Lymphatic filariasis morbidity mapping: a comprehensive examination of lymphoedema burden in Chikwawa district, Malawi

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Background: Managing lymphatic filariasis (LF) morbidity and reducing disability is one of the two primary goals of the Global Programme to Eliminate Lymphatic Filariasis. However, in order to achieve this, the geographical distribution of LF morbidity needs to be better estimated.

Methods: All cases of lymphoedema within a single health centre catchment area (pop. 42,000) in the southern region of Malawi were examined. Maps of lymphoedema burden were produced and trends in patient demographics, severity of lymphoedema (Dreyer staging) and health-seeking behaviour were explored. The number of lymphoedema cases was compared with records maintained by the Ministry of Health, Malawi.

Results: A total of 69 lymphoedema cases were identified (32 per 10,000 population), of which 48 (70%) were female and 21 (30%) male. The majority of cases (51/69) had Dreyer stage 2–3, and almost all (65/69) had experienced acute attacks as a result of their lymphoedema. This burden was much greater than that estimated by Ministry of Health (33 cases).

Conclusions: Current case detection methods underestimate the burden of lymphoedema in Malawi. There is a continued need to develop new LF morbidity identification and surveillance approaches to ensure that future morbidity management strategies are effectively targeted.

Keywords: Dreyer staging, Hydrocoele, Lymphatic filariasis, Lymphoedema, Malawi, Morbidity

Introduction

Lymphatic filariasis (LF) is a mosquito-borne parasitic infection that is currently being targeted for elimination by WHO as part of its resolution to alleviate the burden of Neglected Tropical Diseases (NTDs). Globally, an estimated 120 million people are infected with LF, and LF-related morbidity is considered to be one of the most common causes of long-term disability, affecting approximately 40 million people worldwide. Clinical manifestations are mainly in the form of limb lymphoedema or elephantiasis, affecting approximately 15 million people, and urogenital swelling, principally scrotal hydrocoele, affecting 25 million men. Further, one of the most common symptoms of LF is acute dermatolymphangioadenitis (ADLA), characterised by diffuse cutaneous inflammation and ascending lymphangitis. Other systemic symptoms include: prostration, high fevers, pain, and in rare cases, symptoms of severe sepsis. These are frequently referred to as acute attacks. ADLAs are caused by bacterial infection, such that an increase in the frequency of ADLAs is believed to be responsible for the progression of lymphoedema to elephantiasis.

The Global Programme to Eliminate Lymphatic Filariasis (GPELF) was established by WHO in 2000 with two clear aims: 1. interrupt transmission of the disease through the delivery of annual mass drug administration (MDA); 2. manage morbidity and prevent disability among those already infected with LF. Whilst much has been done to achieve the first aim of interrupting transmission, with 56 of the 73 endemic countries implementing their MDA programmes by 2013, progress to managing morbidity had been much slower such that by 2010, only 27 endemic countries had an active morbidity management component of their national LF programme. WHO recently published guidelines to assist endemic countries to successfully initiate morbidity management programmes. These guidelines recommend that morbidity data should be collected at least annually, and should include information relating to the number of patients who have lymphoedema, hydrocoele and ADLAs, further to the number of those treated for these clinical manifestations. To date, however, no standardised method for data collection and morbidity reporting has been established.

Malawi is one of the 34 countries in the African region endemic for LF, with approximately 12.8 million people at risk of infection.
with *Wuchereria bancrofti*, the most common causative agent of LF, and hence requiring preventative chemotherapy. The Malawi National LF Elimination Programme was initiated in 2008 and at least five rounds of MDA (i.e., the minimum required to interrupt transmission) have been successfully completed in all endemic districts. Following the paradigm of the African Onchocerciasis Control Programme, a community-directed approach for the delivery of MDA for LF has been adopted in Malawi, with MDA being delivered by community drug distributors (CDDs). Although there has been LF-related research conducted in Malawi, there have been no studies that have extensively quantified or mapped the prevalence of lymphoedema or hydrocele in endemic areas. While previous studies found a high number of clinical manifestations, they were very focal in distribution and only provided morbidity prevalence information for a small area (four villages in Songwe, northern region and two villages in the Lower Shire Valley, southern region).

As a first step to quantifying morbidity burden, the Malawi National LF Programme, via the CDDs, collects additional information on the number of lymphoedema and hydrocele cases during MDA. The primary aim of this study was to determine whether this information accurately reflects the magnitude and distribution of lymphoedema within Malawi. As a secondary aim, information relating to the demographic characteristics, LF knowledge and severity of condition of confirmed lymphoedema cases was collected in order to identify trends associated with this condition.

**Materials and methods**

**Study site**

This study was conducted in the Chikwawa District Hospital (CDH) catchment area, within Chikwawa district (pop. 503 000), located in the southern region of Malawi. This catchment area covers an area of 397 km² and contains 74 villages with a total population size of approximately 42 000 (8% of the total population of the district). LF is considered to be highly endemic in this area and is a priority area for the LF programme. Based on data collected during MDA in 2012, there were an estimated 33 cases of lymphoedema in the CDH catchment area, resulting in a lymphoedema prevalence estimate of 0.08%.

**Study design**

A cross-sectional survey was conducted over a 2-week period during May 2013 to verify the number of lymphoedema cases recorded during MDA. Cases were identified using the CDD network, who compiled a list of all cases residing in their respective villages prior to the start of the survey. Each case was visited by the research team and examined by a clinical officer to confirm lymphoedema. Further, cases were interviewed to determine additional information relating to demographics, knowledge and history of LF, MDA history, and reporting of lymphoedema during MDA or at the health centre. To cross-check whether all cases in a village had been identified by the CDD, all participants were asked whether they knew of anyone else in their family or village who also had lymphoedema, and these individuals were added to the list of participants. Additional participants were also recruited if they identified themselves as having lymphoedema. If participants were not present at their household during the survey, a repeat visit was arranged and if the individual was not present for three visits, it was assumed that they did not want to participate or had other responsibilities.

The Dreyer staging survey was used to assess the severity of lymphoedema (of limbs only) in the confirmed cases, and further includes questions relating to ADLAs. If an individual had multiple affected limbs, each limb was assigned a stage independently. The characteristic clinical features of each Dreyer stage (1–7) are outlined in Table 1, and example photographs of stages 1–6 in Supplementary Figure 1. Classification of lymphoedema is progressive and the patient is assigned the stage that includes their most severe clinical feature. For example, if a patient has presence of deep skin folds but does not have skin knobs present, the lymphoedema is classified as a stage 5. Participants with a Dreyer stage of 5 or above were diagnosed with elephantiasis.

GPS co-ordinates of the households of confirmed lymphoedema were recorded using a Garmin eTrex 10 (Schaffhausen, Switzerland). Following each interview, participants were provided with morbidity management advice by the clinical officer/community nurse. If participants stated in the questionnaire that they had not received MDA, this information was communicated to the senior health surveillance assistant (HSA) of the catchment area to ensure that they received ivermectin and albendazole treatment.

This study was conducted in parallel with another study in which the physical, social and economic impact of lymphoedema on affected individuals was explored, with each lymphoedema case identified in this study being further interviewed to assess the impacts. Additional information related to this study can be found in Martindale et al.

**Data analysis**

Questionnaire data were examined for trends in demographics and LF MDA history, with Pearson χ² tests being used to test for significant differences in the distribution of cases between categories (e.g., sex, age groups, whether or not the participant had received MDA). The relationship between lymphoedema stage and relevant characteristics was tested for significance using Fisher’s exact test (categorical variables), independent samples t tests and one-way ANOVA (continuous variables).

<table>
<thead>
<tr>
<th>Dreyer stage</th>
<th>Clinical feature</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Swelling is reversible overnight</td>
</tr>
<tr>
<td>2</td>
<td>Swelling is not reversible overnight</td>
</tr>
<tr>
<td>3</td>
<td>Presence of shallow skin folds (base of the fold can be seen with movement of the leg)</td>
</tr>
<tr>
<td>4</td>
<td>Presence of skin knobs</td>
</tr>
<tr>
<td>5</td>
<td>Presence of deep skin folds (base of the fold can only be seen if opened up)</td>
</tr>
<tr>
<td>6</td>
<td>Presence of ‘mossy lesions’: warty looking epidermal skin lesions</td>
</tr>
<tr>
<td>7</td>
<td>Unable to care for self or perform daily activities</td>
</tr>
</tbody>
</table>
The locations of lymphoedema cases were mapped using ArcGIS version 10 (ESRI, Redlands, CA, USA). Village-level prevalence of lymphoedema was estimated using population denominator extracted from 1 km gridded population data (AfriPop, www.afripop.org) using a 0.5 km buffer around each village. Further, the distance between each village and the nearest river and the distance each participant had to travel to the nearest health centre was calculated using road and river data obtained from Open Street Maps (http://www.openstreetmap.org). Straight line distance was used for the river distance calculations, whereas a network analysis using the local roads was used to obtain the distance to the health centre. The Pearson’s correlation coefficient between village-level prevalence of lymphoedema and distance to the nearest river was calculated and an independent samples t test was used to determine the relationship between distance and health centre reporting behaviour. Further, the relationships between the stage of lymphoedema and the mean distance to both the river and the health centre were examined using a one-way ANOVA.

Results

Overview

In total, the CDDs identified 77 lymphoedema cases to be included in the survey, plus there was one additional self-identified case, resulting in 32 villages in the CDH catchment area being visited. Of these, 2 individuals were unavailable to participate, hence a total of 76 participants were surveyed. Following a clinical examination, lymphoedema was confirmed in 69 out of 76 participants from 42% of villages in the catchment area (31/74). This number of cases was over twice the number recorded in the official MDA reports (33 cases). Of the seven reported cases who were not diagnosed with lymphoedema, no obvious signs of swelling were observed. No alternative diagnosis was made in these instances. Based on the case data collected, the catchment area lymphoedema prevalence was 16.4 per cases per 10,000 population (total), and 31.6 per 10,000 per adult population.

The locations of the 69 confirmed cases are presented in Figure 1. A table outlining the number of cases surveyed at each village and a map of village-level prevalence are also available (see Supplementary Table 1 and Supplementary Figure 2).

Demographic characteristics

Of the 69 confirmed cases of lymphoedema, 70% (48/69) were female and 30% (21/69) male (p<0.01). The median age of participants was 60 years (range: 22–90 years). As some older participants were unable to recall their exact age, their age was either estimated or classified as 60 years, and assigned to the 61–80 years age group. Table 2 outlines the age and sex distribution of the confirmed lymphoedema cases. There was no significant difference in age between males and females (p=0.786).

Of the confirmed cases, 97% (67/69) had lived in the same village for over 5 years. Of those, 60% (40/67) stated that they had been born in the same village, and had therefore always lived in an area endemic for LF. Of the 2 participants that had moved residence between 1–5 years ago, both had moved from other villages within Chikwawa district.

Village-level lymphoedema prevalence

A map of village-level lymphoedema prevalence (Supplementary Figure 2) suggested that lymphoedema prevalence was greater in villages closer to the Shire River. To explore this further, scatter plots of straight-line distance to any river, and more specifically the Shire River against estimated prevalence were produced (Figure 2). A significant negative association between prevalence and the distance to the Shire River was observed, with the correlation distance to (any) nearest river being of borderline significance $r=-0.409$; 95% CI $-0.666$ to $-0.064$ and $p=-0.346$; 95% CI $-0.627$ to $-0.009$, respectively. A curve estimation analysis indicated that a linear relationship between distance to the nearest river or distance to Shire River and prevalence could be assumed.

Clinical characteristics

Of the 69 participants with confirmed lymphoedema, 68 had at least one affected limb whereas one participant had breast lymphoedema (Supplementary Table 2). Of the limbs affected, the majority had lower limb lymphoedema (85% [41/48] females, 91% [19/21] males; p=0.916), with the highest proportion of lymphoedema occurring in the right leg for both males and females (48% [10/21] and 46% [22/48], respectively).

Of the 68 limb lymphoedema cases, 19% (13/68) had more than one limb affected. If the participant had more than one limb affected, the highest Dreyer stage was recorded. The majority of confirmed cases had stages 2–3 lymphoedema (50 cases, 74%), with only one case being diagnosed as stage 1, and no cases being diagnosed as stage 7. In addition to considering each stage (1–7) individually, Dreyer stages were divided into two groups: 1. stages 1–4 and 2. stages 5–7. Of the 68 lymphoedema cases, 83% (57 cases) had a stage of 1–4 and 17% (11 cases) had stage ≥5 i.e., elephantiasis.

There was no discernible relationship between age group and Dreyer stage group or sex and Dreyer stage group (Figure 3). Further, no significant relationship between Dreyer stage and the median distance to the Shire river or the health centre was observed (p=0.51 and p=0.08, respectively). See Supplementary Figure 3 for a map of the location of confirmed cases by Dreyer stage. For the 62 participants able to the recall the length of time for which they had their lymphoedema, the median number of years was 15 years (1–70 years), with the length of time for stage 1–4 cases being marginally less than those with stage 5 or above (15 vs 20; p=0.4).

With respect to ADLAs, 94% (65/69) of lymphoedema cases had experienced an episode during their lifetime with five participants stating that they were having an episode at the time of the survey. Table 3 outlines the frequency of ADLAs among male and female participants. Overall, 23% (16/69) stated that they had not experienced any ADLAs in the past 6 months, with no significant difference being observed between males and females (p=0.419). Of these, 75% (12/16) stated that they had more episodes in the past but these had reduced in frequency since they started receiving MDA. On average, the age of lymphoedema cases who had experienced more than one ADLA was older than those who experienced fewer ADLAs, however the difference was not statistically significant (52.5 and 59 years, respectively; p=0.13). Figure 4 outlines the mean frequency of ADLAs in the past 6 months by Dreyer stage. In general,
the number of attacks increased as the stage increased, however this trend was not statistically significant ($p = 0.541$). No relationship was observed between Dreyer stage and the duration of attacks.

Knowledge and history of LF and the Malawi National LF Elimination Programme

Results relating to the participants’ knowledge of LF include the false positive cases of lymphoedema that were identified by CDDs (76 participants). Of all participants surveyed, 83% (63/76) had heard of LF, with no significant difference observed between males and females (83% [40/48] of females and 81% [17/21] of males; $p = 0.356$). The mean age of participants who had heard of LF was 54 years compared to 68 years in those who had not heard about LF ($p = 0.016$), suggesting that older participants were less likely to have knowledge of the disease or were unaware of what it was called.

Those who had heard of LF were asked about their knowledge of LF symptoms. Of these participants, 76% (48/63) identified at least one symptom, with the main symptom identified being swelling of the limbs (85% [53/63] of those that responded). Other commonly known symptoms were pain (21 cases, 33%) and swelling of the lymph nodes (17 cases, 27%). Hydrocoele and breast lymphoedema were only mentioned as symptoms by one and three participants, respectively.

With regards to their own symptoms, 75 out of 76 participants (including 6/7 false positives) identified themselves as having lymphoedema. Of the confirmed lymphoedema cases, 54 (78%) of participants reported additional LF-related symptoms, including swelling on the lymph nodes (32/54) and pain (30/54). Four lymphoedema cases stated they also had a hydrocoele.
With respect to MDA, 61 participants had received it at least once, with only 5% of these (3/61) reporting that they received MDA the maximum number of five times. Of the 15 participants who had never received MDA, 13 were not aware of the National LF Programme. Over half of these participants (8/15) resided in one of two villages, both of which were in an area that was difficult to access (see Supplementary Table 1). None of the 76 study participants had ever been tested for LF.

In order to obtain accurate information on the number of lymphoedema cases in a community, the CDD is required to directly ask individuals to report their condition during MDA. In this catchment area, only 34% (21/61) of participants receiving MDA indicated that they had been asked about their symptoms by the CDD. Of these 95% (20/21) stated that they had reported their lymphoedema each time they were asked. The one participant who withheld this information did so due to the belief that their condition was not LF-related.

### Health centre attendance

Only the 69 participants with confirmed lymphoedema were asked questions relating to their health centre attendance. Of these, 84% (58/69) had attended the health centre for LF symptoms at least once (81% of males and 85.4% of females; p = 0.725). A significant difference (p < 0.01) was observed between the mean age of participants attending the health centre (53 years), and that of those who had not attended (72 years).

Of those that had attended the health centre, 38% (22/58) attended due to an episode of ADLA, 52% (30/58) stated they attended to receive analgesia for pain symptoms and the remaining 10% (6/58) attended for unspecified reasons relating to their lymphoedema. Of those who did not attend the health centre, three stated that they did not attend due to a lack of access to transport, four felt that their symptoms were not sufficiently serious enough to justify going to the health centre, whereas the remaining four participants felt that their condition could not be treated.

With regards to the frequency of attendance, 57% (33/58) had visited the health centre within the past 6 months, and were marginally younger than those who last attended more than 6 months ago (50 years and 57 years, respectively; p = 0.129). Of those who had last attended the health centre more than 1 year ago, 36% (5/14) reported that they had not gone back to the health centre since that time as they had been told nothing could be done about their condition.

Table 4 shows the frequency of attendance at the nearest health centre for LF-related symptoms by sex. A significant difference in the frequency of attendance between male and female participants was observed (p = 0.01), with males visiting the health centre more frequently. For example, 41% (7/17) of males visited the health centre every 2 weeks compared to 2% (1/41) of females.

### Discussion

The National LF Elimination Programme has seen substantial success since commencing MDA in 2008. All endemic districts have
now received at least five rounds of MDA, and Transmission Assessment Surveys are due to commence to assess whether this has led to the interruption of transmission.\textsuperscript{14,24} Preliminary results indicate that a combination of high MDA and bednet coverage has reduced the LF prevalence in Chikwawa, and across Malawi as a whole.\textsuperscript{14} The focus of the LF programme now needs to shift towards GPELF’s second goal of addressing the problem of LF-related morbidity. Whilst the programme has made progress towards quantifying LF morbidity at the health centre-level during MDA, morbidity data collection methods need to be improved. Further, given that MDA will be scaled-down once transmission has been shown to be interrupted, new methods and tools for morbidity surveillance need to be developed.

Overall, LF burden was higher than previously estimated, with more than twice the number of lymphoedema cases being confirmed than previously reported (69 vs 33), resulting in a prevalence 32 cases per 10 000 adults. This information, in addition to the socio-economic impact survey conducted in parallel to this study (Martindale et al.)\textsuperscript{22} provides evidence to support an increase in morbidity management and disability prevention efforts within this community.

The initial underestimation of cases can largely be attributed to incomplete information being collected by CDDs, as reflected by the large proportion of participants (66%) who were not asked whether or not they had the condition during MDA. These results, however, may be subject to recall bias as multiple disease control programmes are conducted in the district e.g., schistosomiasis and soil-transmitted helminths and as such the participants may not be able to distinguish between them. Whilst undertaking

### Table 3. Frequency of acute dermatolymphangioadenitis (ADLAs) in the past 6 months in participants with lymphoedema by sex

<table>
<thead>
<tr>
<th>Number of ADLAs in the past 6 months</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (%)</td>
</tr>
<tr>
<td>None</td>
<td>10 (21)</td>
</tr>
<tr>
<td>1</td>
<td>15 (31)</td>
</tr>
<tr>
<td>2</td>
<td>11 (23)</td>
</tr>
<tr>
<td>3</td>
<td>9 (19)</td>
</tr>
<tr>
<td>4</td>
<td>1 (2)</td>
</tr>
<tr>
<td>$\geq 5$</td>
<td>2 (4)</td>
</tr>
<tr>
<td>Total</td>
<td>48</td>
</tr>
</tbody>
</table>

ADLA: acute dermatolymphangioadenitis.

Fisher’s exact test: p-value=0.419; n=69 (all confirmed cases).

### Table 4. Frequency of attendance at the nearest health centre for symptoms relating to lymphatic filariasis (LF) in participants with lymphoedema by sex

<table>
<thead>
<tr>
<th>Frequency of attendance</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (%)</td>
</tr>
<tr>
<td>Every 2 weeks</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Monthly</td>
<td>8 (20)</td>
</tr>
<tr>
<td>Every 2 months</td>
<td>10 (24)</td>
</tr>
<tr>
<td>Every 6 months</td>
<td>9 (22)</td>
</tr>
<tr>
<td>Annually</td>
<td>4 (10)</td>
</tr>
<tr>
<td>Less than annually</td>
<td>9 (22)</td>
</tr>
<tr>
<td>Total</td>
<td>41</td>
</tr>
</tbody>
</table>

Fisher’s exact test: p-value=0.010; n=58 (participants that had visited the health centre).
this survey, it also became evident that there was some confusion amongst CDDs and HSAs in recalling LF morbidity terminology i.e., in making the distinction between the terms ‘lymphoedema’ and ‘hydrocoeles’, which may have resulted in the incorrect diagnosis being recorded during MDA. Further training of the CDDs and HSAs on the clinical symptoms of lymphoedema is therefore required.

With respect to ADLAs, previous research indicates that an increased frequency of attacks is responsible for progression to elephantiasis.5,9 In this study, there was no difference in the frequency of ADLAs between lymphoedema (stage 1–4) and elephantiasis (stage 5–7) cases (p=0.541), although this is based on a small number of cases (11/68). Progression to elephantiasis was expected to be more apparent in the older age groups or in those who had suffered with lymphoedema for a longer duration.25 This difference was not observed in the survey, which may again be due to the small sample size plus the inability of some older participants to recall their exact age.

Due to the overall lack of variability in the Dreyer staging of confirmed cases i.e., 74% (50/68) had stage 2 or 3 lymphoedema, it was difficult to fully assess the association between Dreyer stage and other clinical, demographic or behavioural characteristics. There was no relationship between distance to the health centre and Dreyer stage in this study; however, this may be due to the study site being located close to the hospital. More advanced cases of lymphoedema may reside further away from the health centre in more remote areas, however, this hypothesis requires further research, and an extension to this study may better highlight this relationship.

A statistically significant negative relationship between prevalence of lymphoedema and distance to Shire River was found. This association may be related to the local Anopheles funestus mosquitoes, which are considered to be the primary vector of LF,26 and whose preferential breeding sites are permanent water bodies such as stream pools of rivers.27,28 It is therefore plausible that there is a high transmission of filarial infection near rivers.

This study is limited by the lack of information on the aetiology of the identified lymphoedema cases. Whilst LF is the most common cause of lymphoedema in sub-Saharan Africa, it is not possible to definitively state that all identified cases were as a result of LF. For example, non-filarial causes of lymphoedema include podoconiosis, the second most common cause of lymphoedema in the tropics,29 endemic African Kaposi’s sarcoma and cellulitis.30–32 As current tests for the diagnosis of filarial lymphoedema are sub-optimal i.e., it is often not possible to detect circulating microfilariae,33 plus many cases are antigen negative,34 a differential diagnosis is commonly made through taking a patient’s history. In this instance, as podoconiosis is not known to be endemic in Malawi,32 plus all cases reported in this study have indicated that they have resided in Chikwawa district (an LF endemic area) for over 5 years, it is plausible to assume that a large proportion of the cases identified can be attributed to LF.

Conclusions
The verification of LF-related morbidity cases in Chikwawa identified important issues with the current method of collecting morbidity information during MDA, and highlighted how improvements can now be made to ensure that disease burden is better estimated. Considering the GPELF strategic plan stipulates that by 2014 all endemic countries should be collecting and reporting data on morbidity management,12 there is a need for the continued efforts to ensure the populations most in need are identified and receive the best treatment available, and take advantage of new treatment options being developed for morbidity.35–37

Supplementary data
Supplementary data are available at Transactions Online (http://trstmh.oxfordjournals.org/).

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Authors’ contributions: SZM, LAKH and MCS contributed towards the conception and design of this study; ELS and SM collected and analysed the data as part of their MSc dissertations, with assistance from MCS, LAKH and SZM; ELS and MCS drafted the manuscript. All authors read and approved the final manuscript. MCS is the guarantor of the paper.

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Ethical approval: Ethical approval was obtained from the Research Ethics Committee at Liverpool School of Tropical Medicine, UK and the National Health Sciences Research Committee, Ministry of Health, Malawi.

References


