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Cost-effectiveness of community-based management of acute malnutrition in Malawi

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This study assessed the cost-effectiveness of community-based management of acute malnutrition (CMAM) to prevent deaths due to severe acute malnutrition among children under-five. The analysis used a decision tree model to compare the costs and effects of two options to treat severe acute malnutrition: existing health services with CMAM vs existing health services without CMAM. The model used outcome and cost data from a CMAM programme in Dowa district, Malawi and a set of key assumptions regarding treatment-seeking behaviour and mortality outcomes. Under our 'base case' scenario, we found that CMAM cost US$42 per disability-adjusted life year (DALY) averted (2007 US$) and US$493 per DALY averted under an assumed 'worst case' scenario for each variable. The results suggest that CMAM was highly cost-effective in the 'base case' as defined by the World Health Organization, as the cost per DALY falls well below Malawi's 2007 gross national income (GNI) per capita of US$250, and is within the range of DALYs reported for other child health interventions. Under a hypothetical 'worst case' for all variables, the model indicates CMAM is still cost-effective. The results indicate the decision to scale-up CMAM within essential health services in Dowa was a cost-effective one and that scaling up CMAM in similar contexts is also likely to be cost-effective. However, several contextual and programmatic factors should be considered when generalizing to diverse contexts.

Keywords Cost-effectiveness, nutrition, malnutrition, child health, community-based management of acute malnutrition, therapeutic feeding

KEY MESSAGES

- Based on 2007 programme data and a number of key assumptions, community-based management of acute malnutrition (CMAM) in Dowa, Malawi was highly cost-effective using the GNI per capita threshold.
- The sensitivity analysis shows that if all variables are in their assumed worst case scenario the programme is still cost-effective.
- Scaling up CMAM in similar contexts is likely to be cost-effective, but several contextual and programmatic factors, discussed in the paper, should be considered.

Background

Globally, close to 9 million children under-five die each year (UNICEF 2009), and more than 19 million under-fives (3.5%) are believed to be severely wasted (Bhutta *et al*. 2008a). A severely wasted child is nine times more likely to die than a child who is not wasted, and, as a consequence, severe wasting is believed to account for at least 4.4% of the global under-five death burden and 6.0% of disability-adjusted life-years (DALYs) lost among under-fives each year (Bhutta *et al*. 2008a). The actual death and disability burden attributable to severe acute malnutrition (SAM) is likely to be even higher when its other manifestation, nutritional oedema, is also considered (Bhutta *et al*. 2008c; Ndekha 2008). The potential public health impact of treating SAM is therefore great, but access to appropriate care is severely limited. It is currently estimated that only 5% of SAM cases have access to treatment (Horton *et al*. 2010).

What is community-based management of acute malnutrition?

Community-based management of severe acute malnutrition (CMAM) is a relatively new approach to managing SAM. It aims to maximize access to appropriate, quality care from the first signs of SAM. Introduced in 2001 as 'community-based therapeutic care' (CTC), the approach was designed to address the many shortcomings of traditional SAM treatment, which functioned solely through inpatient centres with limited capacity and reach and necessitated long inpatient stays away from children's homes (Collins 2001). Following United Nations (UN) endorsement in 2007, the approach became formally known as 'CMAM' and has four primary components: outpatient therapeutic programme (OTP) for SAM cases without complications; inpatient therapeutic programme (ITP) for SAM cases with complications; community mobilization; and, where appropriate, supplementary feeding programme for moderate acute malnutrition.

CMAM's defining advantage over the inpatient model has been its ability to provide safe outpatient treatment to the majority of SAM cases, thereby improving timely access. CMAM has achieved this with several key improvements to the old model. First, the introduction of ready-to-use-therapeutic-food (RUTF) has provided a critical alternative to the inpatient-only therapeutic milks of the past. Second, a revised triaging system intends to effectively and safely assign SAM cases to outpatient or inpatient care based on the presence of complications. Third, CMAM prioritizes active case finding using community structures and a simplified screening/admission protocol based on mid-upper arm circumference (MUAC) and oedema criteria. CMAM also emphasizes integration of SAM services into existing health systems so they may be better sustained with government budgets over the longer term.

CMAM programmes have consistently delivered on their aims. Coverage has been high—consistently above the international Sphere minimum standards (Sphere 2004) and up to a five times higher than inpatient-only programmes—while performance indicators have been comparable to or better than inpatient-only programmes (Collins 2004; Collins *et al.* 2006a; Collins *et al*. 2006b). As a result, CMAM has been broadly endorsed as best practice by the United Nations (WHO *et al*. 2007), a growing number of ministries of health, and most non-governmental agencies (Khara and Collins 2004; Collins *et al*. 2006a; ENN and FANTA 2008). Despite this endorsement and the clear public health burden presented by SAM, few studies have evaluated the cost-effectiveness of programmes to treat SAM (Ashworth and Khanum 1997), and only one published study has evaluated the cost-effectiveness of CMAM (Bachman 2009). That study, conducted in the urban context of Lusaka, Zambia, concluded that CMAM represented good value for money (Bachman 2009).

Malawi and Dowa district

Malawi's under-five mortality rate of 120 deaths per 1000 live births ranked it as the 32nd worst in the world in 2007 (UNICEF 2008) and 34th in 2009. An estimated 1.6% of Malawian children aged 6–59 months suffer from severe wasting (MNSO and ORC Macro 2005), and nutritional oedema is also endemic. Nutrition surveys conducted since 2002 indicate the prevalence of SAM in Dowa is generally at or close to 1% (range 0.4 to 1.1% based on seven district-wide surveys). Table 1 provides a profile of Malawi and Dowa.

In 2002, Dowa district in central Malawi was the site of the first large-scale CMAM pilot, initiated by Valid International and Concern Worldwide in partnership with the Dowa District

Table 1 Profile of Malawi and Dowa

Characteristic	Malawi	Dowa	Source
Population, total ('000s)	13 066	557	Malawi Population and Housing Census, 2008 preliminary results
Under-five mortality rate (per 1000 live births)	120	139	UNICEF (2008) Malawi Multiple Indicator Cluster Survey 2006 (MNSO & UNICEF 2008)
Percentage of under-fives with severe acute malnutrition	1.6%	0.4% (1% annual average)	Malawi Demographic & Health Survey 2004 (wasting only) (MNSO & ORC Macro 2005) Concern/Ministry of Health Dowa nutrition survey, December 2007 (wasting and/or oedema) (both using <-3 Wt-for-Ht Z-score by NCHS reference)
Percentage of children severely stunted	22.2%	17.8%	Malawi Demographic & Health Survey 2004 (MNSO & ORC Macro 2005) Concern/Ministry of Health Dowa nutrition survey, December 2007 (both using <-3 Ht-for-Age Z-score by NCHS reference)
Percentage of adults (15–49 yrs) HIV+	11.9%	–	UNAIDS (2007)

Health Office. Since that time, the Dowa programme has operated increasingly under the management of the District Health Office, who have reportedly budgeted all CMAM costs from their own budget for the 2010 fiscal year (DDHO and Concern 2009). OTP services for SAM are available at all 21 health centres in the district and linked via referral to ITP services at the district's three hospitals. Malawi's CMAM protocols (Ministry of Health 2006) are in line with international standards (Valid International 2006). In 2007, 2896 children with SAM were admitted to the Dowa OTP; 59% of admissions were oedema cases, 20% wasted according to MUAC or weight-for-height and the rest transfers/other/returning defaulters (CAS 2007). CMAM is now included in Malawi's national health protocol and implementation has expanded from just 2 of Malawi's 28 districts in 2004 to 21 in 2008.

Methods

This paper describes an evaluation of the incremental cost-effectiveness of the CMAM programme in Dowa district of Malawi for 2007, and places the findings within the broader context of other child health economic evaluations that have been undertaken in Malawi or neighbouring countries.

We used a decision tree to model the cost-effectiveness of CMAM integrated into existing health services vs existing health services with no CMAM (Figure 1) for the period January to December 2007 in Dowa district. At year end, 2780 children had been discharged from the OTP (including 85 transfers to ITP) (Table 2). The decision tree is built around this known exit total and outlines the possible treatment pathways for SAM beginning with the primary decision to implement CMAM (scenario 1) or not implement CMAM (scenario 2), and branching at additional decision nodes until a terminal node of either dead or alive is reached. The proportion of SAM cases assigned to each branch was based on data collected from the Dowa CMAM programme from January to December 2007 and key assumptions regarding mortality outcomes and uptake of health services among non-enrolled children. The study took a health services perspective. The respective costs and effects (in terms of DALYs) were calculated and aggregated for each treatment pathway. The difference in costs and effects between the two scenarios was used to estimate the incremental cost per DALY averted.

DALYs are the sum of the present value of future years of life lost due to premature death (YLL) plus the present value of future life years lived with a disease or injury (YLD) (Fox-Rushby and Hanson 2001). The total DALYs for each branch of the decision tree were calculated using the formula outlined by Murray and Lopez (1996, pp. 65–6) in Fox-Rushby and Hanson (2001) and the following assumptions. The average age of premature mortality due to SAM for the study population of under-fives was assumed to be 3 years, for which life expectancy was estimated to be 53 years in Malawi (WHO 2006). The discount rate was 3% for the base case, 5% for the worst case, and 0% for the best case. Age weighting was included by keeping the age weighting modulation factor at 1, and the parameter from the age weighting function was 0.04. CMAM defaulters were assumed to be affected by wasting which has a disability weight of 0.053 (Murray and Lopez 1996).

Decision tree model

Reflecting the CMAM programme structure, children in the model exit the OTP in one of four ways: cured, died, defaulted/non-recovered, or referred to the ITP due to complications. A child defaults after missing two consecutive fortnightly visits.

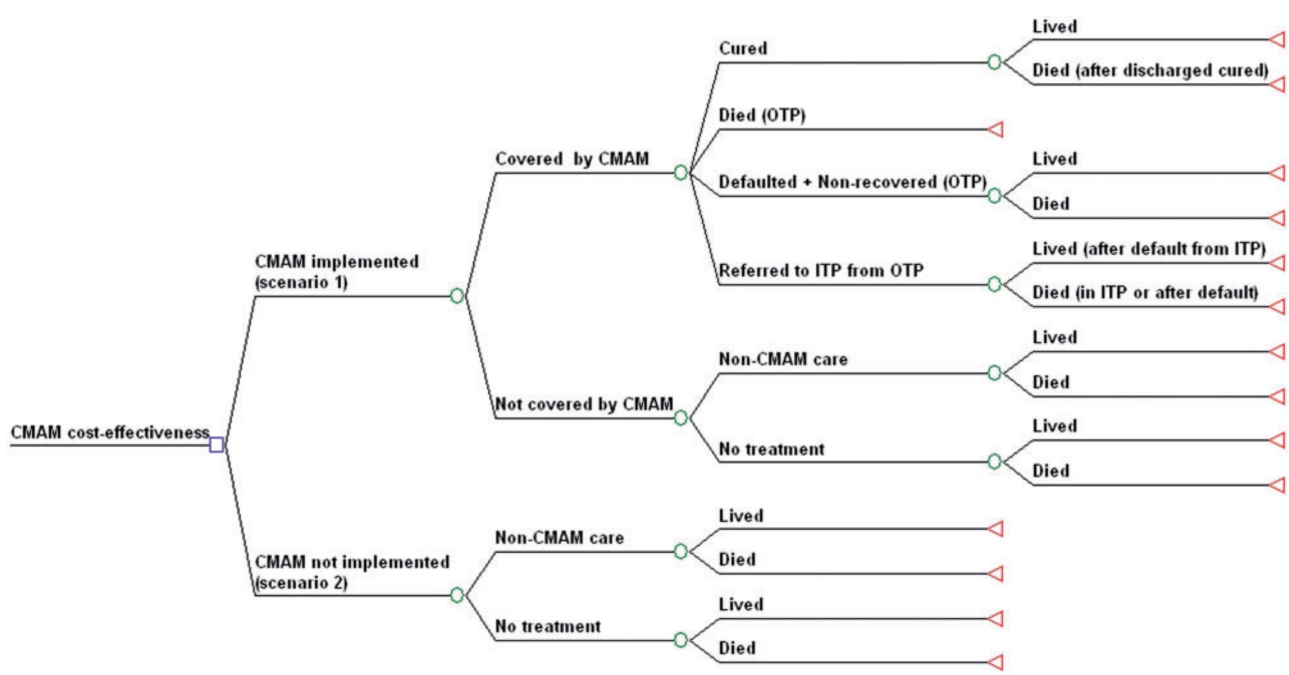

Figure 1 Decision tree

Table 2 Outcomes of outpatients and inpatients (January–December 2007), Dowa

Outcome	*n*	%	Assumed number among OTP to ITP referrals
Outcomes of children exiting the OTP			
Total registered start of year	345		–
Total admissions	2896		–
OTP cured	2538	91.3%	–
OTP death	28	1.0%	–
OTP default (91) or non-recovered (38)	129	4.6%	–
OTP exits referred to ITP	85	3.1%	–
Total OTP exits	2780	100%	–
Total registered end of year	461		–
Outcomes of children exiting the ITP			
ITP cured or stabilized and returned to OTP	678	85.1%	72
ITP death	88	11.0%	9
ITP default	31	3.9%	3
Total ITP exits	797	100%	85

Notes: ITP = inpatient therapeutic programme; OTP = outpatient therapeutic programme.

A child is discharged as non-recovered if he has not reached discharge criteria after his fourth month in the programme. The defaulter and non-recovered categories have been combined for simplicity, assuming a similar mortality risk. Once children referred from the OTP to ITP are treated for complications, they either (a) return to the OTP to exit via one of the OTP exit categories above, or (b) die, either while under ITP care or after defaulting from ITP, or (c) live after defaulting from ITP. The model also accounted for additional mortality risk faced post-discharge during the study year by all children exiting cured, defaulted and non-recovered.

SAM cases not covered by (i.e. not enrolled in) the CMAM programme in scenario 1 or who live in areas where no CMAM is implemented (scenario 2) are assumed to have two treatment options: non-CMAM care or no treatment. Non-CMAM care includes any treatment for underlying illnesses received at a health centre (excluding therapeutic feeding) and any traditional inpatient therapeutic services received at one of the three hospitals (including therapeutic feeding).

The decision tree builds on that used by Bachmann (2009), but introduces a third option of non-CMAM care alongside CMAM and no-treatment. It also accounts for programme coverage, but does not include the effect of HIV on the no-treatment mortality.

Outcome probabilities

Under the CMAM-implemented scenario, the probability of being enrolled in CMAM was based on the results of a CMAM coverage survey conducted in Dowa in early 2008 (Schofield 2008). Mortality outcomes for children during their average treatment period of 6 weeks were known from OTP and ITP data (Table 2), with the exception of defaulters/non-recovered. Additional mortality faced post-discharge was captured by adding 2.4% to the known OTP mortality rate of 1.0%. This 'background' mortality rate was derived from the overall under-five mortality ratio for Malawi in 2006 (120/1000 live births) (UNICEF 2007) divided by five to represent the study year in which 1/5th of the denominator's live under-five births would have occurred (Bachmann 2009). The mortality rate for OTP and ITP defaulters/non-recovered was conservatively assumed to be the same as those receiving no treatment.

The mortality rate among children referred to the ITP within the CMAM-implemented scenario (scenario 1) was derived from the only available dataset—a database combining exit data for all ITP children, including but not differentiating those referred in from the OTP. To specifically estimate the outcomes of OTP referrals, the relative proportion for each exit category from the combined ITP database was applied to the total known referrals from OTP to ITP (85). The resulting numbers were used to represent the ITP outcomes in the model (Table 2).

The mortality rate for non-CMAM care (in scenario 1 and 2) was assumed to be the same as that for the CMAM programme's ITP component (11% as described above) plus the 2.4% annual background mortality rate.

The mortality rate for children seeking no treatment (in scenario 1 and 2) was assumed to be 18.1%. This is based on a prospective cohort study conducted in northern Malawi which found the mortality rate among severely wasted children under-five (MUAC <110 mm) to be 181.8 per 1000 (Pelletier 1994).

The aggregate annual mortality rate for SAM cases covered by CMAM was 4.4% (123/2780); for the CMAM-implemented scenario as a whole it was 11.9% (809/6796); and for the CMAM not implemented scenario, 17.1% (1160/6796).

Costs

To estimate the relative cost of each treatment pathway in the model, two unit costs were calculated: the average cost per child treated in CMAM and the average cost per child treated in non-CMAM care (Table 3). The no treatment arm was assumed to have zero cost.

Table 3 Input values

Parameter	Base case	Worst case	Best case	Source of base case (and range)
General				
Annual background mortality rate for under-fives in Malawi	2.4%	N/A	N/A	Based on Bachmann (2009): under-five deaths per 1000 live births in Malawi, 2007 (UNICEF 2008) divided by 5 to represent 1 year of these live births. *Base and worst* - included within calculations below
Discount factor	3.0%	5.0%	0.0%	Standard factor
Years of life lost (YLL)*	32.7	22.1	67.2	*Base*: Fox-Rushby & Hanson (2001) *Worst + best*: using discount factors above
CMAM implemented and CMAM accessed				
OTP exits died	1.0%	3.0%	0.5%	*Base*: Dowa annual programme data 2007 (Table 2) *Worst*: Annual average for 17 Malawi districts 2007 *Best*: Dowa programme data, best quarter 2007
OTP exits defaulted or non-recovered	4.6%	9.0%	2.2%	*Base*: Dowa annual programme data 2007 (Table 2) *Worst*: Annual average for 17 Malawi districts 2007 *Best*: Dowa programme data, best quarter 2007
OTP exits referred to ITP	3.1%	5.1%	1.8%	*Base*: Dowa annual programme data 2007 (Table 2) *Worst/best*: Worst/best quarter same 2007 programme data
OTP exits cured*	91.3%	82.9%	95.5%	*Base*: Dowa annual programme data 2007 (Table 2) *Worst/best*: Balancing figure from the 3 assumptions above
OTP exits defaulted or non-recovered who died	18.1%	10.0%	22.6%	*Base/worst/best*: Assumed the same as no-treatment mortality rate (see below)
ITP exits who died (in programme or after default)	11.7%	14.7%	8.8%	*Base*: ITP mortality rate (11%) + 18.1% of ITP defaulters assuming they died at same rate as no-treatment (Table 2) *Worst case*: +25% of base case *Best case*: −25% of base case
CMAM not implemented and/or CMAM not accessed				
Mortality of SAM cases receiving no treatment*	18.1%	10.0%	22.6%	*Base*: Pelletier (1994); mortality rate of severely wasted under-fives from prospective study *Worst*: −46% of base case equal to reduction in Malawi's overall under-five mortality rate since 1993 *Best*: +25% of base case
Children not covered by CMAM who seek non-CMAM care	35.0%	43.8%	26.3%	*Base*: DHS survey 2004 for % of under-fives with diarrhoea during previous 2 weeks taken to clinic *Worst*: +25% of base case *Best*: −25% of base case
Mortality of SAM cases receiving non-CMAM care*	14.1%	10.6%	17.7%	*Base*: Assumed to be same rate as ITP exits who died + annual background mortality rate for under-fives *Worst*: +25% of base case *Best*: −25% of base case
Per child treatment costs used in the model (2007 US$)				
Average cost per child treated in CMAM	169.3	211.6	140.3	*Base*: Total CMAM costs (Table 4) divided by total CMAM exits (Table 3) *Worst case*: +25% of base case *Best case*: −25% on all non-RUTF costs with RUTF cost same as base case
Average cost per child treated in non-CMAM care	16.7	12.5	20.9	Assumes 1 in 4 SAM cases receive ITP, while 3 in 4 receive set of 3 clinic visits *Base case*: Average cost of 1 ITP stay + 3 sets of 3 clinic visits with drugs *Worst case*: −25% of base case *Best case*: +25% of base case
Intermediate variables used to estimate cost per child				
Average cost per child treated in ITP	49.7	62.2	37.3	Assumes 7 days of: ITP bed, therapeutic milk and drugs *Base case*: hospital bed (WHO-CHOICE, n.d. b); F-100 milk (Nutriset, France, pers. comm. 2009); drugs as 190% of total bed cost (Bachmann 2009) *Worst case*: +25% of base case *Best cast*: −25% of base case
Cost per child treated via 3 clinic visits (consultation + drugs)	5.7	4.3	7.1	Clinic visit cost (WHO-CHOICE, n.d. b); drug cost as 190% of bed cost (Bachmann 2009) *Worst case*: −25% of base case *Best case*: +25% of base case

Notes: *Indicates increase in this variable results in increased cost effectiveness of CMAM.

CMAM = community-based management of acute malnutrition; DHS = demographic and health survey; ITP = inpatient therapeutic programme; OTP = outpatient therapeutic programme; RUTF = ready-to-use-therapeutic-food; SAM = severe acute malnutrition.

Table 4 Costs of the Dowa CMAM programme, 2007 (US$)

Item	Total cost	% of total cost	Source
Capital costs (annual equivalent)			
Cars and motorbikes (Concern)	11 590	2%	Concern finance system
Computers (Concern)	2543	1%	Concern finance system
Sub-total capital costs	***14 133***	***3%***	
Recurrent costs			
Food: RUTF (Concern)	148 519	32%	Concern finance system
Admin: Concern	97 532	21%	Concern finance system
Direct staff: international (Concern)	56 833	12%	Concern finance system
Transport: fuel, maintenance (Concern)	37 004	8%	Concern finance system
Direct staff: national (Concern)	34 122	7%	Concern finance system
Other miscellaneous costs (Concern) (e.g. surveys/reviews, HIV & AIDS mainstreaming, upgrading storage)	24 946	5%	Concern finance system
Local clinic staff and supervisors (Government)	24 600	5%	Estimated allocation from DHO budget
Admin: government	14 214	3%	Estimated allocation from DHO budget
Training costs, including venue and per diems (Concern)	8800	2%	Concern finance system
Medical supplies (largely government)	5773	1%	Concern finance system and estimated allocation from DHO budget
Inpatient costs for OTP referrals (government)	4227	1%	Unit cost per child stay (WHO CHOICE) multiplied by total OTP to ITP referrals
Sub-total recurrent costs	***456 571***	***97%***	
Total costs	**470 703**	**100%**	

Notes: CMAM = community-based management of acute malnutrition; DHO = District Health Office; ITP = inpatient therapeutic programme; OTP = outpatient therapeutic programme; RUTF = ready-to-use-therapeutic-food.

CMAM costs included those incurred by Concern for the 2007 calendar year and those budgeted by the government for the 2007/2008 fiscal year. All were converted into 2007 US$ at 140 Malawi Kwacha per $ (UNSD 2009a) and 0.73 Euro per $ (UNSD 2009b). Concern covered 90% of the total cost of the programme. RUTF accounted for the largest portion of total costs, followed by Concern administrative and direct staff costs (Table 4).

Concern's CMAM expenditure was tracked through its financial accounting system and split between capital (cars, motorbikes and computers) and recurrent costs (all remaining costs). Purchases prior to 2007, all made in US$, were inflated to 2007 costs by the US Consumer Price Index (US Bureau of Labor Statistics, n.d.). Car and motorbike costs were annualized over 5 years and computers over 3 years, using a 3% discount factor. The cost of RUTF was the total reported spent by Concern for Dowa for 2007, covering the cost of purchase, transport from the producer's factory in central Malawi and warehousing. Because reductions in the price of the main ingredients—milk powder and peanuts—were not expected, the same RUTF cost was kept for the best and base case.

Concern administration costs were comprised largely of an allocation from Concern Malawi's support staff and office costs, with the addition of support transport costs incurred at the Dowa and Lilongwe offices. Recurrent transport costs included the running costs of three shared cars allocated based on logs recording total kilometres driven for CMAM purposes.

Government costs for CMAM included those for OTP and ITP. Total government OTP costs were estimated using allocations from the budget for 1 July 2007 to 30 June 2008 (estimated by consultant Nick Hall and agreed by Malawi Ministry of Health). Allocations were made from annual staff salaries at 21 health centres (10% of one nurse, one medical assistant and four health surveillance assistants), district staff salaries (20%, 10% and 5% of one district nutritionist, two maternal and child health co-ordinators, and one health management information system officer, respectively), the district health budget's operating costs (1%) and the district drug budget (1%). The CMAM portion of the district's operating costs and drug budget were both allocated by multiplying the estimated proportion of health centre staff involved in OTP (15%) by the average proportion of total health centre days spent working in the OTP (10%) by the proportion of the total district health budget spent on health centres (66%).

Actual ITP costs (all covered by the District Health Office) were difficult to determine from district records. Further, it was not possible to distinguish ITP costs for children referred in from OTP (CMAM costs) vs self-referrals (non-CMAM costs). For this reason, a unit cost per child treated in the ITP was calculated using an assumed average stay of 7 days and an

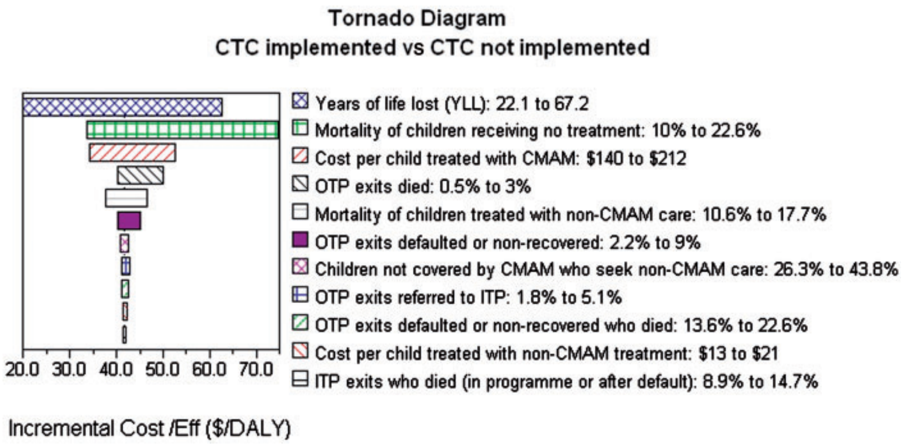

Figure 2 Tornado diagram

estimated cost per bed per day in a tertiary hospital in Malawi (WHO-CHOICE, n.d. b) (Table 3).

The resulting total CMAM cost was then divided by the total programme exits (2780) to arrive at the CMAM unit cost.

The average cost per child treated with non-CMAM care was based on the assumption that one in four children seeking non-CMAM care accessed ITP treatment (using the same ITP unit cost, above), while the remaining three accessed the equivalent of three clinic visits and three courses of drugs, using WHO-CHOICE estimates for the cost per visit to a secondary health facility in Malawi plus drugs (Table 3). This conservatively assumes coverage of inpatient services was higher than the 10% estimated by Collins (2006).

Analysis

The costs and effects were modelled using TreeAge Pro 2009 and Excel 2003 software. A one way sensitivity analysis was carried out using TreeAge Pro 2009 software.

The incremental costs and effects between the two options were combined to estimate an incremental cost-effectiveness ratio (ICER). Based on the 2001 recommendation of the Commission on Macroeconomics and Health, the World Health Organization classifies interventions as 'highly cost-effective' for a given country if they avert a DALY for less than the per capita GNI or GDP (gross domestic product) and cost-effective if they avert a DALY for less than 3 times the GNI or GDP (WHO-CHOICE, n.d. a).

The one way sensitivity analysis involved replacing, in turn, each base case outcome and cost variable with its best and worst case (see Table 3) to see how the ICER changed. The worst case should be interpreted as the case that makes CMAM least cost-effective. Unless otherwise indicated, the best and worst case for outcome and cost variables were +/−25% of the base case. A tornado diagram was created, in which the difference between the ICER under the best vs the worst case for each variable is represented by a bar. The larger the bar, the more sensitive the model is to that variable (Figure 2).

Results

The total cost of providing CMAM (US$470 703, Table 4) and non-CMAM (US$23 394) treatment for SAM in Dowa district in 2007 (scenario 1) was US$494 097. The total estimated cost for treatment services where no CMAM programme was implemented (scenario 2) was considerably lower at US$39 714. However, according to the model, there were 342 fewer deaths in the CMAM-implemented scenario than in the CMAM not implemented scenario, which at a 3% discount rate equates to 10 883 DALYs averted.

The ICER of implementing CMAM in addition to existing health services was US$42 per DALY averted (or US$1365 per life saved) which is within the highly cost-effective GNI per capita threshold (WHO-CHOICE, n.d. a) of US$250 (World Bank 2008). The model was sensitive to changes in the values of some variables, as illustrated in the tornado diagram (Figure 2). However, changes to variable values, either in isolation or in combination, did not affect the conclusion that the programme was cost-effective, using the 3 x GNI threshold (WHO-CHOICE, n.d. a). Using the worst case scenario for all data gives an ICER of US$493 per DALY averted. In the best case it is US$11 per DALY.

Discussion

Results

This study shows that the implementation of CMAM as an addition to the existing standard health services in Dowa district in rural Malawi in 2007 was a cost-effective decision. The ICER of US$42 per DALY averted is very close to the findings of an analysis using similar methods for an urban CMAM programme in Lusaka, Zambia, which estimated a cost of US$41 per DALY (Bachmann 2009, cited in Horton *et al.* 2010, p. 38). The current study complements the Lusaka findings by demonstrating that CMAM is also cost-effective in a rural setting, where population density is lower and transport costs presumably higher.

The resulting CMAM ICER is within the general range of cost-effectiveness ratios estimated for other priority child health care interventions in Africa, including community or facility-based case management of lower acute respiratory infections (US$398), integrated management of childhood illness (US$38), universal salt iodization (US$34–36), iron fortification (US$66–70) and insecticide-treated bed nets for malaria prevention (US$11 for sub-Saharan Africa) (Laximinarayan *et al.* 2006). The CMAM ICER is also comparable with that estimated for interventions such as oral rehydration therapy when added to existing interventions (Tan-Torres *et al*. 2005). The result is also within the most cost-effective band of the 40 main health interventions in the 1998 World Bank study in Guinea ($0 to $50/life year, 1994 US$, and particularly so when inflated to 2007 US$) (Prabhat 1998).

Limitations

The findings may have been subject to certain sources of uncertainty in the data. A deterministic sensitivity analysis was carried out to account for this uncertainty (Figure 2). Below we provide a detailed discussion of the variables to which the model proved most sensitive to change in. One limitation was that a probabilistic sensitivity analysis, which has the advantage of incorporating uncertainty of all parameters simultaneously, was not carried out. However, an ICER was calculated for all variables in their worst case scenario and reported in the results section.

The model proved most sensitive to years of life lost (YLL). The YLL was calculated using a discount factor of 3% in the base case, which is consistent with similar studies (Prabhat 1998; Tan-Torres *et al.* 2005; Bhutta 2008a) and conservative in the worst case by comparison at 5%.

The second greatest source of sensitivity was the mortality rate for children seeking no treatment (18.1%). The Lusaka study, using a simpler decision tree, which did not consider the effect of non-CMAM treatment, but with the same base/worst case also concluded that the model is extremely sensitive to the no-treatment mortality rate (Bachmann 2009). Unfortunately, this variable is one of the most difficult to establish because assigning SAM cases to no-treatment or inferior treatment in a prospective study using controls or a cohort design is and will continue to prove difficult due to ethical considerations. The base case value used in our model is taken from a Malawi study and supported by results from a similar cohort study in Uganda (18.7%) (both Pelletier 1994). It is recognized, however, that both studies were carried out more than 15 years ago and that improvements in child survival—as evidenced by the reduction in Malawi's overall under-five mortality rate from 221 deaths per 1000 live births in 1990 and to 120 deaths in 2007 (UNICEF 2007)—may have resulted in a lower no-treatment mortality rate in Dowa at the time of our study. To account for this, our no-treatment mortality rate in worst case was determined by decreasing the base case by the same proportion (46%) as the reduction in the overall under-five mortality during roughly the same period. The resulting value for the worst case (10%) is also comparable to that found by other studies from other countries in the mid-1980s, which ranged from 6% to 13% (Pelletier 1994; Collins *et al*. 2006a; Garenne *et al.* 2009).

While this variable's sensitivity should be carefully considered when interpreting the results, several factors may have mediated the uncertainty. First, while our CMAM mortality outcomes would have reflected the effects of HIV, which is known to be significant (Bahwere *et al.* 2008), we made no upwards adjustment to account for this in the no-treatment. Second, Pelletier's original mortality rate did not include cases of oedema, which are associated with a higher mortality risk (Schofield and Ashworth 1996). Finally, the relative risk ratio suggested by our study's mortality rate for untreated SAM (18.1%) vs the 'normal' under-five mortality (2.4%) is roughly equivalent to the actual mortality odds ratio of 9.4 estimated for severe wasting by Bhutta *et al*. (2008a). More work is needed to refine this assumption for future studies.

The third largest source of sensitivity was the unit cost per child treated in CMAM. The three biggest elements of this cost are RUTF (32% of total), Concern administration (21%) and Concern direct staffing costs (19%) (Table 4). While RUTF and direct staffing costs are directly coded from Concern's finance system, Concern's administration costs are allocated to the CMAM programme based on the proportion of total Concern staff working directly on CMAM. Although a standard accounting method, this allocation may be less precise than directly coded costs. Another potential source of imprecision are the broad assumptions used to allocate OTP costs from government budgets. A prospective study designed to better capture real administration costs could improve accuracy for future studies.

The fourth largest source of sensitivity in the model was the OTP mortality rate (1.0%). While the base case reflects the actual rate recorded in Dowa's annual programme statistics, there is some indication that this rate may be somewhat lower than reality. This potential limitation is suggested by the fact that the total programme admissions for 2007 (2896) is markedly higher than the total expected considering the recorded SAM prevalence, under-five population and programme coverage when multiplied by a coefficient of 1.6 to account for incidence (731 expected admissions) (coefficient to translate prevalence to incidence from Briend 2010). While this discrepancy may be partially explained by differences in nutrition indices used in surveys vs programme admission and/or migration in from other districts and/or a higher SAM incidence, it may also be due in part to errors in applying the admission criteria, particularly oedema. Such errors could have artificially deflated the CMAM mortality as a result of healthier children being admitted. The worst case value for OTP mortality attempted to account for this by using the average recorded for CMAM programmes in 2007 across 17 districts (3%) (CTC Advisory Service 2007). This value is also very close to the annual OTP mortality rates seen in Dowa in 2003 (2.7%) and 2004 (2.5%), following periods of food insecurity (unpublished databases from Concern Worldwide).

The fifth largest source of sensitivity was the mortality of seekers of non-CMAM care (14.1%). Like the no-treatment mortality, a reliable input value for this value was difficult to ascertain, while the proportion of children assigned to this treatment in the model is considerable. The study's assumption that the rate would be equivalent to the ITP mortality (11.9%) adjusted upwards by the background mortality (2.4%) appears nonetheless conservative because, in reality, many of these children would have received only clinic treatment with no therapeutic feeding, meaning their mortality rate would likely be closer to the no-treatment mortality (18.1%). In this way, the rate assumes better outcomes for non-CMAM care than its cost estimate suggests. Furthermore, several studies suggest that hospital-based SAM treatment may have considerably higher mortality than our study's worst case ITP mortality rate, with SAM case fatality rates of 15–40% even where WHO inpatient protocols were well implemented with supportive supervision (Ashworth *et al.* 2004; Deen *et al.* 2003).

Are the results generalizable?

The scenario presented here for Dowa in 2007 represents a fairly typical non-emergency, rural CMAM programme, where CMAM has been integrated into routine health services but remains primarily funded by an external agency. Malawi is a stable country but seasons of food insecurity are not uncommon. Its health system is well established but continues to face many of the challenges seen across sub-Saharan Africa, including staffing shortages and relatively poor geographical coverage (average walking time from village to health facility of 83 minutes, MEJN 2006).

The results of this study are expected to be relevant and generalizable to CMAM programmes in broadly similar contexts in sub-Saharan Africa treating a comparable caseload and distributed across a similar network of health facilities. A number of additional contextual factors, however, will affect the degree to which the results can be generalized. This study model was not designed to assess variations in all of these, including the effect of changes in caseload or its three main determinants: SAM prevalence, population density and programme coverage. Any extrapolation of this study's results must therefore consider the following. First, higher levels of SAM than the 1% recorded for Dowa in 2007 are common in emergency contexts (WHO-NLIS, n.d.). Second, Malawi's population density of 158 people/km^2 is higher than the majority of Sub-Saharan African countries (World Bank 2010). Third, while Dowa's CMAM programme coverage was generally within the range seen in other CMAM programmes, variations are possible (Collins 2006a).

It is generally assumed that the ICER for CMAM could be reduced as a result of economies of scale achieved through higher coverage and/or more cases treated, as the unit cost for fixed costs such as administration expenditure per child treated would decrease. Economies of scale are less likely to be achieved through reductions in RUTF costs. Although further reductions in the cost per kilo may be possible, significant savings had already been gained at the time of this study as the Malawi-made RUTF was 20% less per kilo than that previously imported from France (Hall 2007). Further, RUTF costs will rise in almost direct proportion to the number of children treated, mediated only slightly by their length of stay. Transport and staff costs will also increase proportionally with the number of admissions, although to a lesser extent. It is also expected that some cost efficiencies will be gained as CMAM is further integrated into existing Ministry of Health systems resulting in parallel Concern costs, particularly administration and staff, being reduced.

Future studies should focus on developing the model and robustness of the dataset to assess the effect of variations in these key variables.

Conclusions

If the Millennium Development Goals are to be met, particularly the reduction in child mortality (MDG 4), effective interventions to address SAM among children under-five must be brought to scale alongside preventative measures. The contribution of SAM to child mortality and loss of healthy life years is now well quantified (Collins 2006a; Bhutta *et al.* 2008a), and the urgent need to scale up effective interventions to both prevent and treat undernutrition can no longer be ignored (Bhutta *et al.* 2008b). While CMAM's effectiveness has been recognized globally for some time (Collins *et al.* 2006a; WHO *et al.* 2007), its cost-effectiveness has only been evaluated recently—by our study and Bachmann's Lusaka study (Bachmann 2009). The results clearly indicate that CMAM was cost-effective within the studies' respective rural (Dowa) and urban (Lusaka) contexts in southern Africa.

It is recognized that the 19 million children currently suffering from SAM globally are dispersed across a variety of contexts and that the findings from the Malawi and Zambia studies cannot be generalized to all of them. It should also be acknowledged that a core tenet of the CMAM approach is to ensure equitable access to treatment services among the poorest and most vulnerable, coverage of whom may not always be the most cost-effective decision. Considering these parameters, the authors believe the study's findings are indicative and relevant to a large number of settings where SAM is found. As such, they make a considerable contribution to the evidence available for effective health and nutrition programming decisions.

Decision makers at global, national and local level are therefore urged to include CMAM as an integrated component of primary health care packages and nutrition programmes in the large number of contexts broadly similar to Dowa or Lusaka. Financial and human resources necessary to ensure scale up of CMAM in these contexts must be mobilized and appropriately allocated. If not, the vast majority of SAM cases around the world (currently 95%) (Horton *et al.* 2010) will continue to be denied cost-effective treatment.

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