Determining health-care facility catchment areas in Uganda using data on malaria-related visits

Kate Zinszer,a Katia Charland,a Ruth Kigozi,b Grant Dorsey,a Moses R Kamya,b & David L Buckeridgea

Objective To illustrate the use of a new method for defining the catchment areas of health-care facilities based on their utilization.

Methods The catchment areas of six health-care facilities in Uganda were determined using the cumulative case ratio: the ratio of the observed to expected utilization of a facility for a particular condition by patients from small administrative areas. The cumulative case ratio for malaria-related visits to these facilities was determined using data from the Uganda Malaria Surveillance Project. Catchment areas were also derived using various straight line and road network distances from the facility. Subsequently, the 1-year cumulative malaria case rate was calculated for each catchment area, as determined using the three methods.

Findings The 1-year cumulative malaria case rate varied considerably with the method used to define the catchment areas. With the cumulative case ratio approach, the catchment area could include noncontiguous areas. With the distance approaches, the denominator increased substantially with distance, whereas the numerator increased only slightly. The largest cumulative case rate per 1000 population was for the Kamwezi facility: 234.9 (95% confidence interval, CI: 226.2–243.8) for a straight-line distance of 5 km, 193.1 (95% CI: 186.8–199.6) for the cumulative case ratio approach and 156.1 (95% CI: 150.9–161.4) for a road network distance of 5 km.

Conclusion Use of the cumulative case ratio for malaria-related visits to determine health-care facility catchment areas was feasible. Moreover, this approach took into account patients’ actual addresses, whereas using distance from the facility did not.

Abstracts in العربية, 中文, Français, Русский and Español at the end of each article.

Introduction

Knowledge of a health-care facility’s catchment area is important for assessing health service utilization, for calculating population-based rates of disease and for performing other important analyses. Different approaches to defining catchment areas have been developed, mostly in the field of health service research.1–3 One simple way of establishing the boundaries of a catchment area is to use distance from the facility – either the straight-line distance, the distance patients have to travel or the distance travelled by patients in a given time.6,7 Under this approach it is assumed that people will visit the closest facility, which implies that distance is the overriding factor influencing attendance. However, distance is only one of many factors that influence the choice of health-care facility; others are the services available and the perceived quality of care.5,8

Another approach, termed the patient-flow method, is based on the proportion of patients visiting or admitted to a health-care facility who come from a particular administrative area, such as a census tract or a postal code area: if the proportion exceeds a set minimum, that administrative area is included in the facility’s catchment area.8 With this approach, the catchment area is not limited by the distance between a patient’s residence and the facility. However, an arbitrary threshold is usually imposed on the minimum proportion of patients who must come from a particular area for it to be included in the catchment area. For example, postal code areas that account for less than 1% of admissions to a facility may be excluded from the catchment area.9 Consequently, some individuals who live in an area not considered part of a facility’s catchment area may regularly attend the facility. The likelihood that these minority “users” would be regarded as living outside the catchment area increases with the size of the administrative area. Another limitation is that an area may be excluded from the catchment area even though a large proportion of its population, or even the entire population, uses the facility because the proportion of patients attending the facility that are from that area does not exceed the minimum.9

In this case, the chance of exclusion increases as the area’s population decreases.

Here we propose a new method for defining the catchment area of a health-care facility that builds and improves on the patient flow approach: the catchment area is defined using a statistical measure – the cumulative case ratio, which is the ratio of the observed to the expected utilization of the health-care facility for a particular condition by patients in an administrative area. We illustrate our method by using data on the utilization of malaria-related services to define the catchment areas of six health-care facilities in Uganda. Then, for each facility, we compare the cumulative rate of confirmed malaria cases in the catchment area derived using this approach with the rate in areas derived using the straight line or road network distance from the facility.

Methods

In this analysis we used data on outpatients attending health-care facilities for suspected malaria collected by the Uganda

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Malaria Surveillance Project, in which a sentinel-site approach to monitoring the malaria burden in the country was adopted. The surveillance programme was implemented in a staggered fashion: it started in July 2006 and the final site opened in August 2008. We selected six sites to represent the diversity of malaria epidemiology in Uganda. They were all government, level-IV health centres that provided care free of charge, including diagnostic testing and medications, as has been described previously, and all had the laboratory equipment and trained staff needed for malaria diagnosis, case management and data collection. The data collected for each patient presenting to outpatient clinics included the patients' demographic characteristics and parish of residence, the results of malaria diagnostic tests, the diagnosis and the treatments prescribed. The parish is the second smallest administrative unit in Uganda and each parish contains 5000 to 6000 inhabitants. A standardized case report form was used and data were entered electronically at each site by a data officer, who was supported by the Uganda Malaria Surveillance Project.

We determined which parishes should be included in the catchment area of each facility using three different parameters: the straight-line distance from the facility, the road network distance from the facility and the cumulative case ratio for malaria-related visits. To derive catchment areas based on straight-line distance, we used distances of 5, 10, 20 and 30 km. These distances were selected because the 2009 Uganda Malaria Indicator Survey found that 96% of respondents lived within 9 km of a health-care facility and because the 2009 Uganda National Household Survey reported that the average distance of a household from a government hospital was 20 km. The catchment area included all parishes that fell within circles centred on the facility with radii of 5, 10, 20 and 30 km, respectively. To derive catchment areas based on the road network distance, we used road distances of 5, 10, 20 and 30 km along the road networks surrounding each facility. The catchment area included all parishes located within a road distance of 5, 10, 20 or 30 km, respectively, from the facility. In addition, parishes were included if they were located less than 2 km from the nearest road. A parish that did not lie entirely within the distance circle or within the road network distance was included in the catchment area only if over 50% of its surface area lay within the relevant limit. Otherwise, it was excluded.

The cumulative case ratio was defined as the ratio of the observed to the expected number of malaria-related visits to a facility from a parish. Malaria-related visits included all visits between 1 January 2010 and 31 December 2012 by patients who had suspected or confirmed malaria or who tested negative for the disease. We used malaria-related visits because we wanted to include all users of malaria-related services, not only confirmed cases. The expected number of malaria-related visits to a facility from a particular parish was calculated by multiplying the parish's population by the cumulative case rate for that facility. A parish was included in the catchment area if the upper limit of the 95% confidence interval for the cumulative case ratio for that parish was 1 or greater because a ratio less than 1 indicated that the parish contributed significantly fewer malaria-related visits than expected for its population.

Catchment areas were derived for each of the six sentinel sites using the three parameters and the cumulative case rate for each catchment area, however derived, over a 1-year period was calculated. The numerator was the total number of malaria cases confirmed between 1 January 2010 and 31 December 2012 from all parishes included in the catchment area. The denominator was the total population of all parishes included in the catchment area, which was derived using population estimates from the 2002 Uganda Population and Housing Census. During this period, an average of 98% of all patients with malaria symptoms were tested for malaria: the proportion ranged from 97% to 100% over the six sites.

Catchment areas were plotted on mapping files obtained from the Uganda Bureau of Statistics and the geographical coordinates of all parishes were recorded using zone 35 north of the Universal Transverse Mercator coordinate system. All analyses were performed using R software v2.14.0 and ArcGIS 10 (esri, Redlands, USA).

Results

Fig. 1 displays the cumulative case rate per 1000 population in each parish for all malaria cases confirmed during 2012 at one of the six Uganda Malaria Surveillance Project health-care facilities. The figure also shows the locations of the six facilities and the variation in disease burden and geographical spread. No catchment area definition was applied. It can be seen from the figure that the parishes with the highest cumulative case rates either contained a facility or was adjacent to one. Over 40% of parishes had a cumulative case rate of 1 per 1000 or less in 2012. Fig. 2 shows the catchment area of the Nagongera health-care facility, as determined using the three parameters: straight-line distance, road network distance and cumulative case ratio for malaria-related visits. The largest geographical area was obtained using a straight-line distance of 30 km, whereas the smallest was obtained using the cumulative case ratio. In addition, use of the cumulative case ratio led to the inclusion of noncontiguous parishes. Figures illustrating the corresponding catchment areas for the other five health-care facilities are shown in Appendix A (available at: http://surveillance.mcgill.ca/users/kzinszer/WHOBulletin/index.php).

As shown in Table 1, the cumulative rate of confirmed malaria cases varied considerably for most sites according to the way in which the catchment area was defined. In particular, the rate decreased with increasing distance from the facility for both straight-line and road network distances and, generally, was highest when the catchment area was defined using a distance of 5 km. The largest rates were observed for the catchment area of the Kamwezi health-care facility: 234.9 per 1000 when defined using a straight-line distance of 5 km, 193.1 per 1000 when defined using the cumulative case ratio and 156.1 per 1000 when defined using a road network distance of 5 km. Although the denominator in the cumulative case rate calculation became much larger as distance increased, there was no corresponding increase.
Fig. 1. Cumulative rate of confirmed malaria cases in parishes containing patients who attended six health-care facilities, Uganda, 2012

Fig. 2. The Nagongera health-care facility’s catchment area as determined using the three parameters: straight-line distance, a road network distance b and cumulative case ratio for malaria-related visits, c Uganda, 2012

<table>
<thead>
<tr>
<th>Straight line distance</th>
<th>5 km</th>
<th>10 km</th>
<th>20 km</th>
<th>30 km</th>
<th>Health-care facility</th>
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<td>+ Health-care facility</td>
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<th>Cumulative case rate quintile (cases per 1000 population)</th>
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<td>4.09–9.83</td>
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<td>9.83–22.67</td>
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<td>22.67–39.07</td>
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<td>116.15–295.51</td>
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<td>+ Health-care facility</td>
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</table>

a Catchment areas were defined as lying within a straight-line distance from the facility of 5, 10, 20 and 30 km, respectively.
b Catchment areas were defined as lying within a road network distance from the facility of 5, 10, 20 and 30 km, respectively.
c A parish was included in the catchment area if the upper limit of the 95% confidence interval for the cumulative case ratio for the parish (i.e. the ratio of observed to expected malaria-related visits from the parish) was 1 or greater.

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in the numerator. Hence, generally, the cumulative case rate decreased as the size of the catchment area increased. Table 2 shows the number of parishes included in each catchment area. When catchment areas were defined using a straight-line distance of 30 km, they included an average of 105 parishes; in contrast, when defined using the cumulative case ratio, they included an average of 10 parishes. The catchment area of the Aduku health-care facility did not contain any parishes when defined using a road network distance of 5 km (i.e. less than 50% of each parish’s area lay within the defined distance).

Table 2 shows the number of parishes included in each catchment area.

Table 1. Cumulative rate of confirmed malaria cases at six health-care facilities in Uganda, by catchment area definition, 2012

<table>
<thead>
<tr>
<th>Catchment area definition</th>
<th>Aduku facility</th>
<th>Kamwezi facility</th>
<th>Kasambya facility</th>
<th>Kihihi facility</th>
<th>Nagongera facility</th>
<th>Walukuba facility</th>
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<tr>
<td>Cumulative rate of confirmed malaria cases, CCR (95% CI)</td>
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<td>13.3 (12.8–14.0)</td>
<td>143.3 (137.8–148.9)</td>
<td>7.2 (6.8–7.5)</td>
<td>17.6 (16.8–18.5)</td>
<td>8.2 (7.6–8.8)</td>
<td>17.2 (16.8–18.0)</td>
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<td>22.0 (21.2–22.8)</td>
<td>218.3 (211.6–225.1)</td>
<td>17.1 (16.5–17.7)</td>
<td>31.0 (29.6–32.5)</td>
<td>22.9 (22.3–23.5)</td>
<td>43.8 (42.4–45.2)</td>
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<td>20</td>
<td>45.5 (44.2–47.4)</td>
<td>218.3 (211.6–225.1)</td>
<td>41.6 (40.3–43.0)</td>
<td>62.0 (60.9–63.2)</td>
<td>55.5 (54.3–56.7)</td>
<td>81.8 (80.4–83.2)</td>
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<td>30</td>
<td>72.1 (68.9–75.3)</td>
<td>218.3 (211.6–225.1)</td>
<td>49.0 (47.7–50.5)</td>
<td>90.9 (89.5–92.4)</td>
<td>72.5 (71.2–73.8)</td>
<td>112.2 (110.8–113.6)</td>
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<tr>
<td>Cumulative case ratio</td>
<td>38.1 (36.3–40.0)</td>
<td>218.3 (211.6–225.1)</td>
<td>67.2 (65.4–69.1)</td>
<td>87.6 (85.0–90.3)</td>
<td>38.4 (37.3–39.6)</td>
<td>43.3 (41.9–44.7)</td>
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CCR, cumulative case rate; CI, confidence interval; NA, not applicable.

Table 1 includes data on the health-care facilities collected by the Uganda Malaria Surveillance Project.

Discussion

The differences observed between different estimates of the cumulative rate of confirmed malaria cases in catchment areas generally occurred because the numerator and denominator in the case rate calculation increased differentially with the distance used to define the catchment area. For example, the catchment area and its population were largest when a straight-line distance of 30 km was used; consequently, the denominator was also large. When a straight-line distance of 5 km was used, the numerator was only slightly smaller but the denominator was much smaller. Clearly the distance between a patient’s residence and the health-care facility was important but doubling the distance did not double the number of cases.

Defining a catchment area according to distance from the facility has the advantage of simplicity but this approach does not take into account where patients actually live. Moreover, although distance is important, it is not the only factor influencing a patient’s choice. Use of the cumulative case ratio is not affected by distance since it uses patients’ actual addresses. As Fig. 2 demonstrates, this can result in catchment areas made up of noncontiguous parishes.

The main limitation of our approach follows from the assumption that the reason the number of malaria-related visits from a particular parish was lower than expected was primarily because utilization of the health-care facility by the parish’s population was low. However, lower than expected utilization could have been due to a low incidence of symptoms characteristic of malaria in the parish. If the purpose of defining a catchment area is to estimate
Table 2. Parishes, population and malaria cases in health-care facility catchment areas, by catchment area definition, Uganda, 2012

<table>
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<tr>
<th>Health-care Facility Catchment Area</th>
<th>Catchment Area Definition</th>
<th>No. of Parishes</th>
<th>Population Confirmed Cases</th>
<th>Malaria Confirmed Cases</th>
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NOTE: Catchment areas were defined as lying within a specified straight-line distance from the facility. A parish was included in the catchment area if the upper limit of the 95% confidence interval for the cumulative case ratio for the parish (i.e. the ratio of observed to expected malaria-related visits from the parish) was one or greater.

a Catchment areas were defined as lying within a specified straight-line distance from the facility.

b Catchment areas were defined as lying within a specified road network distance from the facility.

c A parish was included in the catchment area if the upper limit of the 95% confidence interval for the cumulative case ratio for the parish (i.e. the ratio of observed to expected malaria-related visits from the parish) was one or greater.
area is defined since catchment areas are affected by factors that vary over time, such as changes in the capacity of or the services provided by the facility or the opening or closing of other health-care facilities nearby. After exploring this issue, our findings (not reported) suggest that data from the most recent 2 or 3 years are sufficient for establishing current catchment areas. The use of a longer period would provide an insight into the stability of the catchment area over time. Catchment areas should be reassessed periodically. A final consideration is whether the catchment area should be based on all admissions to the facility or on the utilization of a particular service.

Our analysis demonstrates how population-based measures of disease burden, such as the malaria case rate, are dependent on the method used to define the catchment areas of health-care facilities. The cumulative case ratio approach to defining catchment areas we propose identified administrative units in which the utilization of a health-care facility was substantially lower than expected, thus enabling those units to be excluded from the facility’s catchment area. Our approach is simple and reproducible and is based on using a statistical measure to decide which administrative units should be included in catchment areas.

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**Competing interests:** None declared.

**Funding:** This study was supported by doctoral awards from the International Development Research Centre in Ottawa, Canada and by the Fonds de recherche Santé, Montréal, Canada.

**Abstract**

Objective: Use data on malaria-related visits to determine hospital catchment areas in Uganda.

Methods: Define hospital catchment areas using population-based measures of disease rates to the facility or on the utilization of a particular service.

Results: The catchment areas were defined based on data from the catchment areas over time. New methods were used to define hospital catchment areas. The use of new methods for defining hospital catchment areas would provide an insight into the stability of the catchment area over time. Catchment area definitions were based on using a statistical measure to decide which administrative units should be included in catchment areas.

Conclusion: Use data on malaria-related visits to determine hospital catchment areas in Uganda.

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**Abstract**

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Результаты
Методы

Районы охвата обслуживанием шестью учреждениями здравоохранения в Уганде были определены с использованием данных Проекта по исследованию малярии в Уганде (Uganda Malaria Surveillance Project). Районы охвата обслуживанием также определялись с использованием различных расстояний по прямой и по дорожной сети до учреждения. Затем годовой совокупный коэффициент случаев заболеваний малярией вычислялся для каждого района охвата обслуживанием установленным образом с использованием трех методов.

Результаты

Годовой совокупный коэффициент случаев заболеваний малярией варьировался в зависимости от метода, использовавшегося для определения районов охвата обслуживанием. При применении подхода, предполагающего использование совокупного коэффициента случаев заболеваний, в районы охвата обслуживанием могли быть включены районы, состоящие из нескольких несмежных участков. При применении подходов, предполагающих учет расстояния, знаменатель вместе с увеличением расстояния увеличивался существенно, в то время как числитель увеличивался лишь незначительно. Наибольший совокупный коэффициент случаев заболеваний на 1000 человек популяции был выявлен для учреждения в районе Камвези (Kamwezi): 234,9 (девиационный интервал (ДИ) 95 %, 226,2–243,8) для расстояния по прямой в 5 км, 193,1 (ДИ 95 %, 186,8–199,6) при применении подхода, предполагающего использование совокупного коэффициента случаев заболеваний, и 156,1 (95 % CI: 150,9–161,4) для расстояния по дорожной сети в 5 км.

Вывод

Использование совокупного коэффициента случаев заболеваний для посещений в связи с малярией оказалось неоправданным. Более того, этот подход принимает во внимание фактическое адреса пациентов, в то время как подход, предполагающий использование расстояния до учреждения, это не предусмотрено.
de Kamwezi: 234,9 (intervalo de confianza del 95 %, IC: 226,2–243,8) para una distancia lineal de 5 km, 193,1 (IC del 95 %: 186,8–199,6) para el enfoque de la tasa acumulativa de casos y 156,1 (IC del 95 %: 150,9–161,4) para una distancia de red vial de 5 km.

**Conclusión** El uso de la tasa acumulativa de casos para las visitas relacionadas con el paludismo a fin de determinar las áreas de captación de centros de salud fue factible. Además, este enfoque tuvo en cuenta las direcciones reales de los pacientes, mientras que el enfoque basado en la distancia respecto al centro no las consideró.

**Referencias**


