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Hospitalizations and Costs Incurred at the Facility Level after Scale-up of Malaria Control: Pre-Post Comparisons from Two Hospitals in Zambia

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Abstract.

There is little evidence on the impact of malaria control on the health system, particularly at the facility level. Using retrospective, longitudinal facility-level and patient record data from two hospitals in Zambia, we report a pre-post comparison of hospital admissions and outpatient visits for malaria and estimated costs incurred for malaria admissions before and after malaria control scale-up. The results show a substantial reduction in inpatient admissions and outpatient visits for malaria at both hospitals after the scale-up, and malaria cases accounted for a smaller proportion of total hospital visits over time. Hospital spending on malaria admissions also decreased. In one hospital, malaria accounted for 11% of total hospital spending before large-scale malaria control compared with < 1% after malaria control. The findings demonstrate that facility-level resources are freed up as malaria is controlled, potentially making these resources available for other diseases and conditions.

INTRODUCTION

According to the most recent estimates from the World Health Organization World Malaria Report 2012, malaria accounted for approximately 660,000 deaths in 2010, of which almost 86% were among children < 5 years of age.[1] Most malaria deaths (91%) and cases occur in Africa.[1] Significant improvements have been made over the past decade in reducing the incidence of malaria. Of the 99 countries with ongoing malaria transmission, 50 of these countries are on track to reduce the incidence of reported malaria cases by 75% by 2015.[1] Globally, over the past decade, malaria incidence has decreased by 17% and malaria-specific mortality rates have decreased by 26%.[2]

The principal malaria control interventions include vector control strategies, namely the distribution of long-lasting insecticide-treated nets and the application of indoor residual spraying (IRS), as well as increased use of rapid diagnostic tests (RDTs), first-line treatment of uncomplicated *Plasmodium falciparum* malaria with artemisinin-based combination therapy (ACT), and intermittent preventive treatment of malaria for pregnant women. Zambia, where this study was conducted, is a country in southern Africa with a high prevalence of malaria. Zambia was an early adopter of effective malaria control interventions, including ACTs as a first-line

treatment, free RDTs, mass distribution of insecticide-treated nets (ITNs), and wide deployment of targeted IRS.[2,3]

Compared with evidence on the effect of malaria control on mortality and morbidity outcomes, there is less evidence about the broader impact of malaria control on the health system, particularly at the service delivery level in terms of use of services and costs incurred. Various studies find that malaria inpatient admissions decrease with better malaria control strategies, but study results differ regarding the concurrent effect on admissions for other diseases.[4–7] Other studies have provided cost estimates for treating severe versus uncomplicated malaria cases, or assessed the cost effectiveness or cost savings at the health facility from a particular malaria control intervention.[8–11]

The purpose of this study was to assess how the implementation and scale-up of malaria control in the catchment area affects the health system by focusing specifically at the hospital level. We compare the number of inpatient admissions and outpatient visits for malaria during the pre-post period when malaria control interventions were scaled up in the relevant catchment areas. We also looked at how the proportion of inpatient admissions for malaria relative to admissions for other diseases changes over this period. Finally, we estimate the total yearly costs incurred at the facility level for treating malaria admissions during the pre-post period and assess how the proportion of costs for malaria admission relative to total hospital expenditures changes over time. Unlike other studies that have focused specifically on malaria control and its relationship with inpatient admissions, or its effect on the costs incurred at the facility, this study ties these different components together to provide a more comprehensive understanding of how malaria control affects the health facility in terms of admissions and costs.

BACKGROUND

Study areas and facility selection.

Our study sites include two hospitals in the Southern Province of Zambia. These hospitals were selected because data were available during the period before significant scale-up of malaria control, thus enabling a pre-post comparison of malaria admissions and hospital costs.

The first hospital, Macha Mission Hospital (MMH), is a church-administered hospital located in rural Choma District. It has been involved in malaria research for more than 20 years and is currently the site for the Macha Research Trust, the successor to the independent Malaria Institute at Macha (MIAM), which was officially opened in 2005. This hospital has 208 beds and is the referral hospital for 13 rural health centers (RHCs) located in Choma and in the neighboring districts of Namwala and Kalomo. It has its own Hospital-Affiliated Health Center, which serves as the outpatient department. Malaria transmission has traditionally been hyper-endemic in the MMH catchment area, which covers approximately 160,000 persons.[12]

The second hospital, Livingstone General Hospital (LGH), is located in Livingstone District and serves an urban/semi-urban catchment population estimated to be 240,335.[13] As a government second-level general hospital, LGH is a referral facility for the six surrounding district-level hospitals and a direct referral hospital for 19 primary health centers (urban and rural) in Livingstone District and 17 RHCs in Kazungula District. Although LGH does not have an affiliated outpatient health center, patients can seek care from LGH on an outpatient basis by paying a bypass fee.

Malaria control in relevant catchment areas.

In 2003, the Zambian government announced the introduction of a revised malaria treatment policy using ACTs, more-effective anti-malarial drugs than chloroquine and sulfadoxine-pyrimethamine (SP). Zambia became the first country in Africa to adopt ACTs, using artemether-lumefantrine as the national first-line therapy for the treatment of uncomplicated malaria, and a phased approach. In 2006, purchasing challenges at the central level led to ACT shortages throughout Zambia, although stocks recovered to adequate levels in 2007 (Thuma P, unpublished data).

The MMH began using ACTs as its first line of treatment soon after the government announced its new policy (Figure 1). Kalomo District, in MMH's catchment area, was among the seven districts that had been first selected to receive ACTs in early 2003[14]; the ACTs then became available in Choma District in late 2003 and in Namwala District in late 2004.

In late 2003, MIAM designed a test-and-treat and community education campaign for malaria in a random sample of villages in the hospital's catchment area, whereby all positive cases (symptomatic and asymptomatic) were treated with ACTs. In 2004, this campaign was rolled out and screened 925 persons; this increased to 2,024 persons in 2005 and 3,070 persons in 2006 (Mharakurwa S, unpublished data).

In 2005, the three districts in MMH's catchment area received RDTs in line with a new policy decision by the National Malaria Control Program to roll out RDTs to all districts to strengthen confirmatory diagnosis of malaria.[15] The distribution of ITNs had been gradually scaled up in Choma District during 2003–2005. In 2007, MIAM participated in the Ministry of Health's ITN distribution for the northern part of Choma District, distributing 24,000 ITNs through eight RHCs surrounding the hospital; this increased the self-reported rate of use of an ITN in the previous night to more than 80% in MMH's catchment area.[16] Targeted IRS was rolled out in Choma District in 2008, but only in peri-urban areas, which meant that it did not reach MMH's catchment area.

At LGH, ACTs were introduced in 2003 (Figure 2); in Livingstone District, ITN distribution began in 2003 and continued during the following years (Katebe C, unpublished data). In Kazungula District, although some ITNs were distributed before 2007, mass distribution began in 2007 (Lubinda M, unpublished data). Targeted IRS began in 2005 in Livingstone District and in 2004 in Kazungula District. By 2006, IRS had been significantly scaled-up in Kazungula District.

In Kazungula District in 2007, the District Medical Office trained community health workers (CHWs) and RHC staff in the use of RDTs and community-based treatment with ACTs based on the concept of home management of malaria. This training expanded the availability of diagnostic testing and treatment to the community level by including community-based treatment through CHWs (National Malaria Control Center, unpublished data).

METHODS

Data collection.

Our study relied on longitudinal, retrospective, facility-level and patient record data collected from both hospitals. We obtained aggregate outpatient visit and inpatient admission data for

malaria at MMH from the hospital's archived disease aggregation forms and from previously compiled disease aggregation form data. Similar data on inpatient and outpatient visits for malaria at LGH were collected from Livingstone District's disease database.

Malaria inpatient record data for MMH came from an electronic database of pediatric malaria patient records (patients < 6 years of age) covering all admitted pediatric patients during 2003–2008. The records included data on age, sex, length of stay, malaria microscopy results, primary and secondary discharge diagnosis, malaria treatment, and blood transfusions. The primary and secondary diagnoses were used to categorize patients by malaria diagnosis (uncomplicated, severe, or complicated).

Recognized treatment guidelines (WHO) classify malaria based on symptoms. Severe malaria is used to classify malaria cases with specified complications such as high parasite levels, severe anemia, coma and other complications. Malaria without such symptoms are considered uncomplicated. Because the treatment of malaria differs depending on the presence of complications, for the purposes of our costing estimates, it was necessary to distinguish between malaria cases, which had a complication and malaria cases that were hospitalized and received treatment beyond ACTs or SP alone but did not involve these complications. For this paper, uncomplicated cases (for Macha only) are those that respond to ACTs or SP alone; severe malaria cases are those that do not respond to ACTs or SP alone; complicated malaria cases are those with a related complication (anemia and/or cerebral malaria).

We also obtained a subset of electronic records that were available for adult patients (patients ≥ 6 years of age). The data from male malaria patients ≥ 6 years of age covered January 2002–April 2007 and May 2008–April 2009. Female malaria records for patients ≥ 6 years of age were available only for April 2001–September 2002 and for June 2008–July 2009. The patient record data from MMH for patients ≥ 6 years of age include age, sex, length of stay, and the physician's primary diagnosis, but no data on treatment are available. None of the patient records have information on diagnostic tests except for the malaria microscopy results for patients < 6 years of age. Therefore, we assumed that patients received diagnostic testing according to the hospital's protocol.

At LGH, malaria patient record data were obtained by first reviewing paper copies of patient registries to identify malaria patients. Only a subset of all patient registers was located for the study period. We searched for patient records by identified malaria cases; only a non-random subset of patients < 5 years of age and patients ≥ 5 years of age was found in hospital archives, and this significantly limits the quality of the available data.

For 2005, 2006, 2007, and 2008, the total number of malaria records found was 133, 106, 90, and 124, respectively. Of these malaria records, the number of records for patients < 5 years of age in each of these years was 55, 21, 8, and 2, respectively, and the number of records for patients ≥ 5 years of age was 78, 85, 82, and 122, respectively. The non-random sample reflects the fact that the retrieved patient records were not obtained based on a random selection from the entire set of malaria patient records because only a subset of these records were located. Because the sample is not random, it could be biased, meaning it is not representative of the entire population of malaria patients.

From the LGH patient records, we obtained data on age, sex, length of stay, malaria treatment, other drugs provided, blood transfusions, and, when available, the results of malaria

diagnostic testing. Because not all patient records included a primary diagnosis, we retroactively assigned a malaria diagnosis when it was missing, based on consultation with the hospital's Senior Resident Medical Officer.

The categorization of each patient by malaria diagnosis was based on the available data in the patient record, which included malaria drugs, other drugs, and blood transfusions. However, there were no data in patient records on hemoglobin count (to determine severity of anemia) or malaria diagnosis (whether confirmed or unconfirmed). There were also no data on whether the patient was in coma, which may bias downwards the proportion of cerebral malaria cases because only the cases with convulsions were identified as cerebral malaria cases.

We obtained input cost data from the medical supply order forms from Medical Stores Limited. Except for ACTs, the cost data were available for only a one-year period. Thus, we applied a constant price per input over time for both hospitals. The cost data collected on RDTs include two types of available RDTs: *Plasmodium falciparum* and SD Bioline, which cost $0.16 and $0.41, respectively. Because there is uncertainty about the availability over time of these two RDTs, and how often each was used relative to the other, we used the average of both prices. Because we had yearly price data for ACTs, we accounted for their decrease in price over time.

At both hospitals, we interviewed nurses, physicians, laboratory technicians, and clinical officers to obtain a listing of all supplies and drugs used to treat and diagnose malaria, as well as costs related to procedures such as blood transfusions. To account for labor-related costs, we also relied on the hospital's malaria treatment protocols (available at MMH), and used staff interviews to obtain estimates of time spent on care of malaria patients by task. Because official malaria treatment guidelines were not available at LGH, we interviewed physicians responsible for patient care to obtain a description of malaria treatment protocol by severity and complication. For both hospitals, aggregate hospital expenditure data were obtained from the hospitals' Mid-Term Expenditure Framework Reports, as well as from human resources, laboratory, pharmacy, and stores records.

Data analysis.

Our study is structured as two case studies, rather than a comparative assessment, given differences in the availability and quality of data from each hospital. We use a pre-post approach comparing our outcomes of interest during the period before scale-up of malaria control interventions in the relevant catchment areas with those same outcomes during the period immediately after scale-up. The period selected for each hospital was based on the timing of the malaria control scale-up and data availability. For MMH, we used 2003 as the pre-period, and 2004 through 2008 as the post period. For LGH, we used 2005 and 2006 as the pre-period, and 2007 and 2008 for the post period. The differences in data availability at both hospitals required us to apply, when necessary, different analytical approaches for each hospital.

Our main outcomes of interest were 1) number of outpatient malaria visits at the hospitals' affiliated health center, 2) number of inpatient malaria admissions relative to admissions for other diseases, 3) average financial cost to the hospital of an inpatient malaria admission (by complication/year/age group), and 4) total hospital expenditures on malaria admissions relative to overall hospital expenditures by year.

In comparing malaria-related admissions and outpatient visits over time, we also included the total number of admissions/visits (for other diseases and conditions) during the pre-post period to determine whether the proportion of admissions/visits for malaria changed over time relative to other diseases. Monthly data for MMH were available for both outpatient visits and inpatient admissions, enabling us to impute missing values. Only three months of inpatient admissions for malaria were missing at Macha (2003–2008). We imputed these missing months by using the percentage change in admissions between two consecutive non-missing months, and evaluated this change at the midpoint between the two months, to avoid estimating an undefined value when the first month was equal to zero. At LGH, no imputation could be performed because monthly data were not available. Therefore, outpatient visits and inpatient admissions may be under-estimated in cases where monthly values are missing.

Our costing methods used a financial costing approach from the perspective of the hospital. We did not consider the costs to patients. We included only the direct costs of malaria patients' testing and treatment as well as overhead costs, and exclude the opportunity cost of inputs such as capital and infrastructure. Overhead costs include non-clinical staff costs, staff training, maintenance of buildings and equipment, transportation, office supplies, electricity, water, internet, and hospital project-related costs. In addition, although hospital input costs, such as RDTs, may be partly subsidized by the government or donors, our estimates represent the costs incurred by the hospital and do not reflect the total costs incurred by the government or donors.

At both facilities, we estimated the cost of inpatient malaria admissions, disaggregating our estimates by year according to patient age group and malaria diagnosis. Malaria diagnoses include uncomplicated malaria (only for patients < 6 years of age at MMH), severe malaria, malaria with anemia, malaria with severe anemia, cerebral malaria, cerebral malaria with anemia, and cerebral malaria with severe anemia. Although there are other complications that may occur as a result of malaria, such as acute renal failure and acute pulmonary edema, these are not included in our primary categorizations because they are relatively rare compared to these primary complications associated with severe malaria. For MMH, we included uncomplicated malaria as a category for inpatient admissions for patients < 6 years of age because some young patients with uncomplicated malaria may be hospitalized for better patient management (either because of patient presentation, such as vomiting, or because of distance between hospital and home).

Our costing method relied on available information from patient records regarding treatment received. Using patient record data enabled us to reflect differences between official clinical guidelines and treatment practices because of availability of resources or a physician's need to make clinical decisions while awaiting diagnostic results. For MMH, patient records were available for all malaria patients < 6 years of age during the study period; complete data on malaria treatment per case were also available. Because malaria records for patients ≥ 6 years of age at MMH lacked data on malaria treatment or blood transfusions, we use the ratio of malaria treatments provided to patients < 6 years of age, by year and by complication, to estimate malaria treatment of patients ≥ 6 years of age, adjusting for adult dosing. By accounting for differences in malaria treatment by year, we include the transition from SP to ACTs. For LGH, the malaria patient records for patients < 5 years of age and those ≥ 5 years of age included malaria treatment data by year and by complication.

The costing approach also reflects differences between the two facilities in the malaria drugs available and provided (Supplemental Table 1A). For example, at LGH, there was a higher rate of use of intravenous quinine, administered for more days, but at MMH, there was a higher rate of use of dihydroartemisinin (a monotherapy artesunate) for a subset of patients, in combination with other standard drugs (such as SP or quinine). The cost estimates for drugs include malaria drugs and other drugs, such as anti-convulsants and antibiotics, provided to treat malaria complications. We excluded the cost of drugs used to treat diagnoses not related to malaria.

Diagnostic testing by malaria complication differed between both facilities (Supplemental Table 1B) and is reflected in the cost estimates based on the treatment protocol at each facility. The MMH used microscopy for all inpatient admissions through 2006. The RDTs were introduced at MMH for outpatient visits starting in 2007, before which approximately 50% of outpatient malaria cases were diagnosed based on symptoms; by 2010, RDTs were used routinely for outpatient visits, although for inpatient admissions, they were used only when microscopy was unavailable, such as on weekends. Although microscopy was used throughout this time period to confirm inpatient admissions, microscopy was used in only approximately 50% of outpatient cases before 2007, meaning that the remaining cases were diagnosed based on symptoms. Before 2010, malaria diagnosis for outpatient visits was often based on symptoms if microscopy was not available, or if doing microscopy would delay care. Our costing assumptions presume that all MMH malaria admissions received microscopy and, beginning in 2007, only a subset first received an RDT. At LGH, RDTs were not introduced until 2012 for use in outpatient visits. The RDTs were not introduced at LGH until 2012 because the initial policy was such that any hospital, especially level 2 and upwards, with microscopy capabilities was not supplied with RDT kits. Only in 2012 did it become possible for LGH to stock and use them, after complaints from delays in providing appropriate treatment given the poor courier system from the medical/pediatrics outpatient wards and the laboratory. All inpatient malaria admissions are assumed to have received microscopy at LGH during the study period.

At both facilities, the cost of staff time per patient was estimated using the time per task related to patient diagnosis, treatment, and care, as reported through staff interviews. Yearly staff salaries are used to obtain the cost of staff per minute. The only cost input affected by the length of stay is the cost of staff time per day spent monitoring patients and administering drugs. For MMH patients < 6 years of age, we used individual-level length of stay data for patients < 6 years of age because all of their patient records were available. For MMH patients ≥ 6 years of age and for all patients at LGH, we used the average length of stay by complication and by age group but did not disaggregate by year.

To estimate total hospital expenditures on malaria admissions by year and by age group, we used the ratio of malaria complications by year/age group, our estimates of average costs by complication/year/age, and the total number of admissions for malaria by year/age. We then compared total spending on malaria admissions relative to overall hospital expenditures (for direct expenses and overhead, excluding capital and building costs) to estimate the proportion of total hospital resources devoted to malaria inpatient admissions each year.

All cost estimates (including staff costs) represent real U.S. dollars in 2008. Costs are calculated in real terms (adjusting for inflation) using 2008 Kwacha and then converted into U.S. dollars by using the average exchange rate across all months in 2008 to account for currency fluctuations.

This study was exempted from institutional review board review by the Abt Associates Institutional Review Board. The study received ethical approval from Eres Converge in Lusaka, Zambia and from the Macha Research Trust institutional review board.

RESULTS

Results for MMH.

The comparison over time of outpatient visits and inpatient admissions for malaria at MMH showed a substantial decrease in total malaria cases from 2003 through 2008 (Figure 3).

Outpatient visits and inpatient admissions for malaria at MMH represent a decreasing share of total visits during this period. The percentage of under-5 outpatient visits for malaria decreased from 42% in 2003 to 11% in 2005, increased to 21% in 2006, and reached a low of 4% in 2008 (Figure 3). At MMH, the Health Management Information System (HMIS) disease aggregation forms report data by persons < 5 years of age and those ≥ 5 years of age, and the patient ward data divide patients as pediatric (< 6 years of age) and adult (≥ 6 years of age). A similar trend was observed for the proportion of outpatient malaria visits for patients ≥ 5 years of age and for the proportion of inpatient admissions for malaria for patients < 5 years of age and those ≥ 5 years of age. Inpatient admissions for patients < 5 years of age made up 20% of all inpatient admissions in 2003 compared with 1% by 2008.

The analysis of the case-mixture of patients by disease at MMH over the study period showed that total admissions followed a similar trend to admissions for malaria (Figure 4). In 2003, the number of admissions for patients < 5 years of age was 3,170. Total admissions decreased until 2006, when there was an increase in total admissions, similar to malaria admissions. After 2006, total admissions continued to decrease to their lowest level by 2008. The analysis is restricted to the top 12 conditions for simplicity. The change over time in total admissions is not solely explained by changes in malaria admissions because admissions for other diseases (such as diarrhea, anemia, and malnutrition) also decrease during this period.

For patients ≥ 5 years of age at MMH, total admissions followed a similar trend over time during 2003–2005. Although total admissions increased in 2006, they continued to increase in 2007 but decreased by 2008. Similarly, the trend in admissions for malaria does not completely explain the change in total admissions given that admissions for other diseases increased during this period, e.g., for acquired immunodeficiency syndrome (AIDS), TB, and pregnancy complications.

Summary data (Supplemental Table 2A) from the MMH patient medical records show that for patients < 6 years of age, the percentage of admissions for uncomplicated malaria of total malaria admissions increases during the study period, compared with admissions for severe malaria or malaria with complications. As explained above, the patient record data for data are divided by pediatric ward (persons < 6 years of age) and adult ward (persons ≥ 6 years of age).

In 2003, 24% of malaria admissions for patients < 6 years of age were for uncomplicated malaria compared with 77% by 2008. By 2008, 8% of malaria admissions were for severe malaria without complications, and malaria with moderate or severe anemia accounted for 9% of malaria admissions for patients < 6 years of age, cerebral malaria accounted for 3%, and cerebral malaria with anemia accounted for 2%. The average length of stay of malaria admissions for

patients < 6 years of age increased from 4.5 days in 2003 to 9.3 days by 2008. In addition, the case-fatality rate for malaria admissions in patients < 6 years of age was 4.5% in 2003 compared with 15.5% in 2008. Nonetheless, the absolute number of deaths had substantially decreased over this period. Data from patients ≥ 6 years of age showed that the rate of malaria admissions for severe malaria was higher in 2007 than in 2003 (comparing only male patient data) and the case-fatality rate decreased. The data for 2003–2007 represent only male malaria admissions for patients ≥ 6 years of age because patient records for female patients ≥ 6 years of age were not available for these years. There may be differences in complications rates for malaria by sex, which why we do not use 2008 as a comparison year.

Using the patient record data, we found that the cost estimates for malaria admissions were disaggregated by malaria complication for patients < 6 years of age (Table 1). For patients < 6 years of age, the average cost of malaria admissions increased with the complexity of the malaria diagnosis; in 2003, the average cost of an uncomplicated malaria admission was $32 compared with $77 for malaria with severe anemia. Similarly, in 2003, cerebral malaria costs on average were $52, but cerebral malaria with severe anemia costs were $97. The main differences in average cost over time are primarily driven by the differences in length of stay by year and by complications. For example, the average length of stay for an uncomplicated malaria patient in was 5.2 days in 2003 compared with 9.8 days in 2008. Finally, the reason that cerebral malaria with moderate anemia in 2005 appears as an outlier in terms of costs is that of the three patients in this category in that year, one received six blood transfusions during the stay, and they are relatively costly. Although outlier data for length of stay were truncated, values that represent plausible lengths of stays were kept in the data.

The total average costs were estimated based on the average costs per input category (such as drugs and staff); in results not included in Table 1, the average cost of malaria drugs for uncomplicated malaria admissions among patients < 6 years of age increased from $0.36 in 2003 to $0.75 in 2004, reflecting the introduction of ACTs. Despite subsequent decreases in the unit price of ACTs, the average cost of anti-malarial drugs further increased by 2008 ($0.85) because all patients were receiving ACTs by that year. Similar per-patient costs were estimated for malaria admissions among patients ≥ 6 years of age, by complication and by year (Supplemental Table 3A). Using the average cost per patient by complication and by year, we estimated total spending by year on malaria admissions (Table 2). In 2003, total spending on inpatient malaria admissions at MMH was estimated to be $86,018, which accounts for 10.8% of total hospital expenditures in that year. In comparison, total spending for malaria patient admissions in 2008 decreased to $4,631 and accounted for 0.4% of total hospital expenditures.

Results for LGH.

A comparison over time of outpatient visits and inpatient admissions for malaria showed that total visits for malaria were relatively similar from 2005 through 2007, but there was a substantial decrease in malaria cases by 2008 (Figure 5). These trends were consistent for patients < 5 years of age and those ≥ 5 years of age, as well as for outpatient malaria visits and inpatient admissions.

As a percentage of total hospital visits, the largest change over time occurred for malaria patients < 5 years of age, who accounted for 27% of outpatient visits in 2007 compared with 5% in 2008. The percentage of inpatient malaria admissions for patients < 5 years of age relative to

total admissions for patients < 5 years of age decreased from 18% in 2005 to 2% in 2008 (Figure 5).

The analysis of the case mixture of admissions over time at LGH shows that although admissions for malaria decreased over the study period, there was an increase in total admissions of patients < 5 years of age from 2005 through 2007, after which they subsequently decreased by 2008 (Figure 6). The increase in total admissions was attributed to increases in admissions for anemia, AIDS, trauma, pneumonia, TB, and other major diseases and conditions. There was also a less pronounced decrease in admissions for diseases such as perinatal conditions, diarrhea, and malnutrition. Among patients ≥ 5 years of age, total admissions during 2005–2008 increased. Given that admissions for malaria decreased during this period, the increase in total admissions during 2005–2008 for patients ≥ 5 years of age was driven by an increase in admissions for diseases, including trauma, TB, delivery complications, and cardiovascular diseases.

Summary characteristics (Supplemental Table 4A) for the sample of patient records showed that 53% of malaria admissions for patients < 5 years of age in 2005 were for severe malaria. The rest of the patients represented admissions for malaria with complications; this proportion was relatively constant across the years. For patients ≥ 5 years of age, the proportion of admissions for severe malaria (compared with malaria with complications) was 60% in 2005 and 78% in 2008. The average length of stay of malaria admissions among patients < 5 years of age was 4.5 days in 2005 compared with 7 days in 2008. In comparison, the average length of stay for malaria admissions among patients ≥ 5 years of age was 3.7 days in 2005 and 2.7 days in 2008. There is some uncertainty about the number of cases that we categorized as cerebral malaria cases. The patient records did not have information on whether the patient was in a coma. Therefore, it is likely that certain cerebral malaria cases with coma are under-reported. Cases with seizures were identified and included as cerebral malaria cases.

The average cost estimates for admissions of malaria patients < 5 years of age were relatively similar by year and by complication (Table 3). There were certain outlier costs, such as in 2005, when cerebral malaria with anemia and malaria with severe anemia cost on average more than severe malaria. However, these cost differences do not exist for the other years. In addition, cerebral malaria appeared to cost on average more in 2006 and 2007, relative to the other years. The main cost driver explaining these differences between years and by complication is the higher proportion of patients who received intravenous quinine in certain years. At LGH, the use of intravenous quinine, including supplies such as saline solution, is relatively costly because of the length of time that patients remain receive it. At LGH, patients who receive intravenous quinine receive the treatment for 6 days (1 day with the loading dose and 5 follow-up days). As part of the treatment, they are also given saline twice per day for the length of the intravenous quinine treatment, and this saline is the main cost driver for the supplies associated with intravenous quinine.

Similar costs were estimated for patients ≥ 5 years of age at LGH (Supplemental Table 5A). On average, the costs of treating malaria patients ≥ 5 years of age was lower compared with patients < 5 years of age. This difference in average cost was largely driven by the shorter average lengths of stay.

Finally, using the proportion of patients by complication, year, and age group and the average cost of each complication (by age group and year), we estimated that total spending on

malaria admissions at LGH in 2005 was $50,008, which represented 2% of total hospital expenditures in that year (Table 4). By 2008, total spending on malaria admissions at LGH decreased to $9,346, which represented 0.3% of the hospital total expenditures in that year.

DISCUSSION

At both hospitals, the substantial decrease in outpatient visits and inpatient admissions for malaria during the study period coincides with implementation of malaria control interventions in catchment areas. For MMH, the decrease in malaria admissions from 2003 through 2005 was consistent with introduction of ACTs as the first line of treatment for uncomplicated malaria and implementation of the test-and-treat campaign. The subsequent increase in malaria admissions in 2006 was consistent with the shortage of ACTs that was experienced countrywide during that year, which may have led patients to either bypass the health center or receive hospital referrals because of treatment shortages at the lower levels of care.[16,17] In addition, ACT shortages caused recourse to less-effective monotherapy, primarily SP, to which resistance was prevalent, potentially leading to ineffective treatments that resulted in hospitalization.[18]

After 2006, malaria admissions decreased to their lowest level in 2008, which coincides with improvement in the availability of ACTs as a first-line treatment, the distribution of ITNs in the catchment area, and the high rates of ITN ownership province wide.

At LGH, the substantial decrease in outpatient visits and inpatient admissions for malaria occurred during 2007–2008. These decreases were consistent with introduction of the first mass-distribution of ITNs in Kazungula district in 2007 and implementation of CHW use of RDTs and ACTs provided through community-based treatment. Although both interventions were implemented in 2007, their effects may have been delayed, depending on the timing of the roll-out of these interventions relative to the rainy season. In addition, although IRS in Kazungula began in 2004, it was substantially scaled-up by 2007. Earlier malaria control interventions, including ITN distribution in Livingstone District in 2003, occurred before the period (2005) when data were available for this study. However, it is not clear why there was no change in the trend before 2007, given that IRS was rolled out in Livingstone District in 2005. It may be that malaria admissions and visits were even higher before 2005 and the trend from 2005 through 2007 already captured the effect of this IRS roll-out.

Given the reductions in inpatient admissions for malaria at both hospitals, we inferred the potential implications for the availability of resources for patients with other conditions. At MMH, the decrease in total hospital admissions over time was not entirely explained by the decrease in malaria admissions. However, the simultaneous decrease in admissions for diseases such as diarrhea, anemia, and malnutrition could have been influenced by the reduction in malaria prevalence if, for example, malaria affects an individual's susceptibility to other conditions, or if persons were classified by malaria-related condition such as anemia, rather than being classified as having malaria directly. In contrast, admissions for some diseases, such as AIDS among patients ≥ 5 years, increased.

At LGH, the trend in total admissions increased from 2005 through 2007, and admissions for malaria decreased. The increase in total admissions among patients < 5 years of age was attributed to increases in admissions for other diseases including anemia, AIDS, trauma, pneumonia, and TB. Among patients ≥ 5 years of age, the increase in admissions was attributed to admissions for trauma, TB, delivery complications, and cardiovascular diseases. For both

hospitals, malaria admissions accounted for a smaller share of total admissions by the end of the relevant study periods. In hospitals where resources are scarce, such as when there is full bed occupancy, the decreased burden of malaria admissions on the health facility could potentially free up resources for other patients and improve the quality of care through reduced congestion in wards.

Our cost estimates provide evidence of the financial resources used by each hospital for malaria admissions. Our results highlight that at both facilities, there is a reduction in the proportion of financial resources used to treat malaria admissions. At MMH, this ratio decreased falls from 11% of total hospital spending in 2003 to < 1% by 2008 (Table 2). At LGH, although the difference over time in the proportion is much smaller (2% in 2005 and 0.3% in 2008; Table 4), the relative change represented an 81% reduction in hospital spending on malaria admissions in 2008 compared with 2005. As a comparison, spending on malaria admissions in 2005 at MMH made up 1% of total hospital spending. The similar proportion in spending in 2005 potentially suggests that the malaria burden at MMH may have been higher to begin with, thereby explaining the larger change over time in resources devoted to malaria admissions compared with LGH. Although the reduction in the proportion of spending on malaria admissions, relative to total hospital spending, could be a function of other factors (such as an increase in total hospital spending), these observed reductions are largely driven by the reduction in total spending on malaria admissions (resulting from decreases in malaria admissions).

Compared with 2003, when total spending on malaria admissions at MMH was $86,018, total spending on malaria admissions in 2004 was $22,127, generating cost savings of $63,891 for that year. The cumulative cost savings from 2004 through 2008 is estimated to be $341,559. The cumulative cost savings is calculated as the sum of the difference between the costs of malaria admissions in each year compared to the costs of malaria admissions in 2003 for Macha and 2005 for Livingstone.

At LGH, total malaria spending in 2005 was $50,008, compared with $9,346 by 2008. The cumulative cost savings from 2006 through 2008 was $21,010. However, this comparison underestimates cost savings because malaria admissions did not substantially decrease until 2008. The estimated cost savings from 2007 through 2008 were much larger ($43,275). Overall, these results provide evidence of the financial resources that could subsequently be made available for treating other diseases and conditions, as malaria admissions decrease.

Our study also provides a more nuanced view of the financial resources hospitals use when treating malaria, because our methods rely on data from patient records. The cost estimates reflect clinical practices at each hospital rather than the treatment protocol. Particularly in contexts with shortages of resources, there may be differences between these factors. One example is the difference in use of drugs, such as antibiotics and intravenous quinine, between LGH and MMH. At LGH, 90% of malaria admissions for patients < 5 years of age were provided with antibiotics (which are relatively expensive given the length of time they are administered). At MMH, antibiotics are prescribed only to malaria patients with no other comorbidities in cases of confirmed or suspected sepsis. We suggest follow-up research to compare differences between actual treatment provided by hospitals to malaria patients and national treatment protocols and reasons for such differences. Such analyses would help highlight areas for cost savings and efficiency gains in the health system, as well as resource constraints, training and supervision needs. This research would also help identify where

guidelines may need adjusting or when gui1delines may be absent, and isolate other factors affecting quality of care.

Other factors that also influence resources used for treating malaria admissions include differences in characteristics of the patient population. For example, LGH is a referral hospital and may tend to receive relatively sicker patients than do lower-level hospitals. Although we have case-fatality estimates for malaria patients at both hospitals based on patient records, meaningful comparisons cannot be made because of the small sample size of records for LGH, which might significantly skew these outcomes.

Nonetheless, patient record data from MMH provide suggestive evidence of changes over time in patient characteristics for malaria admissions, which will affect average costs of these cases and total costs of malaria admissions overall. One important cost driver is patient's length of stay in a hospital At MMH, the average length of stay increased over time, as did the case-fatality rate for malaria admissions. At the same time, the proportion of patients being seen for uncomplicated malaria increased over time, relative to the proportion of malaria patients with severe malaria or complications. This finding may be the result of patients being admitted for other conditions as their primary diagnosis, given that the analysis did not distinguish between patients' primary and secondary diagnoses. In addition, anecdotal evidence suggests that physicians may have been more likely to admit patients with uncomplicated malaria cases as malaria admissions became rarer because physicians had less frequent exposure to severe malaria cases. Because our data were obtained from patient records, we were able to show how average costs for malaria admissions change over time in relation to changes in patient characteristics and provider behaviors in terms of treatment decisions and admission patterns.

The primary limitation of this study was data quality at LGH, where only a subset of all malaria patient records could be located. The LGH sample is therefore small and may be unrepresentative of the entire population of malaria admissions at that hospital. Because the analysis is presented by year, malaria complication, and age group, some of these categories have few observations. This situation creates large variations in costs within different categories, and these variations do not necessarily represent real cost differences. However, it was necessary to use the same methods across both hospitals for consistency.

Another limitation was the absence of coverage data for most of the malaria control interventions; without these data, it is difficult to provide causal inference on the impact of malaria control on hospital admissions and costs. Follow-up research using coverage data could provide further substantive evidence of the association between the scale-up of malaria control and its impact at the health facility level. A recent analysis of HMIS data in Zambia showed a significant decrease in the absolute number of facility-confirmed malaria cases and a marked decrease in case-fatality rates in patients < 5 years of age, which is concurrent with introduction of malaria control interventions during 2007–2008.[19] Although our analysis did not show direct causality caused by data limitations, it appeared consistent with trends observed by Chanda and others.[18,19]

We were also not able to control for concurrent interventions that might have affected health-seeking behavior related to malaria during the study period. One factor related to the introduction of RDTs; diagnosis based on clinical presentation has been shown to over-estimate the number of malaria cases, compared with the use of RDTs.[20] At MMH, part of the decrease in outpatient malaria visits during 2007–2008 could be attributed to the introduction of RDTs. However, the

decrease in malaria inpatient admissions during this same period would not be explained by RDTs because these cases are confirmed by microscopy. Outpatient visits for malaria at MMH during 2003–2006 are likely over-estimated given the higher tendency to diagnose malaria based on symptoms only.

The data for outpatient visits at LGH do not distinguish between confirmed malaria and clinical malaria, making it difficult to determine whether the number of malaria visits might be over-estimated. Given that all inpatient admissions were diagnosed based on microscopy, the introduction of RDTs in 2012 cannot explain the trends in malaria admissions during the study period. Nonetheless, anecdotal evidence suggests that even when the MPS was negative for inpatient admissions but symptoms were suggestive of malaria, a malaria diagnosis would be documented. Based on data obtained from HMIS for 2009–2011 for malaria outpatient visits show that, on average, 81% of cases were diagnosed clinically and were not confirmed through microscopy, suggesting the potential for over-estimates of malaria diagnosis for both outpatient and inpatient malaria cases during the entire study period. However, given that there were no changes in diagnosis practice during this same period, this finding would not explain the decrease in malaria cases during 2007–2008 at LGH.

Other factors may have also changed during the study period and may have affected malaria visits and admissions. Data on outpatient malaria visits at the health centers in the relevant catchment area showed similar trends to those for malaria visits and admissions at both hospitals. These similar trends at the health center level provide suggestive evidence that other factors, within the catchment areas, are less likely to explain the changes in malaria admissions at each hospital.

One important potential confounder was the widespread and severe drought during the 2004–2005 rainy season in Zambia. A study in two villages in the Macha region demonstrated that transmission was reduced virtually to zero as a result of this drought and that transmission rebounded during the 2005–2006 rainy season when the rains increased.[19] This drought could partly explain the substantial decrease in outpatient visits and inpatient admissions for malaria observed for 2005. However, it would not explain the reductions in outpatient visits and inpatient admissions for malaria observed during the 2003–2004 rainy season. In addition, because the data include later years during which there were also substantial decreases in outpatient visits and inpatient admissions for malaria (in 2007 and 2008) but no drought, our conclusions regarding the effect of malaria control scale-up at the facility level still hold.

In summary, we provide strong evidence that the decrease in inpatient admissions and outpatient visits for malaria at both hospitals occurred at the same time that the malaria control interventions were implemented and scaled up in the catchment areas for both facilities. The particular type of malaria control intervention, such as the test-and-treat campaign in MMH's catchment area, may not be representative of malaria control strategies in other settings. Nonetheless, their effectiveness in controlling malaria and the subsequent changes in health-seeking behavior at the hospital provide important evidence to inform how the health system at the facility level is affected by the scale-up of malaria control. In addition, the findings identify the magnitude of financial resources devoted to malaria admissions at each hospital and show, over time, the extent to which malaria accounts for less of the financial costs at the facility.

Further research is warranted to replicate these findings in other settings, such as in different geographic locations. Our study also highlights the need for coverage data on malaria control

strategies, data that distinguish between clinical and confirmed malaria cases, and, overall, higher quality HMIS data to better understand the impact of malaria control at the health facility level. As countries scale up and maintain coverage of malaria control interventions, there are benefits to the health facility, with resources that could be made available for other purposes, potentially including under-resourced diseases or conditions.

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FIGURE 1. Malaria interventions in Macha Mission Hospital (MMH, Zambia, catchment area. DhART = dihydroartemisinin; ACT; artemisinin-based combination therapy; IPTp = intermittent preventive treatment of malaria for pregnant women; MIAM, Malaria Institute at Macha; ITNs = insecticide-treated nets.

FIGURE 2. Malaria interventions in Livingstone General Hospital (LGH), Zambia. catchment area. IRS = indoor residual spraying; ITN = insecticide-treated net; IPTp = intermittent preventive treatment of malaria for pregnant women; ACT = artemisinin-based combination therapy; CHW = community health workers; RDTs = rapid diagnostic tests.

FIGURE 3. Outpatient visits and inpatient admissions for malaria at Macha Mission Hospital (MMH), Zambia. This figure appears in color at www.ajtmh.org.

FIGURE 4. Admissions of patients < 5 years of age, by disease, Macha Mission Hospital (MMH), Zambia. AIDS = acquired immunodeficiency syndrome; TB = tuberculosis. This figure appears in color at www.ajtmh.org.

FIGURE 5. Outpatient visits and inpatient admissions for malaria at Livingstone General Hospital (LGH), Zambia. This figure appears in color at www.ajtmh.org.

FIGURE 6. Admissions of patients < 5 years of age, by disease, Livingstone General Hospital (LGH), Zambia. AIDS = acquired immunodeficiency syndrome; TB = tuberculosis. This figure appears in color at www.ajtmh.org.

TABLE 1

Costs estimates (per admission) for inpatient malaria admissions (patients < 6 years of age), Macha Mission Hospital, Zambia

Variable	Year					
	2003	2004	2005	2006	2007	2008
Uncomplicated malaria	$32.40	$32.65	$20.26	$53.08	$35.69	$66.63
Severe malaria	$40.12	$38.15	$39.84	$47.54	$43.70	$64.70
Malaria with anemia	$37.49	$31.03	$39.16	$35.46	$26.53	$39.62
Malaria with severe anemia	$76.50	$73.61	$82.13	$62.62	$58.42	$85.78
Cerebral malaria	$52.36	$38.58	$43.09	$44.97	$47.92	$41.84
Cerebral malaria with moderate anemia	$58.24	$34.51	$112.87	$26.99	$43.19	$117.06
Cerebral malaria with severe anemia	$96.64	$90.50	$89.56	$90.29	$83.54	$65.18

TABLE 2

Summary of yearly costs for all malaria admissions at Macha Mission Hospital, Zambia*

Variable	Year					
	2003	2004	2005	2006	2007	2008
Total inpatient malaria costs (patients < 6 years of age)	$65,336	$16,897	$4,349	$25,893	$12,819	$3,187
Total inpatient malaria costs (patients ≥ 6 years of age)	$20,681	$5,230	$2,602	$10,593	$5,517	$1,443
Total costs for malaria admissions	$86,018	$22,127	$6,951	$36,486	$18,336	$4,631
Total reported hospital expenditures (real USD 2008)	$796,776	$579,701	$680,881	$716,064	$802,949	$1,272,415
Proportion of hospital expenditures on malaria admissions	10.80%	3.82%	1.02%	5.10%	2.28%	0.36%

* USD = U.S. dollars.

TABLE 3

Costs estimates (per admission) for inpatient malaria admissions (patients < 5 years of age, Livingstone General Hospital, Zambia

Variable	Year			
	2005	2006	2007	2008
Severe malaria	$60.69	$61.21	$62.17	$62.52
Malaria with anemia	$61.34	$60.62	$62.19	$62.25
Malaria with severe anemia	$80.53	$61.56	$63.35	$63.41
Cerebral malaria	$65.27	$78.06	$75.41	$62.39
Cerebral malaria with moderate anemia	$81.87	$62.91	$64.64	$64.98

TABLE 4

Summary of yearly costs for all malaria admissions at Livingstone General Hospital, Zambia*

Variable	Year			
	2005	2006	2007	2008
Total inpatient malaria costs (patients < 5 years of age)	$24,401	$27,741	$19,262	$2,308
Total inpatient malaria costs (patients ≥ 5 years of age)	$25,607	$39,305	$33,359	$7,038
Total costs for malaria admissions	$50,008	$67,047	$52,621	$9,346
Total reported hospital expenditures (real USD 2008)	$2,637,976	$2,071,604	$2,262,162	$2,949,503
Proportion of hospital expenditures on malaria admissions	1.90%	3.24%	2.33%	0.32%

* USD = U.S. dollars.

Appendix

Table 1a: Diagnostics and standard treatment protocols at both hospitals

Malaria Category	MMH	LGH
Uncomplicated malaria	• Clinical exam • Diagnostics: ▪ RDT (starting in 2007) or ▪ Malaria parasite smear/clinical diagnosis • Drugs: ▪ Paracetamol ▪ Anti-malarial (SP (later replaced) or ACT)	• Clinical exam • Diagnostics: ▪ Malaria parasite smear/clinical diagnosis • Drugs: ▪ Paracetamol ▪ Anti-malarial (SP (later replaced) or ACT) *No indication for admission*
Severe malaria	• Clinical exam • Basic diagnostics: ▪ Malaria parasite smear ▪ Full blood count • Drugs: ▪ Paracetamol ▪ Anti-malarial (SP (later replaced)/ACT/oral or intravenous (IV) quinine plus DhART	• Clinical exam • Basic diagnostics: ▪ Malaria parasite smear ▪ Full blood count ▪ Urea levels ▪ Creatinine levels ▪ Liver function tests (bilirubin direct, total) ▪ Blood glucose levels ▪ Urine microscopy

		• Drugs: ▪ Paracetamol ▪ Diclofenac ▪ Antimalarial (oral or IV quinine) ▪ If IV quinine: ▪ Dextrose drip ▪ Antibiotics (IV) ▪ Antibiotics (oral)
Malaria with anemia	• Clinical Exam • Basic diagnostics *(see severe malaria)* • Drugs: ▪ Paracetamol ▪ Anti-malarial (SP (later replaced)/ACT/oral or intravenous (IV) quinine ▪ Blood transfusion (possibly)	• Clinical Exam • Basic diagnostics *(see severe malaria)* • Drugs: ▪ Paracetamol ▪ IV quinine ▪ Dextrose drip ▪ Antibiotics (IV) ▪ Antibiotics (oral) ▪ Folic acid and iron tablets ▪ Lasix (if blood transfusion) ▪ Blood transfusion

		(possibly)
Malaria with severe anemia	• Clinical Exam • Basic diagnostics (see severe malaria) • Drugs: ▪ *See malaria with anemia* ▪ Blood transfusion (definitely)	• Clinical Exam • Basic diagnostics (see severe malaria) ▪ Additional full blood count • Drugs: ▪ *See malaria with anemia* ▪ Blood transfusion (definitely)
Cerebral malaria (Coma)	• Clinical Exam • Basic diagnostics *(see severe malaria)* ▪ Blood glucose levels ▪ Lumbar puncture and tests • Drugs: ▪ Paracetamol ▪ IV or oral quinine plus SP or DhART ▪ Dextrose drip ▪ IV fluid drip ▪ Oral rehydration solution ▪ Nasogastric tube	• Clinical Exam • Basic diagnostics *(see severe malaria)* • Drugs: ▪ Paracetamol ▪ Diclofenac ▪ IV quinine ▪ Dextrose drip ▪ Antibiotics (IV) ▪ Antibiotics (oral) ▪ Nasogastric tube ▪ Catheter

Cerebral malaria (Seizures)	• Clinical Exam
	• Basic diagnostics *(see severe malaria)*
	  ▪ Blood glucose levels
	• Drugs:
	  ▪ Paracetamol
	  ▪ IV or oral quinine plus SP or DhART
	  ▪ Dextrose drip (if IV quinine)
	  ▪ IV fluid drip (if IV quinine)
	  ▪ Phenobarbital
		• Clinical Exam
		• Basic diagnostics *(see severe malaria)*
		• Drugs:
		  ▪ Paracetamol
		  ▪ Diclofenac
		  ▪ IV quinine
		  ▪ Dextrose drip
		  ▪ Antibiotics (IV)
		  ▪ Antibiotics (oral)
		  ▪ Phenobarbital
		  ▪ Diazepam

Table 2a: Sample of patient characteristics for inpatient malaria admissions at MMH

	Patients under-6					
Patient characteristics	2003	2004	2005	2006	2007	2008
	n=1,687	n=557	n=215	n=619	n=472	n=233
Age	1.68	1.86	1.60	2.12	1.97	1.58
(St dev.)	(1.26)	(1.42)	(1.44)	(1.54)	(1.60)	(1.43)
Patient sex						
Male	49%	47%	48%	44%	46%	50%
Female	51%	53%	52%	56%	54%	50%
Malaria diagnosis						
Clinical malaria	27%	34%	67%	49%	41%	49%
Confirmed malaria	73%	66%	33%	51%	59%	51%
Uncomplicated hospitalized malaria	24%	39%	57%	39%	62%	77%
Severe malaria and complications						
Severe malaria	36.1%	24.4%	16.3%	20.4%	5.3%	8.2%
Malaria with anemia	13.3%	9.7%	7.9%	9.0%	11.4%	2.6%
Malaria with severe anemia	15.2%	12.4%	9.3%	16.2%	14.2%	6.4%
Cerebral malaria	9.2%	9.2%	5.6%	11.3%	4.4%	3.4%
Cerebral malaria with moderate anemia	1.1%	2.5%	1.4%	0.8%	1.3%	0.9%

Cerebral malaria with severe anemia	1.5%	2.7%	2.3%	3.1%	1.5%	1.3%
Length of stay (days)	4.5	5.2	6.9	5.7	5.4	9.3
(St. dev.)	(4.23)	(4.98)	(7.57)	(5.31)	(4.93)	(7.44)
Case fatality rate	4.5%	4.9%	15.4%	10.2%	5.1%	15.5%
	Patients 6 years and over (mostly men's ward)					
Patient characteristics	2003	2004	2005	2006	2007	2008
	n=119	n=41	n=11	n=48	n=17	n=16
Age	20.7	29.1	27.0	20.6	22.6	28.2
(St. dev.)	(14.94)	(20.10)	(22.25)	(18.52)	(13.80)	(14.41)
Patient sex						
Male	100%	100%	100%	100%	100%	31%
Female	0%	0%	0%	0%	0%	69%
Severe malaria and complications						
Severe malaria	79%	93%	100%	79%	94%	88%
Malaria with anemia	13%	5%	0%	15%	0%	0%
Malaria with severe anemia	1%	0%	0%	2%	0%	13%
Cerebral malaria	8%	0%	0%	4%	6%	0%
Cerebral malaria with moderate anemia	0%	2%	0%	0%	0%	0%

Length of stay (days)	4.6	5.8	2.7	4.6	5.6	3.6
(St. dev.)	(6.03)	(10.47)	(1.19)	(5.09)	(6.59)	(2.70)
Case fatality rate	6%	5%	0%	2%	0%	13%

Table 3a: Costs estimates for inpatient malaria admissions among patients 6 years and over at MMH

Patients 6 years and over						
	2003	2004	2005	2006	2007	2008
Severe malaria	$48.65	$42.60	$34.17	$53.84	$39.13	$47.51
Malaria with anemia	$65.99	$55.51	$54.60	$69.54	$51.17	$61.85
Malaria with severe anemia	$89.25	$79.54	$78.45	$90.60	$75.61	$79.87
Cerebral malaria	$84.09	$57.37	$51.03	$85.57	$53.47	$62.49
Cerebral malaria with moderate anemia	$89.74	$81.46	$99.09	$96.65	$71.15	$101.71

Table 4a: Sample of patient characteristics for inpatient malaria admissions at LGH

Patients under-5				
Patient characteristics	2005	2006	2007	2008
	n=55	n=21	n=8	n=2
Age (mean)	0.85	1.24	0.75	NA
Patient sex				
Male	0.65	0.619	0.5	NA
Female	0.35	0.381	0.5	NA
Severe malaria and complications				
Severe malaria	53%	57%	38%	50%
Malaria with anemia	33%	33%	13%	50%
Malaria with severe anemia	4%	0%	0%	0%
Cerebral malaria	7%	10%	50%	0%
Cerebral malaria with moderate anemia	4%	0%	0%	0%
Cerebral malaria with severe anemia	0%	0%	0%	0%
Average length of stay (days)	4.5	4.6	NA	7
Case fatality rate	7%	0%	100%	50%

Patients 5 years and over (continued)				
Patient characteristics	2005	2006	2007	2008
	n=78	n=85	n=82	n=122
Age (mean)	33.7	29.4	30.5	34.0
Patient sex				
Male	0.54	0.31	0.23	0.59
Female	0.46	0.69	0.77	0.41
Severe malaria and complications				
Severe malaria	60%	55%	68%	78%
Malaria with anemia	21%	29%	16%	9%
Malaria with severe anemia	3%	0%	12%	1%
Cerebral malaria	12%	4%	9%	9%
Cerebral malaria with moderate anemia	4%	12%	6%	3%
Cerebral malaria with severe anemia	1%	0%	0%	0%
Average length of stay (days)	3.7	2.0	2.7	2.7
	(5.95)	(1.45)	(2.26)	(2.59)
Case fatality rate	18%	0%	20%	4%

Table 5a: Cost estimates for inpatient malaria admissions among patients 5 years and over at LGH

Patients 5 years and over				
	2005	2006	2007	2008
Severe malaria	$55.83	$55.76	$55.36	$55.67
Malaria with anemia	$52.43	$52.29	$53.63	$53.66
Malaria with severe anemia	$78.17	$61.82	$66.30	$63.84
Cerebral malaria	$82.09	$79.89	$85.62	$87.60
Cerebral malaria with moderate anemia	$90.98	$98.08	$102.19	$107.71

Figure 1

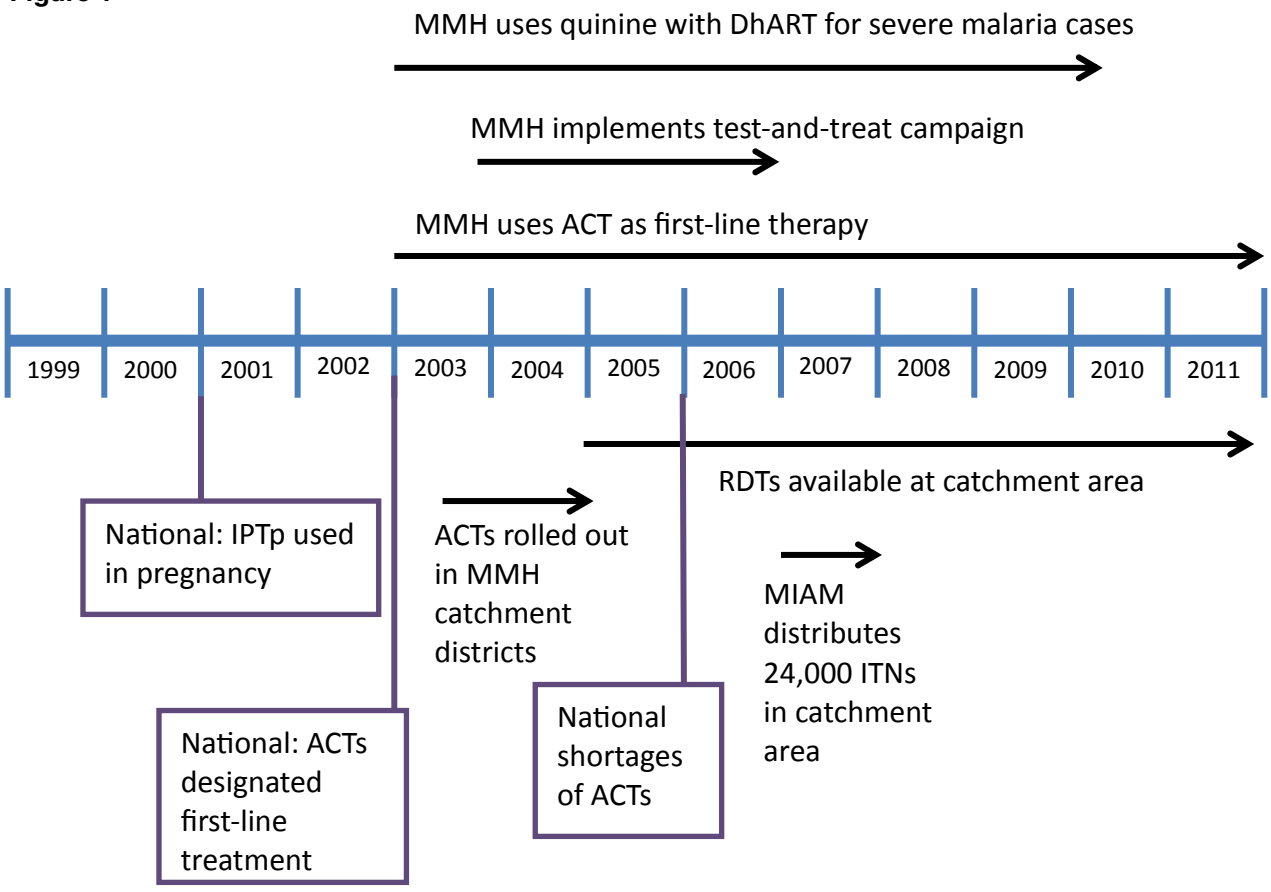

MMH uses quinine with DhART for severe malaria cases
MMH implements test-and-treat campaign
MMH uses ACT as first-line therapy
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
RDTs available at catchment area
National: IPTp used in pregnancy
ACTs rolled out in MMH catchment districts
MIAM distributes 24,000 ITNs in catchment area
National: ACTs designated first-line treatment
National shortages of ACTs

Figure 2

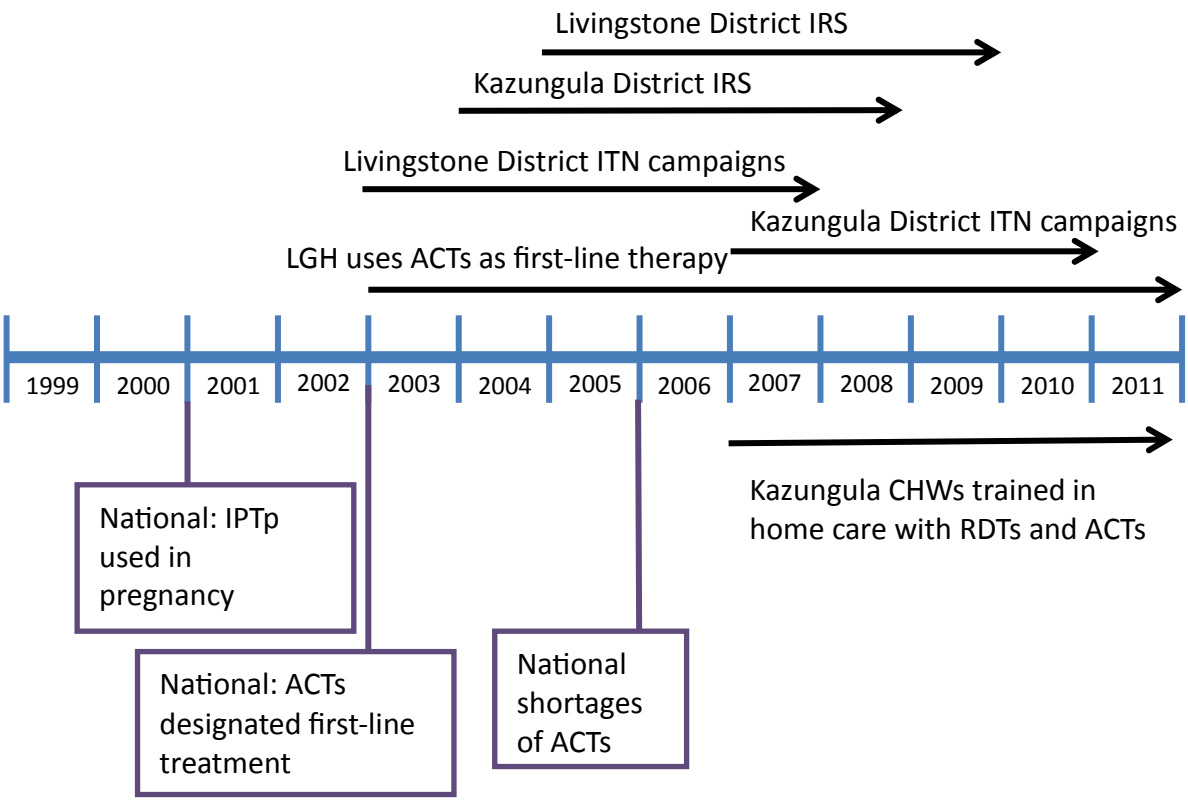
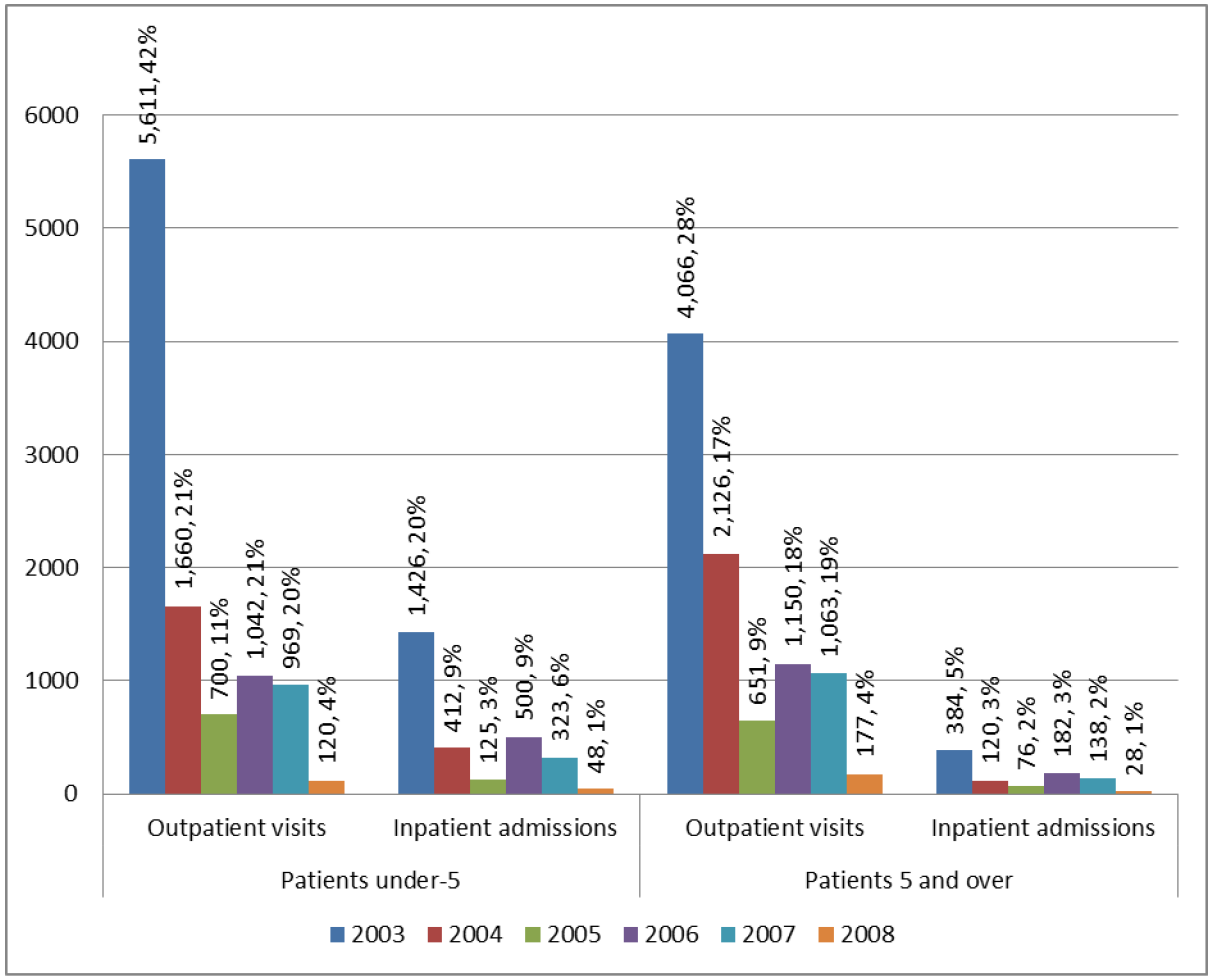

Livingstone District IRS
Kazungula District IRS
Livingstone District ITN campaigns
Kazungula District ITN campaigns
LGH uses ACTs as first-line therapy
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Kazungula CHWs trained in home care with RDTs and ACTs
National: IPTp used in pregnancy
National: ACTs designated first-line treatment
National shortages of ACTs

Figure 3



Note: The percentages represent the number of outpatient malaria visits out of total outpatient visits (by age group) at MMH and the number of inpatient malaria admissions (by age group) out of total admissions for all ages at MMH. Since data on inpatient admissions at MMH could not be disaggregated by age group, these percentages are likely to be under-estimated.

Figure 4

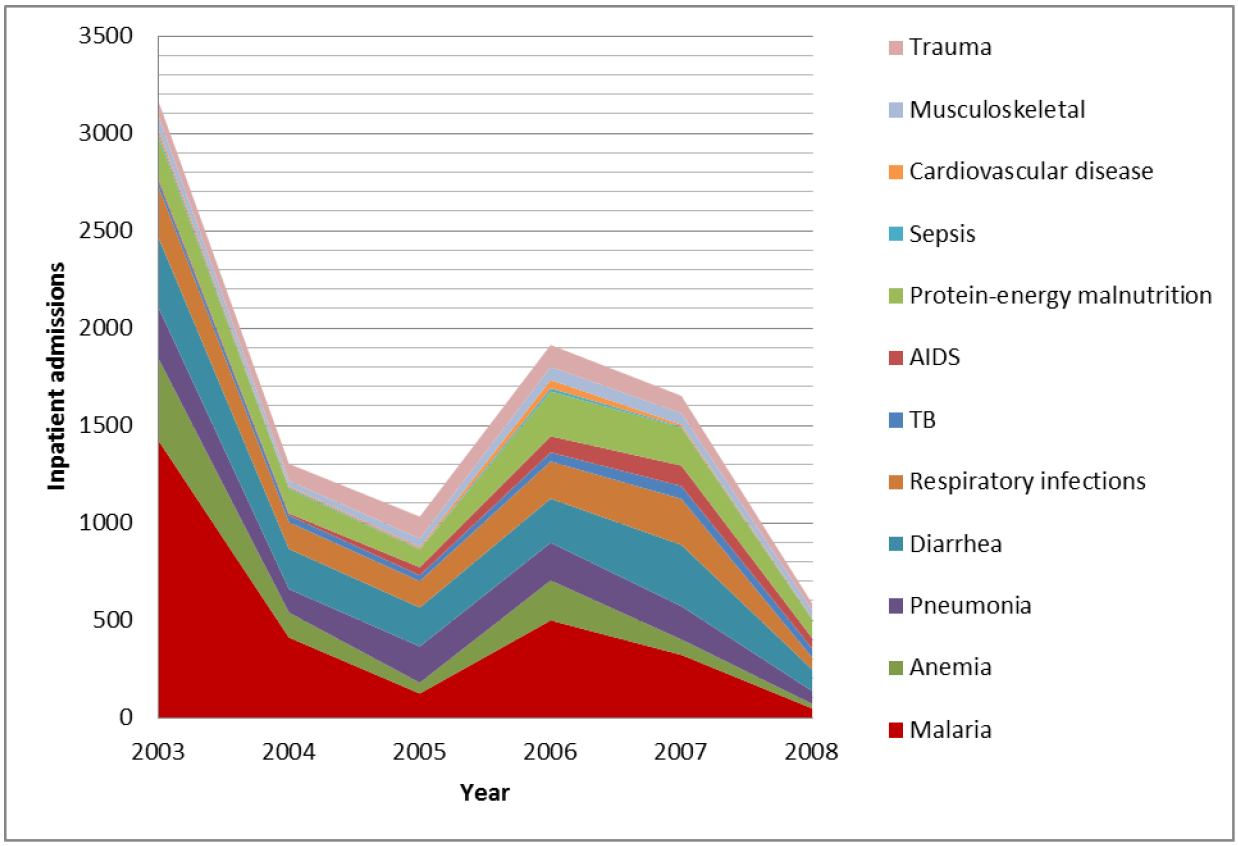
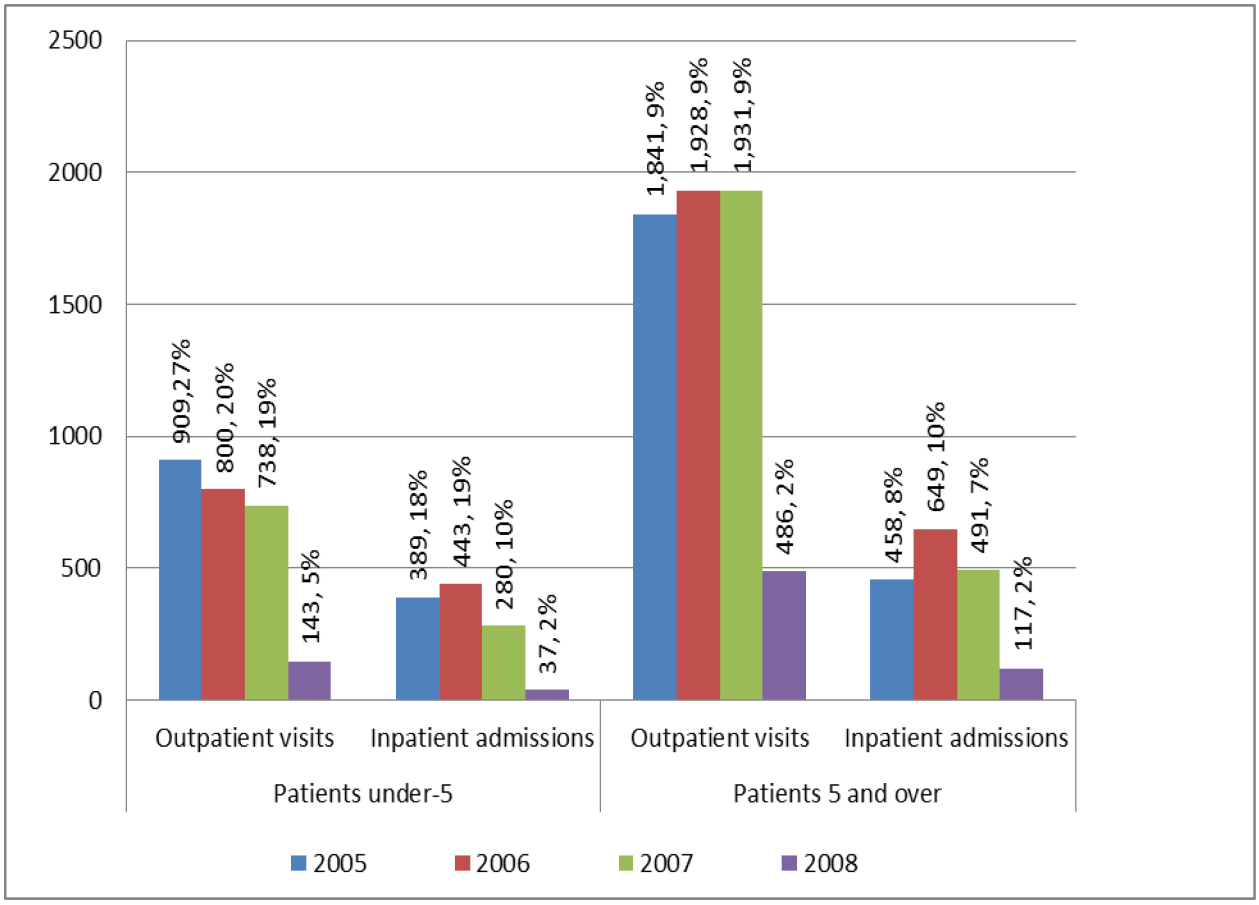
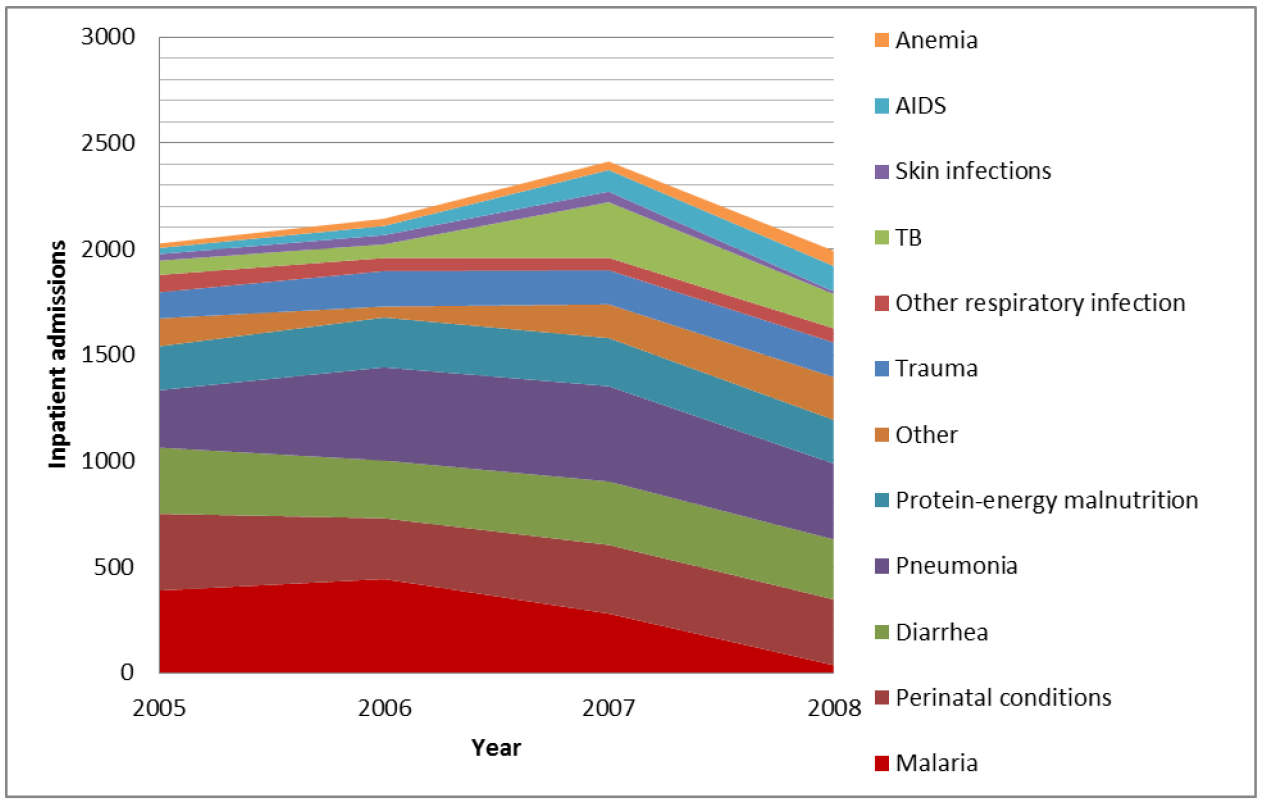

3500
3000
2500
2000
1500
1000
500
0
Inpatient admissions
2003
2004
2005
2006
2007
2008
Year
Trauma
Musculoskeletal
Cardiovascular disease
Sepsis
Protein-energy malnutrition
AIDS
TB
Respiratory infections
Diarrhea
Pneumonia
Anemia
Malaria

Figure 5



Note: The percentages represent the number of outpatient malaria visits out of total outpatient visits (by age group) at LGH and the number of inpatient malaria admissions out of total admissions at LGH (by age group).

Figure 6


3000
2500
2000
1500
1000
500
0
Inpatient admissions
2005
2006
2007
2008
Year
Anemia
AIDS
Skin infections
TB
Other respiratory infection
Trauma
Other
Protein-energy malnutrition
Pneumonia
Diarrhea
Perinatal conditions
Malaria