Review of delivery strategies for insecticide treated mosquito nets – are we ready for the next phase of malaria control efforts?

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Abstract

Background The renewed interest in malaria elimination using long-lasting insecticidal nets (LLIN) for malaria prevention has shifted from targeted distributions of vulnerable groups to universal access. Many countries are now reaching high net coverage levels and need to consider options for sustained control.

Objectives This review addresses the question: which LLIN distribution mechanisms might be best suited for these approaches?

Methods We searched PudMed, EMBASE, Popline, BIDS, African Journals Online, and SciELO using a board list of search terms to identify studies on bed nets. Additional searches were conducted in Google and through reference tracking. The net distribution mechanisms in the included studies were categorized using an open system of six characteristics with the distribution channel serving as the primary descriptive element. Studies were then further evaluated on net coverage, equity and cost per net delivered.

Results Searches of the eight electronic databases produced 258 articles. The secondary search using reference lists and other search engines revealed an additional 44 sources. After an initial screening, 174 reports and studies were included in the detailed review. Community-based distributions (campaigns) achieve rapid increases in net coverage of 30-80%-points among the targeted population and no differences between different implementation models (stand-alone or integrated, house-to-house or distribution point) was found. Equity ratios post distribution were found to be around the 1.0 mark of perfect equity and remained high. However, following the campaign distributions a drop in coverage can be observed in the range of 5-13%-points per year for the first two years.

Continuous distribution mechanisms through routine services and/or retail outlets avoid coverage fluctuations but are much slower in build-up, ranging between 3-5%-points increase/year for the unassisted commercial sector and 6-25%-points/year for combination of commercial market with free or highly subsidized nets through routine services. These delivery mechanisms can eventually achieve high equity when they reach high levels of coverage but this can take up to eight years. Cost per net delivered for campaigns appeared slightly better than other distribution mechanisms but no definite advantage can be stated for either mechanism, given methodological and within-study variability.

Conclusions Campaign distributions that target the general population are best suited for the scale-up phase of universal access to LLIN, but more work is needed to define the best distribution algorithms for full intra-household coverage, as well as indicators to measure it. For the phase of sustained control and LLIN replacement, a mix of continuous delivery mechanisms through community, routine services and retail outlets is suitable as long as equity issues are addressed with subsidies. Whether and how campaigns can also be used for replacement strategies can not be answered adequately until the concept of "useful life of a net" is better understood and more data available.

Introduction

Insecticide treated mosquito nets (ITN) are a more recent addition to the accepted tools for malaria. ITN were intensively studied in the 1990s and a Cochrane review of 22 high-quality randomized controlled studies on ITN (1) concluded that "insecticide-treated nets can reduce deaths in children by one fifth and episodes of malaria by half" in sub-Saharan Africa. Another critical question regarding a potential rebound mortality effect through delayed development of immunity was also answered, with a clear indication that even seven years after initial exposure of infants to ITN, no increased mortality could be observed (2-4).

Two recent developments influence the debate on net distribution strategies: i) the maturation of the long-lasting insecticidal net (LLIN) technologies (5) and ii) the strategic shift from ITN as primarily for the protection of individuals (high risk groups), to LLIN as a tool for vector control for which universal access to the entire population in the target area is essential (6). Both are closely linked with the renewed interest in the prospects of elimination and eradication of malaria (7). First, with five LLIN products now having at least temporary recommendation from the WHO Pesticide Evaluation Scheme (8), LLIN have become accepted as the current standard, replacing conventionally treated nets. This creates new challenges and debates, namely around ways to support and subsidize LLIN sales in the commercial market vis-à-vis conventional mosquito nets, and on best strategies for LLIN replacements in the public sector. Second, by defining ITN/LLIN as one of the key vector control elements on the road to potential malaria elimination, the malaria control community needs to reconsider how best can universal access be achieved; which delivery strategies or mix of approaches is best suited for the initial attack or scale-up phase; and which approaches would work best in the sustained control phase.

In recent years, there have been a number of reviews of net delivery mechanisms (9-13). Building on this work, we review the available literature regarding the various delivery mechanisms and strategies looking at their resulting outcomes, and evaluating them with respect to the desired achievements. We also reflect on information that is currently missing but required in order to optimally move LLIN distributions forward.

Methods

Literature search

We searched PubMed, EMBASE, Popline, BIDS, African Journals Online (AJOL), and SciELO using a combined search string. Key words searched were ITN, LLIN, *nets, insecticide, treated, insecticide-treated nets, insecticide-treated bednets, bednets, malaria, distribution, delivery, system, voucher (voucher system), social marketing, commercial, targeting, subsidy, campaign, IDP, camps, emergency, health facility, ANC, useful life, holes, bio-assay, willingness to pay, cost, effectiveness, economic, evaluation, access, equity, use, and acceptability. Additional studies were retrieved through reference tracking and searching with Google and other search engines.

Quality assessment

Given the broad inclusion criteria (i.e. search terms mentioned above) for the literature search, the quality of reviewed sources differed significantly and in many cases only certain aspects of the distribution analysis were addressed. Additionally, the scope of operations differed widely from national level activities to small scale projects that were implemented over a short period of time. A source was only considered for the review if sufficient information was provided on at least one aspect of the distribution so that valid comparisons could be made. This information was more descriptive for the categorization of distribution mechanisms and required adherence to minimum standard requirements for household survey design, implementation and analysis for the evaluation criteria of coverage, equity and cost.

Conceptual framework for categorization and evaluation of delivery strategies

Descriptive criteria

There currently is no generally agreed system to capture and categorize net distribution mechanisms in a standardized manner (6,9,11-21). Rather than using a closed matrix, we here propose an open system of descriptive categorization which is presented in Figure 1. Each ITN delivery mechanism can be uniquely described by six specific criteria allowing flexible combinations between the elements of each category. Several delivery mechanisms can then be combined forming the ITN delivery strategy in order to achieve scale-up (attack phase) or sustained control, which that roughly equate to the terms "catch up" and "keep up" (22). The first and central category for each delivery mechanism is the channel or

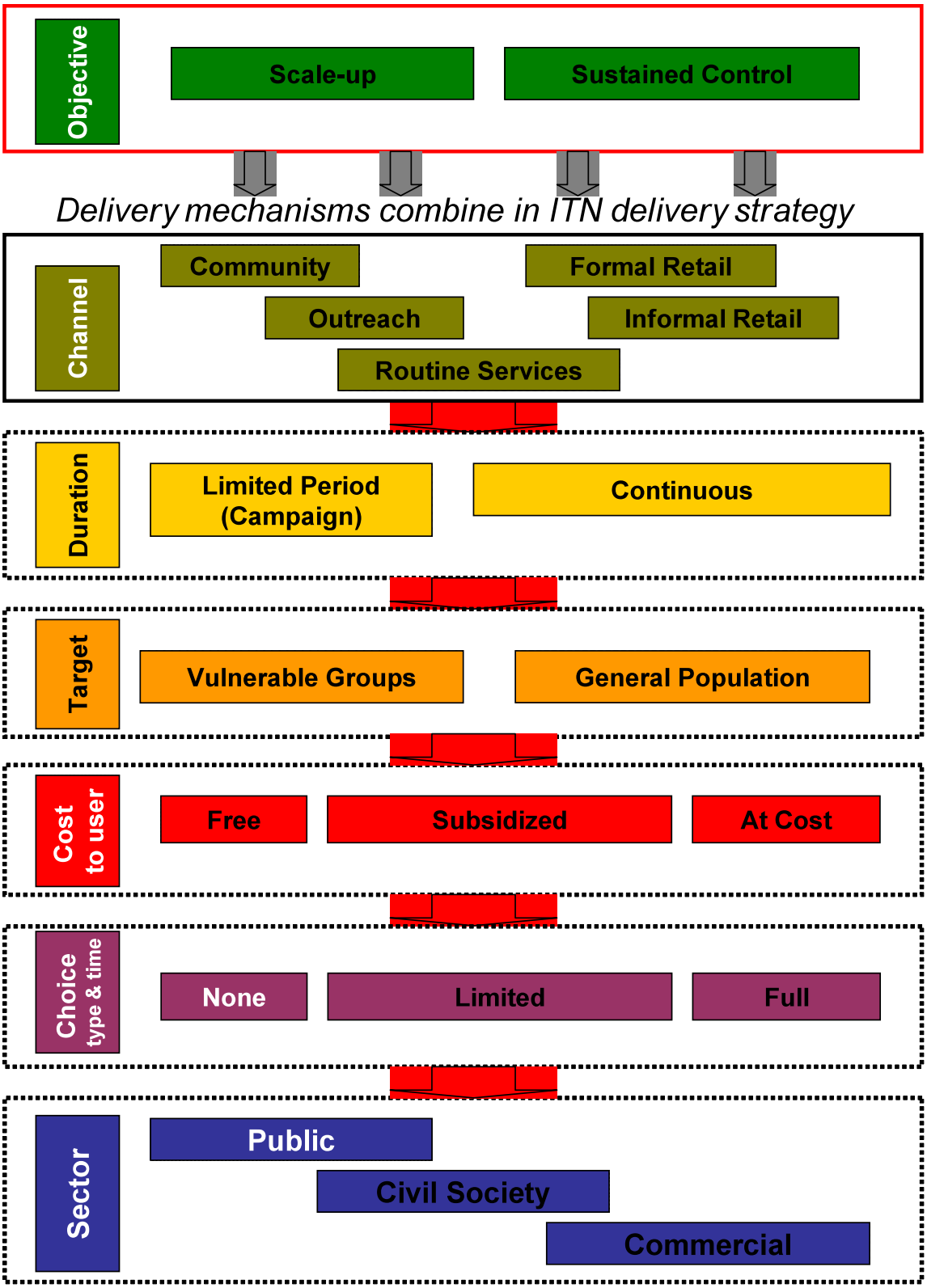

Figure 1: System to categorize ITN delivery mechanisms. Each mechanism is defined by 6 criteria where the elements of each level can be combined with any of the other levels. The primary or central level is the distribution channel. Several delivery mechanisms can then be combined to reach a specific overall malaria strategic objective. Overlapping bars indicate that elements can be combined or mixed within a single delivery mechanism.

outlet which is then further described by population group(s) targeted, duration of distribution, cost to user, choices of net recipient and finally by sectors involved. While elements of the channel and sector can be combined or mixed within a delivery mechanism, the elements of the other categories are mutually exclusive. The categories are defined as follows:

Channel: the delivery channel is described by its endpoints or outlets and includes

i) direct community delivery, meaning that the community (or the targeted group within the community) has direct and indiscriminate access to nets outside commercial outlets, either through house to house delivery, or at a specific gathering point which could be a church, school, health facility or any other common meeting place. This channel, when undertaken over a limited period of time, is commonly referred to as a "campaign";
ii) routine services (generally health services, but could also be others). Access to nets is associated with the utilization of these services;
iii) outreach activities of health services, such as mobile brigades/clinics or immunization outreach (also referred to as enhanced routine);
iv) formal retail outlets (shops, pharmacies, supermarkets etc);
v) informal retail outlets (mobile vendors, open markets).

Each of these represents a distribution channel that involves several stations through which nets flow such as government supply chain, commercial wholesalers or distributors. Multiple elements of the channel category can be combined within the same delivery mechanism as occurs in voucher[1] schemes.

Duration: this category distinguishes between time-limited and continuous distribution and refers to the time period nets are available to the potential recipient at a specific outlet. We define distribution as continuous if this period is longer than one month. This implies that what is commonly referred to as a "campaign" is categorized as time-limited distribution and therefore the term "campaign" is used synonymous with a time-limited, community-based distribution. A continuous delivery mechanism on the other hand may be interrupted at times of stock-out or be discontinued after a project ends.

Target: the target group can either be the general population (either national or a limited geographical area) which is termed universal coverage or alternatively a vulnerable biological, social or economic group.

Cost to user: the three mutually exclusive categories are free (or fully subsidized), subsidized to any degree other than fully, and commercially sustainable cost.

Choice: refers to the net user's ability to a) obtain the net of choice (shape, size and/or colour) and to b) get it when he or she needs it to either cater for additional sleeping places in the family or replace a net which is no longer in the household's possession or cannot be used any longer.

Sector: the public sector refers to local or national government, while the private sector is split into civil society (NGO, faith or community-based organizations) and the commercial sector is comprised of the for-profit health care providers and the ITN market. We further define a delivery mechanism as a mixed sector approach if there is a significant logistical or human resource contribution beyond financing or manufacturing.

Evaluation criteria

As with other health interventions, ITN distribution mechanisms and strategies need to be subjected to rigorous effectiveness and cost-effectiveness assessments. In line with criteria suggested by Victoria et al. (23), we have used the following measures:

Coverage: the principle criterion for achieved coverage at a given point in time following start of net distribution is the proportion of households in the general population with at least one net or ITN and within subgroups of households for targeted distributions. As this indicator does not capture the intra-household net saturation, the average proportion of sleeping places covered, or people to nets ratio within a household would ideally be used as a secondary criterion, but these data were rarely reported and can, therefore, not be considered here. We explicitly do not consider net use as an outcome, as this involves many additional factors such as behaviour and seasonality that are independent of the performance of the actual net distribution strategy.

[1] A voucher is a bond with a specific monetary value that can be exchanged against a variety of different ITN/LLIN products. It must be distinguished from a coupon as it is used in house-to-house campaigns and can only be exchanged against one particular LLIN at the distribution point.

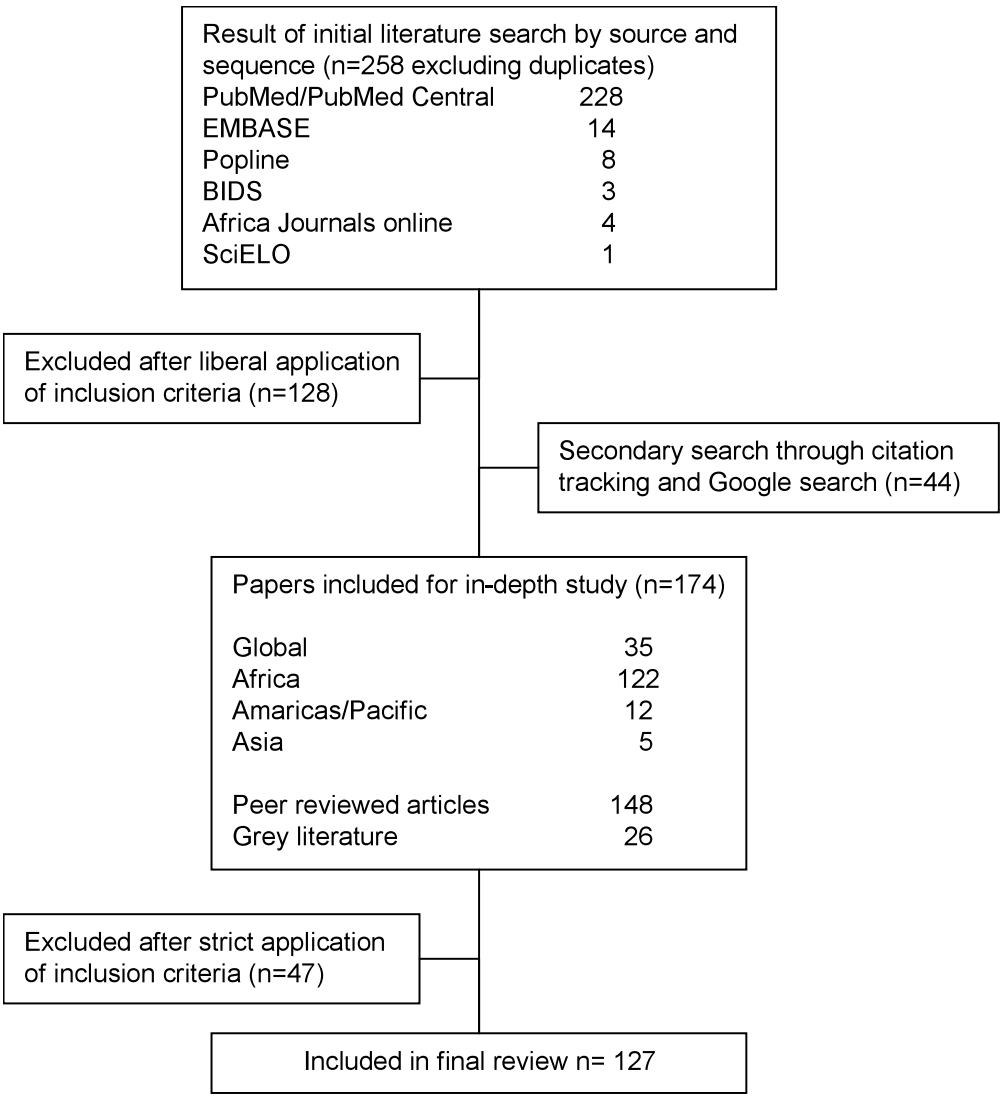

Figure 2: Overview of literature search and selection process

Equity: describes the degree to which the poor have access to nets or ITN compared to the wealthier groups of society or a community. The concentration index or curve would be the most comprehensive way to assess equity of net distribution (17) which is most often only described as an equity ratio, i.e. the ratio (range zero to infinity) between proportion of households owning a net/ITN in the poorest quintile compared to that in the least poor quintile, where a ratio of 1.0 describes perfect equity, values below 1.0 inequity towards the least poor and values above 1.0 in favour of the poor. In contrast, the concentration index includes not only the highest and lowest wealth quintiles but takes into account the full data set. A value of zero represents perfect equity, while a negative value indicates disproportionate concentration of net ownership among the poor, and a positive value disproportionate concentration among the wealthier.

Cost: in the context of net delivery mechanisms and strategies, we only considered cost per net delivered to the end user, and not cost-effectiveness measures such as cost per life saved, cost per DALY or cost per treated net life, as these latter measures include aspects of the net (ability to prevent malaria and/or durability of the material) which are independent of the distribution mechanism.

Results

Results of the search and selection process are summarized in Figure 2. Of the 174 selected studies whose primary topic was the description of net distributions: 48% discussed coverage outcome or impact; 20% dealt primarily with cost, equity or other economic aspects; and 19% were general

Box 1: Inclusion criteria for comparison of coverage and equity outcomes (Tables 1 and 2, Figures 3 and 4).

- Implementation at scale within the target area, which should ideally be national but at a minimum district-wide.
- For continuous distributions, minimum time frame of more than one year.
- Clearly defined distribution strategies within the area which can be categorized as either continuous, time-limited (campaign) or campaign combined with continuous.
- Sequence of household surveys representative for the implementation area with relevant information on coverage and equity indicators over a minimum of three years.
- Low initial net coverage rates so that increases are not limited by the already high starting point.

discussions, strategy or opinion papers. Seven percent were survey reports such as Malaria Indicator Surveys (MIS), Multi-Indicator Cluster Surveys (MICS) or Demographic and Health Surveys (DHS) and 6% dealt with issues of net maintenance, physical condition and durability of nets. DHS, MIS and MICS were not generally consulted but rather served as a source of information in specific scenarios identified for a sub-analysis of outcomes (see box 1).

Delivery channel

Community-based

A total of 25 studies were identified that describe community-based distributions outside of net efficacy studies. Community-based distribution occurs in three ways: i) as a house to house delivery with the number of nets determined according to pre-set criteria, ii) distribution from one or several delivery points where the community members receive or buy a net without pre-registration and iii) a combination of these two approaches, i.e. the households are registered during a house to house activity and are allocated nets which they obtain from a central distribution point immediately thereafter or after a certain time interval.

Time-limited campaigns

This type clearly is currently the dominant form of community-based distributions with 19 studies found. These campaigns were conducted for a few days in each community using any of the three delivery scenarios described above. Seven studies had campaigns that were combined with immunization programs (measles, polio or both), four of which used central distribution points without pre-registration (22,24-29). In Togo (24) and Niger (25) these were national campaigns, while in Ghana, Kenya, Tanzania, Zambia and Mozambique they were geographically limited (22, 26-29). However, according to the measles-malaria partnership, at least 33 campaigns have been carried out between 2004 and 2007, of which seven were national campaigns (Grabowsky, personal communication). In the Mozambique campaign, a coupon[2] was issued at the vaccination point because nets where not available at the time of the immunization (29) and in Zambia, a voucher was given with the immunization that could be redeemed at a retail outlet (28). These can be seen as variants of a pre-registration with later net delivery (scenario iii above). Ritmeijer et al (30) describe a net distribution campaign in the context of visceral leishmaniasis control in Sudan, where a household level pre-registration was used followed by distribution at a central point in each village according to that register. In the Niger polio/ITN campaign, coupons were given during the house to house vaccinations and nets were then collected at a central delivery point (25).

A direct house-to house delivery has been reported from camps of Internally Displaced People in Western Uganda (31) and Central Nigeria (32). In the latter case, the campaign was integrated with mass drug administration (MDA) for onchocerciasis and lymphatic filariasis. The delivery for each village was only a few days but the overall roll-out to the two districts (Local Government Areas) took five months. Stand alone community-based campaigns, i.e. not integrated with other interventions, have been reported in Eritrea (33), Ethiopia (34), Kenya (26), Vietnam (35,36) and Vanuatu (37), however no detailed information was provided on delivery point procedures. In three further cases, community distribution (sales) days without pre-registration were organized by community committees in Tanzania (38) and project staff with support from government officials in Burundi (39) and Afghanistan (40).

Continuous distribution

In six cases community-based distributions have been carried out as a continuous activity over longer periods of time from particular delivery

[2] These coupons have sometimes also been called vouchers but strictly speaking they are not as they are only valid for one particular product

points (scenario ii above). All of these were either part of implementation research, smaller scale projects, or social marketing approaches that have since been terminated. Community health workers or community leaders have been used to sell subsidized nets in Afghan refugee camps in Pakistan (41), in several communities in Latin America (42), and in social marketing projects in Kilombero, Tanzania (43) and Sofala and Manica Provinces in Mozambique (44). In other cases, community-based organizations such as committees or cooperatives have been used for the same purpose in four areas in Kenya (45), Mexico and Columbia (46).

Net allocation per household

The allocation of nets to households varied from one for each person (except children sleeping with their mother) in Sudan (30) to one net per every two persons (35,36) to 1-4 per family in Uganda (31) to an average of two per household in Ethiopia (34).

In the integrated immunization/ITN campaigns nets were targeted at children under 5. In two cases, the target group for the immunization differed from that of the nets, specifically measles catch-up vaccinations in Ghana (47) and Zambia (28) where children up to 14 years were eligible. Net allocation generally was one net per child under 5 with three exceptions: in Niger (25), Mozambique (29) and Ghana (47) one net was allocated per mother or household with one or more children under 5. The Nigerian integrated ITN/MDA campaign targeted children and pregnant women with one free net for each sleeping place used by this target group (32). Among the stand alone campaigns, children were targeted in Kenya (26) while all the others targeted all household members aiming for universal coverage. In Eritrea the target was on average two nets per household but children and pregnant women were given special emphasis (33).

Cost to user

Nets were generally free of charge except in the three projects with social marketing characteristics and campaign style sales at subsidized prices in Tanzania, Burundi and Afghanistan (38-40). Interestingly, in the leishmaniasis control programme in Sudan (30), a fee of US$ 0.80 was charged but poor families were exempt.

User's choice

Large scale community-based, time-limited distributions (campaigns) generally require the net user to obtain the net within the days the net delivery point is open, with the exception of a study from Zambia where a voucher was given during the campaign for redemption at a commercial outlet over a longer period of time (28). Similarly, these distributions generally provided only one type of net, with the exception of a campaign in Tanzania where three different sizes of nets were offered during community-based sale days (38). Of the six studies on continuous distribution, two reported a choice in net type with two different sizes of nets offered in Tanzania (43) and two shapes (rectangular and conical) offered in Mozambique (44). In all the continuous distributions studies, the user could choose when to acquire the net, within the time frame of the project (41-46).

Sector involvement

Only the distributions in Eritrea (33) and Pakistan (41) were carried out by a single sector (public and CSO respectively) whilst all others were implemented by a public/CSO mix, or in the case of the campaign-based voucher scheme in Zambia (28), all the three sectors were involved.

Routine services and outreach activities

Net delivery outreach activities by the health services (enhanced routine) have been defined as a separate category in a review by Webster et al. (10) and a recent WHO manual (48). However, while Webster et al. mentioned such activities in the context of child health days in Ghana and Senegal, we are aware of net distributions through mobile brigades in Mozambique (Brownlow, personal communication) but were unable to identify any source in the literature describing this distribution mechanism.

ANC and EPI services

For the net distributions through ANC or EPI services found in this literature search, delivery was in principle continuous, i.e. the recipient had the opportunity to obtain a net at any service outlet as long as they fulfilled the eligibility criteria. Similarly, all used targeted distribution. Direct free distribution of nets during ANC services was reported in Eritrea (33, 49), Burkina Faso (50) and Kenya (51). This was implemented by the public sector alone or in collaboration with NGOs. In Lawra district, Ghana they were sold at a subsidized price in line with national policy (22). Direct delivery of nets at the point of service was also implemented in Malawi (62) and Kenya (26). In both cases, nets were sold at highly subsidized prices through a public/CSO sector social marketing project with the target group expanded to include mothers bringing their children for immunization.

The alternative to direct delivery of nets during ANC services is to distribute a voucher, which then provides a price subsidy for the purchase of an ITN

at retail outlets participating in the voucher scheme. Pilots or geographically limited implementation have been conducted in Ghana (53), Uganda (54) and Tanzania (43), the latter being the only country that then went on to implement the voucher scheme at a national scale (55, 56). All these and other voucher schemes described by Worrall et al. (57) were implemented involving all three sectors, public, CSO and commercial.

Small scale projects

Using routine health services for delivery of subsidized nets, i.e. allowing all clients to benefit, has been used by social marketing projects in Pakistan (41) and Tanzania (38) both of which were implemented by a public/CSO sector mix. In contrast, three reports of continuous, routine distributions were found that utilized specialized services. In Malawi, LLIN were given free to people living with HIV/AIDS attending antiretroviral treatment clinics (59), in Uganda a health insurance scheme offered ITNs at a 50% subsidy to their clients (60) and in Kenya large employers partnered with an NGO to make ITNs available to their employees at full cost recovery, but with credit attached (45).

User's choice

While all these delivery mechanisms made ITNs available on a continuous basis, recipients did not always have a flexible choice of time when to acquire the net. Particularly when distribution was targeted to clients of ANC and EPI services, the choice of time was limited to the pregnancy or when the child was being immunized. Choice of net also differed in these approaches from none during ANC/EPI distributions (22,26,49-52) to a maximum of five different nets offered in a project in Tanzania (58). A varying but generally high level of choice of net shapes, sizes and colours was found in the voucher schemes (43, 53-55).

Retail outlets

It has been repeatedly shown that commercial delivery mechanisms, in particular the informal retail channels, represent the most important source of nets in many countries and settings (9,17,61-64). This may not be quite the case for ITN and specifically LLIN, as there were very few sources other than social marketing projects found in our literature search describing commercial delivery mechanisms (9,10,12,19).

Commercial deliveries are continuous. The un-assisted commercial sector sold nets to anybody who was able to buy at a profit. There was normally full consumer choice on when to purchase the net and the type of net. This situation differed only when the commercial sector was supported by the public and/or CSO sectors in a "total market approach" (9) with either a voucher scheme, or in the classical social marketing approach, the CSO delivered nets through formal commercial retail outlets (10). In these cases net sales were mostly subsidized to some degree, although at times the support by the CSO only applied to the distribution and marketing cost but not the price to the customer (10,44,65,66). The target group was restricted in voucher schemes with vouchers given either to pregnant women during ANC (43,53,54) or children during a vaccination campaign (28).

Outcomes of distribution mechanisms and strategies

Coverage

While many of the reviewed sources provided some measurement of net coverage, not all of these were suitable to make inferences on the potential of a particular delivery mechanism to increase net ownership, partially because in some cases only use rather than ownership was reported. As Webster and colleagues have pointed out in their 2007 review (10) the time since (for time-limited) or duration of distribution (continuous) needs to be taken into account as well as the scope of operation, i.e. has the delivery mechanism been implemented to its maximum operational capacity or was its output limited by available funding for ITN or subsidies? We suggest that several points in time should be examined to assess the gains in coverage in settings where only one delivery mechanism is used or is the most dominant in distributing ITN.

Direct comparison of distribution mechanisms

Three studies made comparisons between either delivery mechanisms, combination approaches, or variations of one mechanism. Grabowsky et al. (28) compared the outcome of direct distribution of LLINs to every child under five attending the central measles vaccination point in four districts in Zambia with one district where a coupon was given at the vaccination point that could be redeemed against a particular ITN brand in retail shops later. The ITN coverage in households with at least one child under five was measured six months after the campaign, with baseline values estimated retrospectively from the post-campaign survey. With direct distribution, coverage increased from 21% to 88% and with the coupon, from 49% to 82%, showing no major difference. Müller et al. (50) compared a rural province in Burkina Faso, which subsidized sales of LLINs through retail outlets using a classical social marketing approach, to a

combined market and free LLIN distribution through ANC service providers. After one year social marketing alone showed a 6%-point increase of household ITN coverage (25-31%) while the increase was 22%-points for the combination (21-43%). Cohen and Dupas in Kenya (67) compared the uptake of nets from ANC clinics when they were either free or had different levels of subsidy. They found that uptake, which would eventually translate into coverage, reduced by 75% when the price of ITN was increased from zero to $ 0.75, indicating that free net distribution would produce a higher coverage in a given time period than subsidized ANC distribution.

Distribution by multiple sources

As few reports provided a series of coverage estimates over more than one year, we have tried to identify scenarios from multiple sources that allow a comparison of coverage outcomes of different distribution mechanisms or strategies along the criteria outlined above (22,24,29,47,63,68-83). The inclusion criteria for this sub-analysis are presented in Box 1. Results are presented in Table 1 and

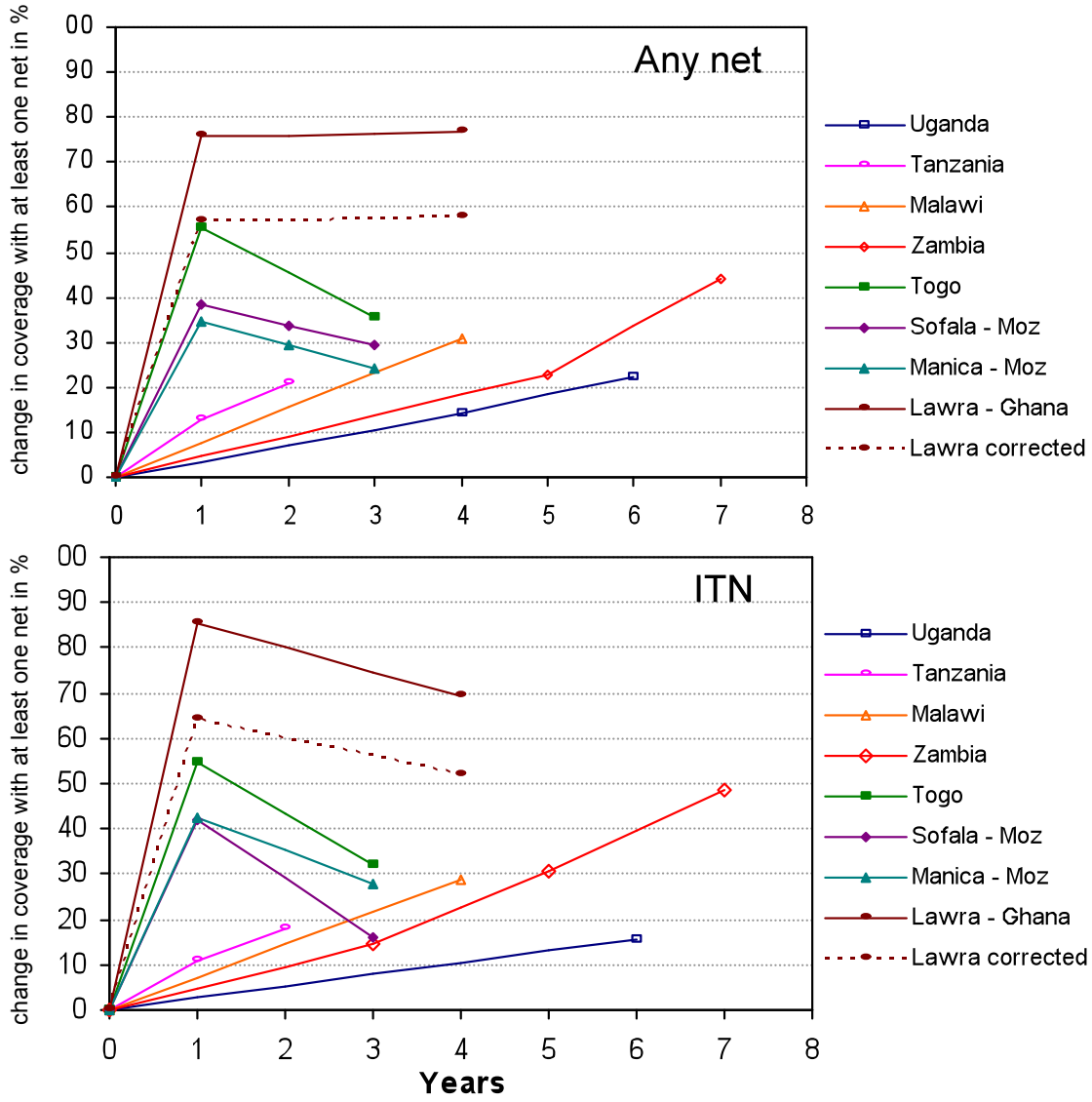

Figure 3: Coverage outcome expressed as change in household net or ITN ownership over time. Open symbols represent distribution strategies with continuous net delivery (details see Table 1 and text). "Lawra corrected" refers to adjustment to the general population.

Table 1: Trends over time in net and ITN household coverage of various country scenarios and distribution mechanisms or strategies. DHS=Demographic and Health Survey; MIS=Malaria Indicator Survey; HAIS=HIV/AIDS Indicator Survey

Country	Distribution and scale	Indicator	Data type	2000	2001	2002	2003	2004	2005	2006	2007	2008	Sources
Uganda	Continuous – national mainly commercial at cost sales with some subsidy and minor free distributions through CSOs	Any net (%) ITN (%)	DHS, HAIS	12.0 0.3				26.0 n.a.		34.5 15.9			80 – 82
Tanzania TNVS area	Continuous – sub-national mainly subsidized ANC based distribution (voucher) and commercial at cost, some local free campaigns	Any net (%) ITN (%)	Sub-national surveys						43.9 17.9	56.9 28.9	64.6 36.0		55, 56, 63, 77, 78
Malawi	Continuous – national mainly highly subsidized ANC based distribution (direct sales) and sub-sidized and at cost commercial sales	Any net (%) ITN (%)	National survey	12 5				42.9 33.8					74 – 76
Togo	Campaign – national integrated with immunization campaign, no significant continuous input	Any net (%) ITN (%)	National survey, MICS				10* 8	65.6 62.5		45.7 40.2			24, 69, 69
Mozambique Sofala	Campaign – provincial integrated with measles campaign, no significant continuous input	Any net (%) ITN (%)	Provincial survey, MIS, DHS				24.6 7.0		59.6 47.6		50.5 21.7		29, 70
Mozambique Manica	Campaign – provincial integrated with measles campaign, no significant continuous input	Any net (%) ITN (%)	Provincial survey, MIS, DHS				20.6 8.9		55.1 51.5		44.8 36.9		29, 70
Ghana Lawra	Campaign followed by continuous – district integrated with measles campaign, followed by ANC distribution	Any net (%) ITN (%)	District survey			18.8† 4.4†	94.4† 90.0†			95.7† 73.7†			22, 47
Zambia	Continuous followed by campaigns – national initially mainly commercial, subsidized and free ANC, then adding campaigns	Any net (%) ITN (%)	DHS, MIS		27.2 13.6			n.a 28		50.1 44.4		71.5 62.3	70-73, 83

* estimated as not supplied in data
† only households with at least one child under 5

Figure 3. For Ghana, the publication only reported coverage for households with at least one child under five years of age. In order to allow a comparison with the general population results from the other countries, these coverage rates were adjusted assuming 65% of households having at least one under-five (24,29,68) and 5% of non-targeted households having any nets. There was no significant difference between the patterns of coverage increase between ITN and any mosquito net. Continuous distribution strategies showed a constant increase averaging 6.7%-points/year with slightly higher increases (7-10%-points/year) for the combination of commercial sector and subsidized ANC distributions in Malawi and Tanzania, and lower rates (3-4%-points/year) for commercial sector alone in Uganda. This is supported by the pattern shown in Zambia, where increases were around 6%-points in the first years and between 9 and 11%-points/year when focal campaigns were added. In contrast, the examples with exclusive or primary campaign distributions to under-fives show very steep initial increases between 35 and 60%-points and then drop off again in the following two years at a rate between 5 and 13%-points/year, ending up only slightly above the rates of coverage increase achieved by continuous distributions after this time. The only exception is the Ghana study, where campaigns were followed by subsidized ANC distribution and coverage remained high even after three years. The observed drop in ITN coverage was due to the conventional treatment of nets and failure to re-treat and would not have been seen with LLIN (22). The proportion of target group reached by the campaign was above 90% both in Togo (24) and Ghana (47), where ITNs were given directly at the distribution point, and somewhat lower in Mozambique (68%) where coupons were issued for pick-up of nets two months later (29). However, as the proportion of families with at least one child below 5 years ranged between 50% and 79% of all households (24, 25, 29, 49), the overall result with respect to universal coverage achieved by these campaigns did not exceed 65-72%.

Other sources: campaigns

The picture seen in Table 1 and Figure 3 is supported by other data not presented in the table as they did not fulfil all the selection criteria. In the Lindi region in Tanzania, an integrated immunization/ITN campaign reached 85% of children less than five years and 80% of them received a net (27). However, due to only 53% of households in the area having any eligible children, the overall household net coverage only increased from 53% to 69%. In a nationwide polio/ITN campaign in Niger where 79% of rural households had children <5 years, 73% of eligible households picked up an LLIN at the distribution point after receiving a coupon during the house-to-house immunizations (25). One month after the campaign general household ITN coverage had increased from 6% to 61%. Interestingly, any net coverage was already 67% pre-campaign and increased to 81%, indicating that the general population had considerable access to untreated nets, presumably from the commercial sector. Better household ITN coverage of 74% (up from 9% pre-campaign) was achieved in Nigeria following a house-to-house campaign during a mass drug administration. It targeted households with both children under five and pregnant women, which therefore made the proportion of eligible households higher (32). Higher coverage rates were achieved with campaigns that included all households or family members (universal access) (30,31,49,84). LLIN distribution among displaced people in a post conflict situation in Bundibugyo district, Uganda, achieved 98% ITN coverage immediately after the campaign (31). In Gadaref, Sudan ITN distributions as part of leishmaniasis control reached 94% of households (30) and community distributions in Eritrea reached 82% (49). Lower figures for net (73%) and ITN coverage (68%) were reported in three regions in Ethiopia following a community-based general LLIN campaign (84).

The decline following campaigns without further net input is also documented from Bundibugyo where coverage with nets dropped from 98% to 76% after 12 months (85). However, part of the loss was due to people moving away and taking their nets. When only nets from people still present were considered, the loss was 11% of the originally distributed nets. In Nigeria (32), the loss after one year was 6%, and in Sudan (30) 20% after two years (excluding people who had moved away with their nets). Hassan et al. carried out a follow-up study 18 months after community distribution of 150 denier polyethylene nets in Kassala, Sudan, and they reported a loss of 7% and further 19% "totally damaged" (86). All these rates of post-campaign loss are in the same range as those shown in Table 1.

Other sources: continuous distribution

Continuous distributions using the commercial sector and a classical social marketing approach, including health facility based sales or a voucher scheme, have been reported from Malawi and Tanzania. These are very similar to those examples

presented in Table 1 and Figure 3 but limited to smaller geographical areas and preceding the data points used at national scale. Holtz and colleagues (87) reported an approximate 20%-point increase of net coverage within 15 months (16.0%-points per year) in Blantyre district, Malawi, and 6%-points (4.8%-points per year) in rural areas. The KINET project in Kilombero and Ulamga districts, Tanzania described earlier reached an increase of net coverage from 37% to 72% in three years (11.7%-points per year). While during the same time, the unassisted commercial sector sales in a neighbouring district produced a household coverage increase from 21% to 28% (2.3%-points per year) (88).

The NetMark commercial sector experience

Baume and Marin (89) present the results of repeated surveys between 2000 and 2004 in Nigeria, Senegal, Uganda and Zambia, all of which at the time had predominantly continuous distribution through retail outlets (unassisted and assisted) and some routine ANC distribution in Zambia. The increase in net coverage was 3.5%-points/year in Uganda, 3.4%-points in Nigeria, 5.6%-points in Senegal and 5.8%-points in Zambia. The rates for Uganda and Zambia are identical to those found in the national surveys (Table 1 and Figure 3) with 3-4%-points per year for Uganda and 6%-points in the early phase in Zambia.

Continuous mechanisms

The increases observed with continuous distribution suggest that, given sufficient time, these mechanisms can reach the targeted coverage levels in 8 to 18 years (Figure 3). There are, indeed, several examples to show that continuous delivery mechanisms can reach high coverage. These include The Gambia, with net coverage in the four regions reported between 51% and 76% in 1991 (90), and countries like Mali, Guinea Bissau, China (61) and Cambodia (91) with net coverage exceeding 90%.

Success of mixed models

Bhattarai et al. provide evidence from Zanzibar (92) of sequential use of different distribution mechanisms, where 2 years of free distribution to children and pregnant women through ANC and local leaders was followed by a campaign targeting the same group. Three household surveys were undertaken at baseline, before and after the campaign. During the two years of continuous distribution a 12%-point annual increase in net use rates in children was achieved (from 35% to 59%) and another 34%-point increase following the campaign (59% to 93%), very much like the rates seen in Figure 3. Khatib et al. (63) reported from Rufiji district, Tanzania where commercial sector sales, social marketing and the National Voucher Scheme were combined in an integrated child health campaign to deliver ITN to children. While the immediate result of the campaign was already reported above (27), this survey was undertaken 3 years after. Again only net use rates are given (87% for infants, 82% young children, 54% older children, 60% adults) but these suggest a sustained high coverage following the 69% household coverage rate achieved after the campaign. Most importantly, analysis of source of existing nets by age group (63) demonstrates the contributions of each mechanism, with the voucher scheme being the most important source for infants (42%), campaign nets for young children (50%), campaign and commercial market equal for older children (37% and 38%) and commercial market for adults (60%). Another mixed approach is reported from Kenya by Noor et al. (26). Three annual surveys in four districts coincided with three distinct phases of ITN delivery. Following two years of subsidized commercial sales (classical social marketing model), the household net coverage was 25% (approximately 10%-point increase per year assuming a 5% baseline coverage). This was followed by highly subsidized ANC based distribution in the second year, increasing net coverage by 22%-points to 46% and then a measles/ITN campaign targeting children in the third year added another 33%-points to reach 79% coverage. Noor et al. also recently compared the outcome of ITN distribution efforts in Africa based on nationally representative surveys (93), categorizing countries in to predominantly free distribution, routine subsidized delivery and full cost recovery. Although only ITN use by children is presented and the duration of distribution by each mechanism is not considered, the main conclusion is in keeping with the findings presented so far: free distributions achieved the highest (fastest) increases followed by subsidised routine service delivery while full cost recovery was lowest (slowest).

Evidence from modelling

Further evidence on the coverage outcome of distribution mechanisms or strategies comes from simulation models (94). A simple compartmental model was used that applies the relationship between mean number of nets per net-owning households and coverage with any net derived from empirical data similar to that shown by Miller et al. (95) to translate annual net crop (i.e. the existing nets at the end of the year) into coverage estimates. The net crop for each year is adjusted for losses of previously distributed nets by using a

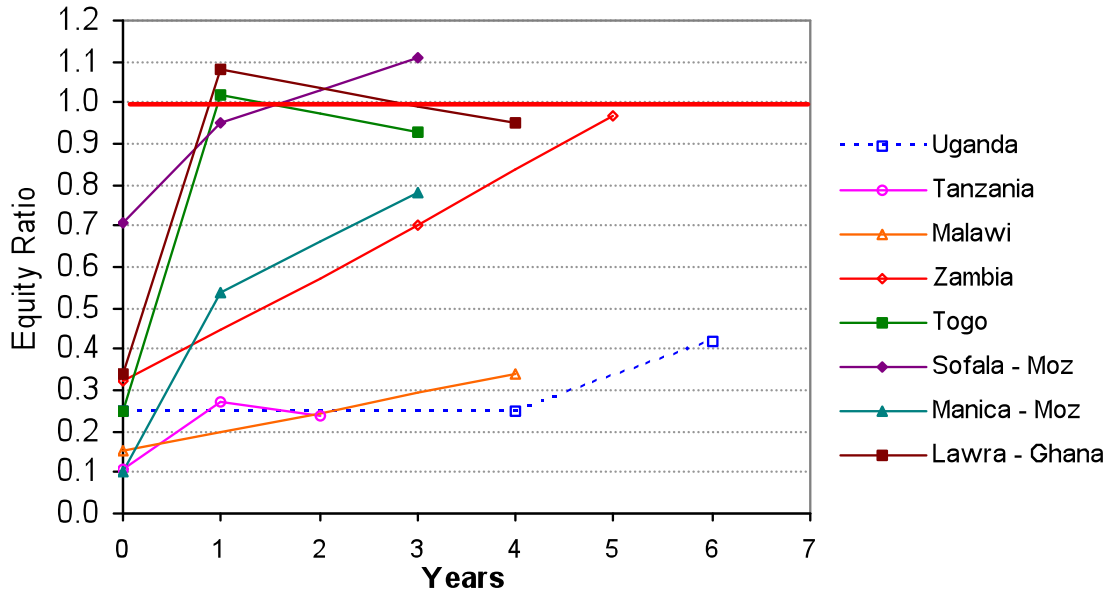

Figure 4: Equity ratios for ITN ownership (solid line) or any net (dotted line) over time. Open symbols represent distribution strategies with continuous net delivery (details see Table 1 and text), in Zambia this was followed by campaigns (mixed approach).

non-linear loss function, which implies a loss of 3% or 7% after one year depending on net type, and 10% or 26% after two years, and has a mean net durability of 3 and 5 years respectively. This is a loss rate very similar to that which has been reported from the field (see above). Simulating implementation of only campaign-style distributions repeated every three to five years resulted in model output with high initial coverage but drop in coverage of up to 40%-points before the next campaign. Continuous distribution models based on ANC and EPI coverage plus 20% of households obtaining an additional net from the commercial sector, on the other hand, reached coverage levels of 70% and more only after 8 years of implementation. Rapid scale-up combined with continuous high coverage levels was only obtained in these simulations with mixed delivery strategies combining campaigns with continuous distributions.

Intra-household net coverage and "universal access"

We have so far only considered net ownership of at least one net or ITN/LLIN per household as assessment of coverage outcome. While this is a good indicator for geographical spread, it does not say much about intra-household net coverage or saturation as it is implied in the "universal coverage" approach now widely accepted (6). There is evidence that the mean number of nets per household increases as ownership of "at least one net" increases (93, 94) and also that some intra community redistribution of nets takes place (63). To fully evaluate this aspect of distribution, a measure such as "proportion of sleeping places covered", "proportion of households with full coverage" or at least the ratio between family members and nets would be needed. However, only very few studies have reported on this aspect. The mean number of people sharing a net has been reported from several countries in Latin America (42) where it varied between one and three. In Africa, one study reports from five countries (96) with an average of 2.03 to 2.37 and a range of 1.7 to 2.7. In Mozambique, they reported a mean of 2.1 varying between 1.8 and 2.4 depending on wealth quintile and number of persons in the house (70). From Eritrea, Macintyre et al. (97) reported the mean nets-per-two-occupant ratio as 0.82 to 1.0; equivalent to a mean people-to-net ratio of 2.0-2.43 following a combined campaign/ANC services distribution. This study, in addition, presented the proportion of households with all members using a net last night as only 32.9% even when 90.6% of households had at least one net. The same indicator was also reported from the Tanzania National Voucher Scheme surveys (78), which showed an increase from 23.4% to 38.4% over three years. The Cambodian Malaria Baseline Survey reported the proportion of households with "sufficient" nets,

which is defined as at least one net per 2.3 persons (91), as 37.2% of households, although at the same time, 84% of all household members reported to have slept under a net the night before the survey, and the mean people-to-net ratio was 2.6. Only two sources were found reporting the average number of children under 5 sharing one net, which was estimated to be 1.4 in Ghana (22) and 1.2 in Mozambique (70). These results are not sufficient to allow a detailed analysis of intra-household coverage outcomes by distribution mechanism, and more data needs to be generated in a comparable fashion to more clearly define "universal access" within households in the future.

Equity

Equity ratios

The equity ratios of household net and ITN ownership for those scenarios presented in Table 1 are shown in Table 2. Campaign distribution achieved the most dramatic changes with equity ratios around 1.0 (equal probability for the poorest and the least poor) after the campaign with equity ratios continuing to increase in Mozambique or showing only minimal declines in Ghana and Togo (Figure 4). In contrast, the three settings with predominantly continuous distributions showed significantly lower increases not exceeding a ratio of 0.50.

Evidence from other sources

Post-campaign equity ratio improvements of a similar magnitude have been reported from the Lindi region, Tanzania, where three months after the campaign the ratio for any net ownership had increased from 0.60 pre-campaign to 0.86 and for ITN from 0.30 to 0.48 (27). A study in Zambia (28) shows an increase from 0.32 to 0.89 for ITN ownership among households, with at least one eligible child in four rural districts, and an increase from 0.60 to 1.19 in one urban district. A study also among households with children in Niger (25) showed an increase from 0.17 to 0.79 for ITN ownership.

From a continuous distribution in Tanzania, the frequently mentioned KINET social marketing project, Nathan et al. (98) reported an increase in equity ratio for any net ownership over a period of three years from 0.3 to 0.6. A similarly high equity ratio of 0.68 was also reported from Nigeria based on a consumer survey in 2000 when no campaign distributions had yet taken place and the commercial sector was the primary source of nets (64). These ratios are somewhat higher than those presented in Table 2 but clearly did not reach the same level as post-campaign results.

Concentration index

Other authors have used the concentration index to assess the equity of net distributions. Mathanga and Bowie (75) calculated concentration indices for the same Malawi data as presented in Table 2 as 0.33 for 2000 and 0.11 for 2004, showing a similar improvement as the equity ratio in this case. In Zambia, districts with classical social marketing distribution through commercial outlets were compared to districts with unassisted commercial sector sales and the reported concentration index for "ever had an ITN" was 0.34 and 0.71 respectively (99). Equity for three different, sequential distribution scenarios is described from Kenya, comparing the concentration indices for classical social marketing approach (0.28), additional highly subsidized distributions through routine services (0.13) and additional campaign with free nets targeted to children under five (0.00) (26). A similar result is provided from Rufiji district, Tanzania (63) where a concentration index for commercially obtained nets (unassisted) was found to be 0.25, that for subsidized nets from the voucher scheme 0.07 and free campaign nets 0.02. Finally, Webster et al. compared concentration indices from 28 national surveys for never-treated nets, thought to represent the unsupported commercial sector, with ever-treated nets (ITNs) as a proxy for publicly supported and subsidized net distributions and child immunization coverage (17). They found that equity for never-treated nets (median 0.17) was very similar to that of immunizations (0.08) and generally more in favour of the poor than ever-treated nets (0.45). They also related the concentration indices for nets and immunizations to the level of coverage and show a curvilinear relationship that approaches 0 (perfect equity) when coverage is above 70-80%. The study showed a decreasing variation of the concentration index as coverage increases, which is valid as high coverage levels are impossible to reach without also including significant parts of the lower wealth quintiles. This suggests that any intervention or distribution mechanism that can achieve high coverage will also reach reasonably high equity. Therefore the primary outcome of interest to judge the effectiveness of net distributions should be achieved coverage rather than equity.

Table 2: Trends over time in equity ratios of various country scenarios and distribution mechanisms or strategies. For sources see table 1. DHS=Demographic and Health Survey; MIS=Malaria Indicator Survey; HAIS=HIV/AIDS Indicator Survey

Country	Distribution and scale	Indicator	Data type	2000	2001	2002	2003	2004	2005	2006	2007	2008
Uganda	Continuous – national mainly commercial at cost sales with some subsidy and minor free distributions through CSOs	Any net (%) ITN (%)	DHS, HAIS	0.25 n.a				0.25 n.a.		0.42 0.58		
Tanzania TNVS area	Continuous – sub-national mainly subsidized ANC based distribution (voucher) and commercial at cost, some local free campaigns	Any net (%) ITN (%)	Sub-national surveys						0.28 0.11	0.38 0.27	0.45 0.24	
Malawi	Continuous – national mainly highly subsidized ANC based distribution (direct sales) and sub-sidized and at cost commercial sales	Any net (%) ITN (%)	National survey	n.a 0.15				n.a 0.34				
Togo	Campaign – national integrated with immunization campaign, no significant continuous input	Any net (%) ITN (%)	National survey, MICS				0.25 0.25	0.92 0.95		0.85 0.93		
Mozambique Sofala	Campaign – provincial integrated with measles campaign, no significant continuous input	Any net (%) ITN (%)	Provincial survey, MIS, DHS				0.71 n.a.		0.92 0.95		0.54 1.11	
Mozambique Manica	Campaign – provincial integrated with measles campaign, no significant continuous input	Any net (%) ITN (%)	Provincial survey, MIS, DHS				0.10 n.a.		0.50 0.54		0.68 0.78	
Ghana Lawra	Campaign followed by continuous – district integrated with measles campaign, followed by ANC distribution	Any net (%) ITN (%)	District survey			0.29 0.34	1.00 1.08			n.a 0.95		
Zambia	Continuous followed by campaigns – national initially mainly commercial, subsidized and free ANC, then adding campaigns	Any net (%) ITN (%)	DHS, MIS		n.a n.a		n.a 0.32*	n.a n.a		0.72 0.70		1.04 0.97

* from local pre-campaign survey (47)

Table 3: Average cost per net delivered by channel and duration of net distribution.

Channel	Duration	Cost per ITN delivered in US$				Sources
		(n)	Median	Inter-quartile Range	Range	
Community	Limited (campaign)	(12)	4.08	2.44 – 5.21	1.46 –6.40	27,28,30,31,47,105-110
Routine Services	Continuous	(6)	4.28	3.36 – 5.26	2.63 –6.24	51, 74, 105, 111,114
Retail*	Continuous	(7)	7.57	3.59 – 8.05	2.05 –8.30	88, 105, 112, 113
Community	Continuous	(3)	10.50	n.a.	4.68 -14.40	65, 115, 116

* includes social marketing and voucher schemes

Wealth index as a basis for equity assessment

Another factor that needs to be considered when interpreting equity data is the methodology by which it has been obtained. Usually this was done by an asset based wealth score (obtained by principle component analysis) from which the sample was divided into equal wealth groups (e.g. quintiles). While it has been shown that an asset based index is able to adequately reflect wealth levels (100) and some even have argued that it can better capture inequality compared to an income and consumption expenditure based score (101), there potentially are problems with reliability of the asset registration (102) or the selection of variables and interpretation of data (103) that can cause misleading or non-comparable results. Of particular importance is the fact that quintiles or other subdivisions are always data driven and therefore the comparison between the least poor 20% of the sample to the poorest 20% may mean very different things depending on whether it is a national sample or a sample of a purely rural population, where differences between households are small to begin with.

Cost per net delivered

A total of 28 data points for cost per ITN or LLIN delivered were identified from 21 studies of 12 African countries (Table 3). Half of the cost estimates (14) came from the comprehensive review of costing studies for net deliveries by Kolaczinski and Hanson (104), another five from a recent detailed analysis by Yukich and co-workers (105) and the remaining 9 from other recent studies or reports. Figure 5 plots all estimates of cost per ITN distributed by duration of distributions. They appear very similar to those of limited duration distribution (campaigns) slightly lower (median US$ 4.08 per ITN distributed) compared to continuous distributions (median US$ 5.03). However, when continuous distributions are further disaggregated by the dominant distribution channel (Table 3), the average cost for campaigns are almost identical to those from continuous distributions through routine health services but clearly higher in retail based distributions. This group includes classical social marketing schemes (75, 113) as well as voucher programmes (105, 112). Finally, three community-based programmes with continuous distributions (65, 115, 116), all of which were medium term projects of a rather small scale, appear to have higher delivery cost with a median of $ 10.50 per ITN delivered. Most of the cost estimates are for the conventional ITN, only 5 studies report on LLIN distributions (all campaigns) with a median cost of $ 4.67. Direct distribution cost (without the ITN cost) is provided for 10 distributions, six campaigns (median $ 0.88) and four continuous distributions (median $ 1.63).

Methodological constraints

Kolaczinski and Hanson have described in detail the potential limitations that are inherent in the comparison of costings for net and ITN distributions (104). They identified as the two major problems differences regarding which costs are included in the analysis and the failure to adjust financial costs to arrive at an economic cost estimate. This is also the case in three of the studies found (28,30,31). Differences in costing methodology can also be demonstrated with the data presented here, with two estimates from the same distribution scenario and country having different results. Stevens et al. (74) report the

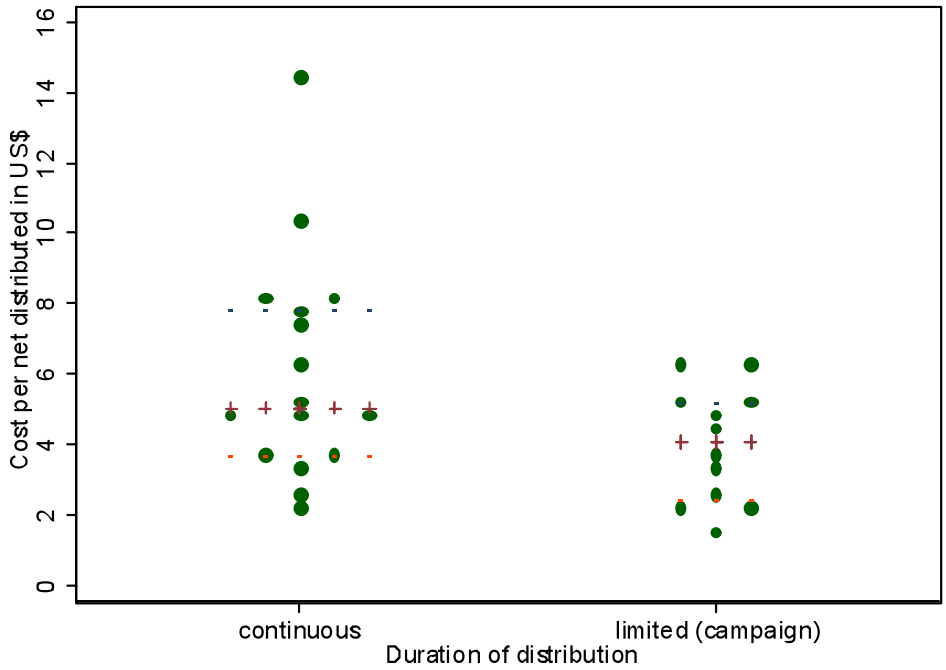

Figure 5: Cost per ITN delivered based on 21 reports from 12 African countries by distribution duration. Crosses depict median, dashed line inter-quartile range. For sources of information see Table 3. Note that methodologies are not always identical limiting comparability.

average cost per net distributed in the social marketing programme in Malawi as $ 2.63 per bundled ITN while Yukich et al. (105) report it at $ 3.36. The latter study includes a longer time period (1999-2005 rather than 1999-2003) but the actual annual estimates for each year also differ with consistently higher estimates in the Yukich et al publication. Similarly, Mueller and co-workers (110) report a cost of $ 4.41 per LLIN distributed in the Togo campaign in 2004 while Yukich et al. (105) arrive at a cost of $ 6.11, with the major difference appearing to be the way shared costs in the integrated LLIN/immunization campaign were handled.

Changes over time and scale

In addition to methodological problems, some variation also is due to changes in costs over time as distributions achieve economies of scale. In Eritrea, the cost per ITN delivered decreased with increasing net volume from $ 8.51 when 108,000 nets were distributed to $ 3.32 at a volume of 276,000 (105). In Malawi costs per net delivered in a classical social marketing scheme decreased continuously from $ 5.04 in the first year to $1.92 in the fourth in one study (74) and from $ 8.17 to $ 3.27 (in the sixth year) in the other (105). Such a decrease was, however, not always observed as the cost per ITN distributed in the Tanzania social marketing programme SMARTNET increased over time from initially $ 3.05 to $ 4.53 in the third year (105). Particularly continuous distribution mechanisms with significant start-up costs are likely to show significant declines of cost when run at scale. This is shown for the Tanzania National Voucher Scheme where the initial annual costs were estimated at $ 32.39 reducing to $8.37 in the second year and for full scale functioning projected at $ 4.62-6.84 (105).

In view of the methodological uncertainties and annual variations in costs, it appears that from the available data, no significant differences between the major distribution mechanisms can be established that would justify preference of one over the other.

Discussion and Conclusions

In this review, we have analysed delivery mechanisms by categorizing them in an open descriptive system that uses the distribution channel as the primary criterion and allows flexibility between five additional criteria, namely duration, target group, cost to end user, choice in time and type of net and sectors involved in implementation. It appears that duration can be

defined as the criterion with the second highest descriptive value and the other categories align themselves predominantly, as presented in Figure 1, on the horizontal axis. This is particularly true in the case of targeted distribution where examples of targeted or general distributions can be found for almost every channel. Community-based mechanisms seem to offer the highest flexibility but are mostly time-limited (campaigns) with free ITN delivered through a public/CSO sector mix with no choice in time or type of net. The examples in the literature are mainly targeted to vulnerable groups but examples of inclusion of the general population also exist.

Limitations

Although a very broad initial search had been applied through a wide range of search mechanisms, a selection bias may have occurred. This may have particularly applied to the "grey" literature which might bias results towards finding what one knows exists and omitting other relevant experiences. Also, a number of distribution programs – especially campaigns – are ongoing and have not been published yet, or are only available on various web-sites in insufficient detail for this review. However, we believe that this would not have lead to substantially different conclusions than those presented.

Our analysis of the core outcome variables is based on a group of scenarios for which we have defined inclusion criteria which we felt suited best the purpose (Box 1). We are aware that these are somewhat arbitrary and different criteria may have resulted in other scenarios being included. In addition, the number of data points thus utilized are few. However, in the text we also have provided a comprehensive review of all other reports found in our original search that did not fulfil our inclusion criteria and have shown that these data in principle agree with the conclusion drawn from the selected scenarios.

Finally, we have included also smaller scale distributions that have later been abandoned in our descriptive analysis. While this may appear superfluous to some, we believe that documentation of these approaches is justified as there still is a need to creatively think about new or better ways of distributions, especially in situations where common approaches do not work.

Service deliveries are continuous, limited to the service users, mostly free or subsidized, provide some choice in time and sometimes also type of net, and are either implemented by a public/CSO sector mix or all three sectors in the case of voucher schemes. Finally, delivery through formal and informal retail outlets is continuous, untargeted, at cost prices unless implemented in some form of social marketing approach (classical or total market approach in a mix with CSO and/or public sector) and provides the maximum in consumer choice.

These delivery mechanisms have been combined in various ways by countries into more comprehensive ITN delivery strategies either at national level as shown for Zambia (18) and Tanzania (55, 56) or locally as described for Lawra district in Ghana (28) and Rufiji district in Tanzania (63). In more general terms, the potential strategic combinations have been described in the RBM strategic framework of scaling up ITN programmes in Africa (19). A recent review of the delivery mechanisms for ITN concluded that not enough comparative studies were available to allow any judgement regarding the merits of one over the other (10). However, since then new data has become available a fresh look may allow inferences previously not possible. Two questions are of particular interest to National Malaria Control Programmes and the RBM community in view of the reorientation of malaria control towards elimination and ultimately eradication: i) which delivery mechanisms are most suitable to achieve universal coverage and ii) which delivery mechanisms, or combinations thereof, are best for the next critical phases towards elimination, i.e. scale-up (attack phase) and sustained control?

Universal access to LLIN

Universal access, also referred to as "full population coverage" (6, 18) is generally understood to mean that every household at risk of malaria transmission and every person within the household should be protected with an LLIN. Interestingly, no document specifically defines when "universal access" can be considered to be achieved, although the target of "80% of people at risk of malaria protected" formulated in the RBM Global Strategic Plan 2005-2015 can provide orientation (117). Alternatively, one could use the work on mass effects of ITN as a basis, which has provided solid evidence that households not protected by ITN can benefit from the ITN presence in their neighbour's house (118-121). The minimum threshold for such protective effects has been described as 50% ITN household coverage in Kenya (120) and 35%-65% by modelling approaches (122). However, these sources also clearly described a dose-response relationship so that a higher coverage, i.e. at least 80% of households, seems advantageous and very reasonable.

In order to explore how different ITN distribution mechanisms can contribute to full population coverage and where the knowledge gaps are, it is useful to divide universal access into two distinct aspects, the spatial and intra-household net coverage. Spatial coverage, i.e. the proportion of households in a sample of the total population with at least one net or ITN, is probably the most common indicator for malaria prevention with ITN targets set at 80% or higher in most country strategic plans. We have reviewed ample data for the various distributions mechanisms.

Spatial coverage

Community-based, time-limited distributions (campaigns) reached 80-98% of the eligible target population even when nets were not free but rather a small fee was charged. There is no evidence of any significant difference between integrated and stand-alone campaigns, house-to-house and fixed point distributions nor between direct and coupon based distributions, as long as the time interval between coupon and net delivery was short. However, targeting only households with young children results in coverage rates immediately following the campaign of rarely more than 70% of all households as the proportion of eligible households is in the range 50-75% depending on demographics. This implies that if universal access with household coverage rates exceeding 80% is the target, then campaigns delivering LLIN only to households with young children or pregnant women are not likely to be the best way to achieve this. Additional efforts would have to be undertaken covering the same geographical area but only a small proportion of the population. However, it does not imply that integrated campaigns combining immunization for children with LLIN distributions to the general population will not work as several examples were found that these campaigns worked well, even if different target groups existed for the different interventions (28,32,47).

Continuous distributions through routine health services have a similar limitation in that they can not generally be expected to reach 100% of clients for logistical reasons (stock-outs, time pressure during service delivery) although no actual data on reach of eligible clients was found in the review. Furthermore, the reach of the services as well as equity in access is often limited (17) so that even if the general population is the target of the services, coverage rates in the general population exceeding 80% are not likely to be reached by a single mechanism, particularly when ANC and EPI services are the ones most commonly used. Distributions through retail outlets have no restrictions with respect to eligibility but can be limited in geographical access and were shown to have the lowest equity if prices are not subsidized. However, the review has demonstrated from countries such as The Gambia (91), Mali and Guinea Bissau (17) in Africa, and China (60) and Cambodia (91) in Asia, that given the right circumstances or subsidies, a combination of continuous distributions can achieve spatial universal access.

Intra-household coverage

Coverage within the household is as yet poorly defined and no generally accepted indicator is available. The two measurements that were found in this review were a) mean people-to-net ratio with the proportion of households reaching a specific ratio as the adequate indicator for overall reach of intra-household coverage and b) the proportion of households where all members used a net/ITN last night. The latter indicator may be a good programme indicator but is not suitable for the evaluation of net delivery mechanisms as it was shown that many aspects other than the delivery influence use (25,27,30,32,40,86). The former indicator appears better suited to capture the intra-household aspect of universal coverage but also has its problems. While the available data on people sharing one net suggest that a ratio of approximately 2 people per net seems realistic in many settings, the example from Cambodia (91) clearly showed that in some situations the mean people-to-net ratio is significantly higher then 2.0, and a too low cut-off (in this case it was 2.3 or better) will lead to an underestimation of the intra-household coverage. A third option would be to measure the proportion of households with all sleeping places covered by a net/ITN. This would avoid the inclusion of behavioural aspects as well as the variations in people sharing the same net, but would need a clear definition of a sleeping place and what is to be considered "covered". Most likely a triangulation of all three measurements would be the best option, but clearly a lot more work is needed in this area.

Given the lack of clear indicators and data, the inferences that can be drawn with respect to suitability of delivery mechanisms to achieve intra-household coverage are limited. Services based distributions generally provide one net per client and visit but allow repeated deliveries over time as they are continuous. Similarly, retail based

Table 4: Comparison of objective, requirements and possible solutions for LLIN distributions in two phases of malaria control

	Scale-up (attack phase)	Sustained Control
Primary Objective	Get LLIN quickly to people and reach critical coverage levels in order to decrease transmission	Replace LLIN where and when needed and cover additional needs (population growth) to sustain high coverage levels
Requirements	Rapid increase in universal coverage with high equity and low cost. Choice in timing and net type less important when baseline LLIN coverage rates are low.	Ideally a pull system where families can acquire new LLIN when they need them and have some choice in type of net. LLIN should be free or highly subsidized for lower wealth quintiles to sustain high coverage and equity.
Possible Solution	Community-based, time-limited distributions (campaigns) that target the general population and provide sufficient free nets per family for full intra-household coverage. Implemented mainly by a public/CSO mix.	Mix of continuous distribution mechanisms that include community-, routine service-based deliveries (e.g. as free LLIN) and distribution through retail outlets. Subsidies provided through voucher schemes or total market approach. All sectors are included and systems need to be established early to avoid post-campaign dips in coverage.

distributions are only limited in number of nets accessed by the cost or affordability which, of course, can be significant (21,50,67). However, both mechanisms can significantly contribute to coverage of all family members, i.e. provision of ITNs for those not reached by campaigns, particularly when subsidies are included which has been shown in Rufiji district in Tanzania (63).

Campaigns targeted only at children under five will not achieve full intra-household coverage even when the allocation is one net per child rather than one per household with any children. This is another reason why this type of distribution does not seem adequate if universal access is the objective. Some campaigns targeting the general population have given nets according to sleeping places found, such as in Sudan (30) or number of family members such as in Uganda and Vietnam (30,35,36). These are likely to have achieved full or high intra-household coverage at least initially even if it was not documented based on findings from recent surveys in Nigeria, Uganda and Sudan (Kilian, unpublished data). For other studies in the review, only an average number of nets per household was given, e.g. two per household (34) which seems to match the mean number of people sharing a net. However, for the actual distribution at household level, it is critical how this average is translated into an allocation algorithm, as survey data on the distribution of number of members per household (69-73) strongly suggests that just applying the mean to every household will leave a high proportion of families under- and some over-supplied. Additional operational research in this area is clearly needed before any firm conclusions can be drawn.

Scale-up (attack) versus sustained control

As a first step towards trying to determine which delivery mechanisms and strategies for LLIN may be most suitable for the scale-up and sustained control phases of malaria control, we look at the overall objectives of these phases with respect to prevention with ITN and consider the desirable characteristics of interventions (Table 4).

Outcomes campaign vs. continuous distribution

Summarizing the findings from our review, it can be said that time-limited, community-based distributions (campaigns) achieved rapid increases in net coverage immediately following distribution with increases of 30-80%-points among the targeted population depending on the baseline. There was no evidence that wealthier community members are more likely to receive LLIN through this mechanism as equity ratios post distribution were found to be around the 1.0 mark of perfect equity. However, following the campaign distributions a drop in coverage could be observed if no or

minimal nets are delivered thereafter and this drop was in the range of 5-13%-points per year for the first two years. In contrast, equity ratios did nots eem to follow the same pattern and remained high, suggesting that losses of nets post-campaign do occur at similar rates among the lowest and highest wealth quintiles.

Continuous distribution mechanisms through routine services and/or retail outlets avoid coverage fluctuations but were much slower in build-up, ranging between 3 -5%-points increase per year for the unassisted commercial sector, and 6-25%-points/year for combination of commercial market with free or highly subsidized nets through routine services. These delivery mechanisms eventually also achieved high equity if or when they reached high levels of coverage (after 6-8 years) so that equity increases can be seen as a secondary effect of high coverage. Cost per net delivered for campaigns appeared slightly better than other distribution mechanisms but no definite advantage can be stated for either mechanism, given methodological and within-study variability.

Consequences for implementation

In conclusion, and keeping in mind what was discussed previously for universal access, community-based campaigns targeting the general population and providing "sufficient" LLIN per household at no cost to the user clearly seem to be the best option for the scale-up phase, as long as pre-campaign net coverage is not too high. Deciding on the best option for the phase of sustained control is a bit more ambiguous but the findings seem to support the strategies outlined in the RBM strategic framework (19) and Global Strategic Plan (117). Based on improved performance of the timing of when new nets are needed for replacement or family expansion, a mix of continuous distribution mechanisms that include community distributions and routine service-based deliveries through retail outlets appear suitable for this phase in many settings. LLIN should in part be free, partly subsidized through voucher schemes, classical social marketing or total market approach and partly at cost. Given the complexity of some of these approaches, it would be advisable to start implementation of distribution systems already during the scale-up phase in order to avoid significant post-campaign reduction of coverage. There may, however, be situations where commercial markets are not developed and public services not accessible to a sufficient part of the population, so that the question remains whether or how campaign style distributions can be used also for the sustained control phase.

Replacement using campaigns and "useful life" of the net

Campaigns usually depend on a very clear eligibility policy at the point of registration or distribution in order to be implemented smoothly and perceived as "fair". The challenge is how that could be done in situations where some but not all households need additional nets and some but not all nets need to be replaced due to physical destruction or loss. In other words, the critical issues are centred around our understanding of what has been termed the "useful life of a net", which is to date very limited. Estimates of the average life of a net have been given as early as 1994 (123) and range from 1-2 years (124) to 3 years (42) up to 7 years (125) depending on net material and study design or setting. This has lead to the more recent and commonly applied notion of a "three year" and a "five year" net with the first thought to be made from polyester and the second from polyethylene (6,18,104,105). Based on this assumption, a three to five year interval of campaigns has been suggested as feasible (18). While it is acceptable to work with a mean value of the life of a net for estimations of needs or cost, its application for campaign distributions would have to assume that there is no or at least very little variation around that mean, i.e. all nets are lost at about the same time. But this is clearly not the case. Post-campaign losses described in this review indicate that loss of nets begins immediately following distribution, even if initially physical destruction may not be the most common reason. There is also good evidence that some nets may survive much longer than the average, exceed 6 years (121) which is true for 150 denier polyethylene nets (125) as well as 70 denier polyester nets (126).

The physical condition of nets has also been explored (124,127-129) but it remains unclear how many holes make a net unusable (irrespective of the functionality of the insecticide) and to what extent this depends on perceptions by the user are subject to change over time (127). Given this situation it must be expected that at the time of a repeat or replacement campaign, a considerable proportion of families still have nets but some are in a condition that makes them useless. There are two options for the implementation of the distribution. Either new nets are given out according to the original distribution strategy ignoring any nets still present, or a detailed pre-distribution assessment

and application of a clearly defined algorithm for net replacements is undertaken. In the first scenario old nets can either be left with the owners or attempts be made to collect all previous nets. Neither of these approaches to repeat campaigns has ever been published and a great number of questions exist: what happens to excess nets in the community if old nets are left behind? Can a huge amount of nets be collected and destroyed or recycled after a campaign within reasonable logistical efforts and cost? How can we arrive at a robust algorithm of when nets should be replaced that can be applied in the field? Until these questions are answered, a general recommendation to campaigns as to the best replacement strategy for LLIN cannot be made.

What is known with high certainty

- Campaigns (community-based, time-limited distribution) can achieve rapid and equitable spatial net coverage (households with at least one LLIN) among the target group if implemented well
- Targeted campaigns only to children under five and pregnant women will not achieve universal coverage
- Shortly after distribution the net coverage will begin to drop at a rate of 5-13%-points per year if no additional nets are made available. Such losses can be avoided if this approach is combined with continuous distributions
- Continuous distributions (routine health services, retail market etc) can also achieve high spatial coverage rates but the increase is at a rate of 3-25% points per year and hence a period of 6-8 years is needed to scale up from initial low coverage rates

What is likely to be true but of less certainty

- There is no indication that integrated vs. stand-alone campaigns, house-to-house vs. central distribution point or coupon vs. direct distribution have different outcomes with respect to coverage or equity when implemented well
- Loss of nets seems to be similar among the poor and wealthy groups of society so that achieved equity levels are maintained after distributions
- As coverage rates increase above 80% , equity becomes less and less of an issue because such levels imply reasonably high rates also among the poorest.
- Cost per net distributed depend on the scale and duration of implementation as well as the analytical methodology used. Differences between campaign and continuous distributions are not very high with a possible slight advantage for campaigns

Implications for public health practice

- For rapid scale up only campaign style distributions will give quick results
- Early establishment of continuous distribution mechanisms is essential to sustain high coverage levels
- Campaigns are not very suitable for replacement distributions at this point in time and should be avoided where possible. Only if continuous strategies are not applicable in a given situation should campaigns be used creatively

Priority research areas

- Better understanding of the concept of “useful life” of net, development of methods to measure it and, based on findings, refinement of algorithms for calculation of replacement needs and mechanisms
- Clearly define indicators for intra-household coverage and based on these explore best algorithms for household net allocation to achieve universal coverage

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