the problem of residual transmission, including information on human and vector behaviour, and intervention effectiveness.

- Industry and their partners are encouraged to develop new tools to address residual transmission. Financial, human and infrastructural resources are urgently needed to support development, evaluation and implementation of such tools.

- National regulatory authorities should ensure that registration processes support the rapid availability to the local market of validated new vector control products.
Thank you