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Trends in the Marginal Cost of Male Circumcision in Rural Rakai Uganda

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Abstract

Male circumcision (MC) is an effective intervention to reduce HIV acquisition in men in Africa. We conducted a cost analysis using longitudinal data on expenditures on services and community mobilization to estimate the marginal cost of MC over time and understand cost drivers during scale up. We used a time-series with monthly records from 2008 to 2013, for a total of 72 monthly observations, from the Rakai MC program in Uganda. GLM models were used to estimate the marginal cost of a MC procedure. The marginal cost per MC in a mobile camp was \$23 ($p < 0.01$) and in static facilities was \$35 ($p < 0.1$). Major cost drivers included supplies in mobile camps with increasing number of surgeries, savings due to task shifting from physicians to clinical officers and

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Natalia Alfonso collected and cleaned data, conducted analyses, wrote first draft of manuscript and edited it. David Bishai collected data, conceptualized the study methods, reviewed analyses and manuscript. Agnes Nantongo, Rebecca Kakembo, Sarah Kobusinge, Seema Kacker and Godfrey Kigozi collected data and reviewed manuscript. Gray Ronald conceptualized the idea and reviewed manuscript.

increased efficiency as personnel became more experienced. As scale up continues, marginal costs may increase due to mobilization needed for less motivated late adopters, but improved efficiency could contain costs.

Keywords

Male Circumcision; Marginal cost; Scale up; HIV; Uganda; Generalized linear model

INTRODUCTION

Voluntary medical male circumcision (MC) is an effective intervention to prevent acquisition of HIV and other sexually transmitted infections (STIs) in men. Three randomized control trials, in Uganda, Kenya and South Africa, showed that MC reduced HIV incidence in men by 50–60% [1–3]. In 2007, the World Health Organization (WHO) and the Joint United Nations Programme on HIV and AIDS (UNAIDS) recommended scaling up MC as part of a comprehensive HIV prevention strategy [4]. Using data largely from African countries, economic evaluations have all found MC to be a very cost-effective intervention for reducing HIV transmission [5–14]. MC has been promoted in 14 eastern and southern African priority countries with high HIV prevalence and low MC coverage. The UNAIDS goal is to increase MC coverage to 80%. Scaleup may require increased funds for demand-generation when easy-to-recruit motivated patients are exhausted and harder-to-reach men make up more of the caseload. Scale up may also require additional capital for surgical theaters. At the same time programs may find cost reductions from efficiency improvements gained through experience. As MC programs scale up it is important to evaluate how program costs change and thus how cost-effectiveness results may vary.

There has been significant improvement in the pace of MC scale up, with about 9 million procedures performed between 2008–2014 achieving approximately 44% coverage [15]. Data show that MC programs are still achieving economies of scale [16]. This means that unit costs should continue to decline [17]. Economies of scale occur where programs run at less than full capacity. In this phase programs can do more surgeries without building more surgical theaters. Since 2006, the average cost range per MC procedure from ten African countries, inflation adjusted to 2013 US dollars, was between \$50 and \$164 (Supplement Table 1). Recently, Bollinger et al (2014) using cross-sectional data from six African countries estimated the average cost per MC surgery was \$52, ranging between \$24 in South Africa to \$74 in Tanzania, with 78% of surgeries performed in static clinics [17]. Similarly, Menon et al (2014) using data from 12 sites in Tanzania found that the average unit cost per MC surgery was \$66 [18].

Prior studies of the cost of MC programs estimated average costs by dividing total cost by total number of surgeries. This estimate is less helpful to guide policies on future scale up because many of the capital costs, infrastructure and training, are already spent. Both average costs and marginal cost estimates can help policy makers decide on how to project the costs they will face during scale up [19]. Marginal cost estimates take into account that for every additional MC procedure some operating costs change (e.g. MC kits) and others

remain fixed (e.g. rent and capital). If there are returns to scale, marginal cost should decline during program scale up. Planners who only have average cost estimates might overestimate the resources required to make incremental changes in the number of surgeries and whether there will be returns to scale up of MC programs.

Bollinger et al provided the first estimate of the marginal cost of MC and estimated that, with MC coverage of 31%, the marginal cost was \$6.81 in 2013 US dollars but excluded costs for mobilization activities. Moreover, marginal cost estimates require data on how costs and number of surgeries co-vary over time but this could not be estimated from this cross-sectional study. The present study aims at contributing to the literature estimating the marginal cost per MC surgery using a time-series dataset over six years from the Rakai Health Sciences Program in Uganda, including expenditures on mobilization activities and measuring the marginal cost for both mobile camps and static services surgeries as well as evaluating other cost trends. This cost analysis can better inform program managers, policy makers and donors on the marginal costs of MC scale up and reveal the most important cost drivers.

METHODS

Kalisizo town and extended area in the Rakai district in southwestern Uganda is a rural area served by the Rakai Health Sciences Program (RHSP). RHSP conducts HIV research, prevention and treatment services. In late 2003, the RHSP provided MC services as part of a randomized trial for HIV prevention [1]. After completion of the trial in 2006, MC procedures were provided free to consenting uncircumcised males aged 13 and older at the main RHSP Kalisizo health service center as well as two small static satellite facilities (Kakuuto and Lyantonde). In 2003, MC prevalence among non-Muslims (85% of the population) was 4%, by 2011, after a four years scale up, MC prevalence was 28% [20].

In addition to the three static facilities, to increase access and generate demand for MC services, RHSP started mobile MC camps in areas with low MC coverage and increased mobilization and HIV counseling services. Mobile MC camps are intensive community outreach programs with full MC services and mobilization activities brought to communities. Mobilization activities at MC camps included sporting events, marketing at bars, taxi stations and text reminders. Camp days range between 2 and 4 weeks. The length, frequency and number of camps vary depending on availability of clients to be circumcised and funding available. Mobile camps' startup costs included tents and new variable costs included more transportation and mobilization resources.

To reduce overall program costs, cost saving strategies were employed including use of clinical officers (equivalent to physician's assistants) [21] and research on use of the Shang Ring and PrePex devices, which require less time and equipment than conventional surgical procedures [22, 23].

Data

This cost analysis is done from the financial perspective which involves examining the activities and resource flows needed to run a male circumcision program during scale up.

The analysis does not estimate economic costs, which would require assessing the value of resources used at their market value. The major resource input into MC is surgeon's time and the market for surgical labor in Uganda is heavily distorted by donor support for MC. It is simply out of our scope to attempt to estimate the dynamic changes in the value of surgical labor in the current Ugandan labor market. The data consist of a time-series with six years of monthly records from January 2008 to December 2013, for a total of 72 monthly observations. Local RHSP program administrators were visited for one week to collect and review accounting records. Accounting records were kept using standardized Ministry of Health tools. Program costs were determined from total program expenditures using standard costing procedures as described by Drummond et al (2005) [24]. Descriptive statistics of data and graphs showing cost trends over time were reviewed and cross checked with program managers for validity. All fixed and variable program expenditures were included, excluding costs related to research activities, and collected by month. Program managers reported no known missing expenditures. Fixed costs (costs that do not change within a year or that do not change when the quantity of output changes), including rent, equipment, training and renovations, were annuitized (except the rent) using a standard three percent discount rate and a useful life specific to each item determined by local program administrators [25]. Variable costs (costs that vary with the quantity of products made or that last less than a year) included wages, surgical supplies, administrative costs and other (e.g., vehicle maintenance, fuel, utilities etc.). Expenditures were converted from Uganda shillings to US dollars monthly using the Barclays Bank Uganda's currency exchange rates. All expenditure data was inflation adjusted to 2013 US dollars using the IMF, World Economic Outlook Database, Uganda inflation, average consumer price index [26].

Econometric model

Histograms of total expenditures showed that the data were skewed and Breusch-Pagan and Cook-Weisberg tests of expenditures revealed heteroskedasticity [27, 28]. Therefore, we used generalized linear models (GLM) with a log link and a Huber-White correction of variance [29]. The dependent variable was the log of monthly total expenditure. Skew and specification tests were used to determine if heavy-tailed log error terms were present [30, 31].

The principal independent variables were the monthly counts of surgeries at mobile camps and fixed sites. The coefficients on these respective variables estimated the marginal cost per additional surgery at each service site. Time dummies and cumulative number of surgeries at each facility type were included as independent variables. A time variable controls for secular trends such as changes in technology, cost of living and others. A time dummy for each year is also tested to estimate the savings from each year. The cumulative number of prior surgeries per month since January 2008 estimated efficiency gains from doing more surgeries as distinct from the simple passage of time. We included a dummy for months during the dry (June–August & Dec.–Feb.) and wet (Sept.–Nov. and March–May) seasons to assess whether expenditures varied between seasons. We also tested an interaction term between season and count of surgeries. We examined scatter plots to identify outliers but none were found.

The following estimating equation was used:

$$\begin{aligned} \text{TotalCost}_i = & \beta_0 + \beta_1 \text{MobileCampSurgeries}_i + \beta_2 \text{StaticServiceSurgeries}_i \\ & + \beta_3 \text{Time Or TimeDummies}_i + \beta_4 \text{PriorSurgeriesCount}_i + \beta_5 \text{DrySeason}_i \\ & + \beta_6 \text{DrySeason} \times \text{Surgeries}_i + \varepsilon_i \end{aligned}$$

Where TotalCost_i is the dependent variable, β_0 is a constant, β_1 and β_2 are the main parameters of interest and can be interpreted as the marginal cost for an additional MC surgery at each program site, β_3 Time is a dummy for the average savings over the passage of time or TimeDummies is a vector of five year dummies with the base year 2008 excluded and coefficients are interpreted as the amount of savings for a given year compared to 2008. β_4 Prior Surgeries Count is a vector for the sum of prior surgeries and is interpreted as an experience indicator. β_5 and β_6 are parameters for differences in costs during the dry and wet seasons.

Various combinations of cost determinants were tested in sensitivity analysis. First, we added one parameter at a time to observe which parameters caused significant changes to marginal cost estimates. Second, we ran the same set of regressions on all MC surgeries together not distinguishing the difference in cost between mobile and static services to observe if the magnitude of the marginal cost changed significantly. Then, we ran the same set of regression models on just the MC at static services to observe if the magnitude of the marginal cost changed significantly, however, these results would likely be bias with an overestimate of costs given that it would count resources used for mobile camps as resources used for static service. Lastly, we ran the same set of regressions adding one year at a time starting with just the year 2008 to evaluate how the marginal cost estimate changed overtime.

RESULTS

The monthly average number of MC surgeries between 2008 and 2013 was 795, with a maximum number of monthly surgeries of 4,073 (Table 1). The monthly average number of surgeries at mobile camps and static services were 345 and 450, respectively. Figure 1, illustrates the number of surgeries performed by month at mobile and static sites over the study period. The program has not reached maximum capacity and the number of surgeries done has been restricted by the amount of funding available. For instance, the reduction in surgeries in the year 2012 was due to decreased funding, and the significant increase in surgeries during the last 12 months of observations, particularly in the mobile camps, was due to more funding available. The larger increase in mobile camp surgeries than in the static services was a strategy employed by the program to increase MC coverage by reaching out to the community.

The monthly average total expenditure for the MC program between 2008 and 2013 was \$72,480 of which wages (\$38,457; 53%) and supplies (\$26,774; 37%) were the main components (Table 1). For a list of resources used for the MC program, see Supplement Table 2. Figure 2 shows the change in monthly average total expenditure by major cost category and year. Total expenditures increased slightly between 2009 and 2013. However,

2012 had a significant reduction in expenditures due to reductions in PEPFAR funding. Figure 2 also illustrates that the main proportional increase in expenditures over time was due to clinical supplies. The increase in clinical supplies was due largely to increased expenditures on mobile camps in 2013 as this mode of service delivery increased (Supplement Figure 1). Likewise, demand-generation (mobilization and marketing activities) doubled with mobile camps from 4% to 8%. There also was a decreasing trend in expenditures on wages likely associated with efficiency gains such as task shifting at both mobile camps and static services from physicians to clinical officers. While the exact decrease in costs due to task shifting cannot be measured because change in costs is influenced by multiple factors, data shows that the proportion of expenditures on physician wages decreased from 62% in 2008 to 35% in 2013 (Supplement Figure 2). Similarly, the proportion of expenditures on physician, junior and assistant clinicians, out of the total expenditure on non-administrative wages, decreased from 94% in 2008 to 80% in 2013.

Table 2 shows marginal cost estimates from the GLM log link regression. Columns 4–10 and 11–16 show the same combinations of cost determinants but use different variables to control for secular trends. The former group uses a year categorical variable. The latter group uses a year dummy for each year of data, excluding the base year 2008, to measure the savings from each individual year compared to the year 2008. Columns 9 and 16 show the full multivariate model with all covariates included. Columns 10 and 17 exclude the experience indicator from the full model and columns 18–20 exclude the secular trend controls. The conditional mean retransformed marginal costs for one additional MC surgery in mobile camps and static service centers based on the full model (column 9) were \$23 ($p<0.01$) and \$35 ($p<0.1$), respectively. Our findings were robust across over 100 regression combinations of cost determinants tested in sensitivity analysis, a few of which are shown in Table 2 and supplement Tables 3–4. The ranges in marginal costs for an additional MC surgery were between \$17–\$27 in mobile camps and \$35–\$40 in a static service centers.

The year and experience dummies were negative, indicating reduced costs, but together these were not statistically significant (Table 2 columns 5–9 and 12–16), thus we could not statistically differentiate the effects of the passage of time and gains in personnel experience. There was a strong correlation between secular trends and cumulative number of surgeries ($r=0.7$), so models including experience without year dummies (columns 18–20) or year dummies without experience (columns 10 & 17) were tested to reduce collinearity. Excluding the prior number of surgeries as a proxy for experience, there was a statistically significant secular decline in marginal costs overall or specifically during years 2009, 2012 and 2013. Excluding year dummies, the prior cumulative number of surgeries proxy for experience at static service sites was statistically significant suggesting that experience contributed to cost savings at these sites (Table 2 columns 19–20). The coefficient for dry season was not statistically significant.

Lastly, supplement Table 3 shows that the marginal cost estimates for static services have decreased steadily overtime from \$300s in 2008 to \$35–\$40 in 2013, consistent with economies of scale and that adding the third year of data with mobile camp activity, 2013, improves the precision (statistical significance) of the marginal cost estimates compared to less years. The average variable cost (AVC) per surgery has also decreased steadily overtime

from \$400 in 2008 to \$40 in 2013. Whenever the marginal cost is smaller than the AVC, as it has been in this case, one can infer that the average cost per male circumcision will decrease as surgeries scale up. For other sensitivity analysis results see supplement Table 4.

DISCUSSION

Using time-series data for six years between 2008 and 2013 from Kaliziso city and extended area in Rakai, Uganda we found that the marginal cost for a MC procedure in a mobile camp and a static service center were \$23 ($p<0.01$) and \$35 ($p<0.1$), respectively. There were substantial savings throughout the study period compared to the 2008 base year, particularly on clinical supplies and personnel costs, while demand for surgeries increased. Savings on personnel costs could largely be attributed to task shifting from physicians to clinical officers at both static centers and mobile camps. Similarly, savings on static service center surgeries could also be attributed to efficiency gains from clinicians' experience, particularly early in the program implementation when clinicians completed guided training. However, during scale up it is typical of programs to first reach people who are receptive and additional efforts may be required to reach more resistant individuals so marginal costs are likely to increase over time. Total monthly expenditure increased with the volume of surgeries due to increased expenditure on clinical supplies, particularly for mobile camps and slightly from community mobilization investments. Increased expenditures on fixed costs were not observed indicating that the program is still running under maximum capacity. Also, the marginal cost continues to be lower than the average cost consistent with economies of scale.

Bollinger et al [17], found that the marginal cost for a MC procedure in Kenya, Namibia, South Africa, Tanzania, Uganda, and Zambia was ~\$7. This is much lower than our findings for either mobile camps or static services and may in part be due to exclusion of expenditures on community mobilization in Bollinger's estimates. Overall, the marginal cost for a MC procedure, particularly for mobile camps, is small compared to the large individual and community health benefits gained from the procedure (i.e. reduction in HIV infections and lower health system costs) [12, 32].

We could not statistically differentiate the effects of the passage of time and gains in personnel experience because these variables were highly correlated. The lack of statistically significant effects on these control variables was due to their collinearity and does not invalidate the main results which are marginal cost estimates. Nevertheless, it is not possible to determine from the data how much of the savings were due to efficiency gains or secular trends. However, qualitative data suggest that the reductions in marginal costs in Rakai can be explained by efficiency gains over time. For instance, optimal competency guidelines were used to train new personnel on safely performing circumcisions. Data from a randomized control trial showed that these training guidelines reduced the time required for surgery from 40 to ~20 minutes after personnel had performed more than 100 procedures [33], suggesting that optimal competency was achieved with experience. While gains in experience from these trainings likely reduced costs soon after the training was completed, the level of savings would be maintained in the form of fewer surgeons and lower labor costs

needed to meet the same surgery targets. Likewise, significant reductions in expenditure on wages as demand for procedures increased indicates that there are program efficiency gains.

This study was limited by data from only one region and country and few facilities. However, the data included all three static facilities offering MC services in the area, the main RHSP Center and two satellite facilities, all mobile camps data, and comprehensive multi-year expenditure and surgery counts data not used before and necessary for studies on programs' cost during scale up. Similarly, this study did not find a seasonal effect on costs. However, a seasonal effect is unlikely to change overall marginal cost estimate. Nonetheless, future studies with longer periods of data may find this association. Lastly, the data was limited by the accuracy of expenditure data from book keeping records. However, we conducted in depth review of the data gathering data directly from the program administrators, visiting the program on site, interviewing surgeons, nurses, health educators, HIV counselors and program managers to ensure all costs and resources were included, and cross checking descriptive analysis of expenditure data and graphs showing cost patterns over time with program managers.

As shown by the multiple regression tests with consistent marginal costs and statistical significant estimates validating measurement accuracy our results are robust and may be representative of rural areas with similar socioeconomic standards of living to Rakai, Uganda. Future studies including similarly detailed data from different regions or facilities would inform what program components, geographical or socioeconomic components may vary estimates. In conclusion, the Rakai MC program has shown decreasing marginal costs with scale up of services, reflecting task shifting, increased efficiency and economies of scale.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Trend in number of Male Circumcision (MC) surgeries between 2008 and 2013

Figure 2.

Total male circumcision (MC) program expenditure by major category and year

Table 1

Data Descriptive Statistics (72 months of program expenditures and surgeries)

Variable description	Mean	Std. Dev.
Number of Male circumcision (MC) surgeries	795	955
Surgeries at mobile camps	345	822
Surgeries at static service centers	450	253
Surgeries at the main service centers	316	119
Surgeries at satellite service center	134	177
Total costs	\$72,568	\$34,486
Fixed costs	\$1,960	\$2,276
Variable costs	\$70,608	\$33,483
Average Cost	\$190	\$166
Average fixed cost	\$5	\$8
Average variable cost	\$185	\$162

* This table shows the average monthly mean and standard deviation of the data. See regression results for program marginal cost results.

Table 2

average marginal effects (expenditure results in 2013 US\$)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]	Expenditure [SE]
		9.49*** [4.16]	15.94*** [4.637]	22.61*** [5.621]	20.08*** [5.803]	22.78*** [5.751]	22.52*** [6.152]	22.79*** [6.092]	15.76*** [3.395]	19.14*** [5.009]	21.91*** [5.869]	21.14*** [6.778]	22.20*** [6.467]	21.96*** [6.826]	22.15*** [6.447]	19.22*** [3.259]	26.23*** [6.993]	20.25*** [4.202]	23.27*** [5.541]
12.72 [12.19]		-1.66 [1.86]	38.25*** [18.10]	34.18* [19.43]	40.74*** [17.24]	36.21* [18.54]	37.15* [20.20]	34.84* [19.82]	38.19*** [18.29]	38.07* [21.63]	33.49 [24.42]	39.16* [20.86]	35.52 [22.53]	37.76 [23.42]	34.34 [23.87]	38.09* [21.62]	6.111 [11.10]	40.44*** [16.68]	36.02* [20.81]
			-10.317*** [3.770]	-8.324* [4.853]	-1.816 [12.247]	-5.135 [12.903]	-5.352 [12.989]	-5.472 [12.865]	-10.330*** [3.759]	-23.335* [12.625]	-23.186* [12.701]	-19.426 [15.946]	-21.014 [17.122]	-21.145 [16.949]	-21.182 [17.168]	-23.334* [12.623]			
										-16.792 [10.721]	-16.150 [10.876]	-8.818 [21.054]	-11.827 [22.935]	-12.241 [23.092]	-12.141 [22.844]	-16.786 [10.704]			
										-24.071 [17.001]	-21.951 [18.207]	-10.110 [41.468]	-14.693 [44.034]	-15.651 [44.175]	-15.184 [43.984]	-24.039 [17.144]			
										-45.343*** [16.627]	-41.076** [19.695]	-24.109 [57.593]	-30.349 [61.567]	-31.537 [62.331]	-30.626 [61.264]	-45.324*** [16.546]			
										-63.577*** [20.598]	-53.980** [26.390]	-36.398 [69.307]	-41.535 [72.244]	-44.446 [72.954]	-40.930 [72.373]	-63.566*** [20.602]			
				-1.587 [1.444]		-1.204 [1.583]	-1.154 [1.612]	-1.561 [2.098]			-0.933 [1.412]		-0.648 [1.490]	-0.520 [1.520]	-0.854 [1.957]		-3.831** [1.851]		-1.069 [2.089]
					-1.860 [2.235]	-0.803 [2.687]	-0.788 [2.674]	-0.656 [2.732]				-1.156 [2.699]	-0.655 [3.139]	-0.642 [3.141]	-0.597 [3.139]			-2.232*** [0.697]	-1.889* [1.137]
							1.713	-2.191	-325.4					2.376	-996.3	143.2	-4.053	-1.011	-2.030