Heterogeneous preferences for medical male circumcision services for HIV prevention among uncircumcised men in Uganda: a discrete choice experiment

Abstract
Objective: The success of policies to improve uptake of valuable health services depends on how these policies align with preferences for those services or their mode of delivery. We studied heterogeneity of preferences for multiple stakeholder-identified attributes of medical male circumcision (MMC) services in a high-HIV prevalence community in Uganda. MMC uptake remains low in this region despite evidence of its cost-effectiveness for HIV prevention.

Methods: We conducted a discrete choice experiment among 406 self-reported uncircumcised, HIV-negative men between 18-45 years-old. We estimated conditional-logit, and mixed-logit and latent-class-logit models to examine heterogeneity in preferences for seven attributes of MMC services. Based on these estimated preference distributions, we simulated uptake of five potential MMC service delivery policies.

Results: Mean utilities (μ, se) were highest for permanent (versus outreach) health facilities (3.860, 0.511), device (versus surgical) circumcision (-2.900, 0.456) and cash (versus none) incentives (2.499, 0.607). There was significant heterogeneity in preferences for all attributes. The latent class model identified three groups of individuals with distinct preference patterns. Uptake was highest for cash incentives, except in one class of individuals in whom uptake with the introduction of circumcision with devices was highest.

Conclusion: MMC uptake could be optimized by designing services that cater to preferences for fixed versus outreach site options, method of circumcision and incentives. However, to maximize MMC uptake, policy makers should offer a combination of services and allow people to self-select according to their individual or group preferences.

Keywords: Medical Male Circumcision, Preferences, Heterogeneity

Running head: Preferences for Medical Male Circumcision Services

Word count: 4270

1 Introduction

Medical Male Circumcision (MMC) of adolescent boys and men is an effective intervention for the prevention of female-to-male HIV transmission,[1] with a potentially positive return-on-investment if coverage can be scaled-up.[2] In 2011, the WHO/UNAIDS set a target of performing 20.3 million circumcisions in 14 priority countries by 2016. However, by 2015, an estimated 11.7 million adolescent boys and men had been circumcised, representing 58% of this target.[3]

Economic evaluations have shown that MMC is highly cost-effective when compared to no MMC,[4-6] and to a portfolio of biomedical HIV prevention interventions.[7] However, qualitative studies have documented intangible (psychological and socio-cultural) costs that impede acceptability of circumcision,[8] that are not captured in economic evaluations. Quantitative studies have also shown that demand for MMC is lower than projected in economic evaluations, is highly price elastic,[9, 10] and is concentrated among lower risk individuals.[11] Other than price effects, these studies did not elucidate other factors that may influence demand for MMC.

Supply-side interventions to increase uptake of MMC have centered around enhancing MMC service delivery, through task-shifting, use of strategic campaign and outreach services, and introduction of circumcision devices.[12] Demand-side strategies involved the use of financial and behavioral interventions to incentivize the utilization of MMC services.[13] Understanding individual preferences for the components of these interventions could inform the design of better MMC demand creation strategies.

We set out to evaluate the potential impact of alternative MMC service delivery policies for increasing uptake of MMC in Uganda. In order to inform these evaluations, we designed a discrete choice experiment (DCE) to study heterogeneity in preferences for the demand of MMC. DCEs advantageous over other economic valuation methods because of their ability to identify the characteristics of goods that influence choices,[14] and are attractive in settings without readily available revealed preference data. We analyze preferences for contemporary attributes that characterize MMC service delivery in Uganda and use these preference distributions to examine the potential demand effects of alternative policies for MMC service delivery.

2 Methods

2.1 Study setting

The study was conducted in Mukono district, among predominantly fishing communities at landing sites on Lake Victoria, Uganda. The incidence and prevalence of HIV are higher in fishing communities compared to non-fishing communities.[15, 16] Residents of fishing communities exhibit a high-HIV-risk profile characterized by high rates of multiple sexual partnerships, alcohol consumption before sex, and non-marital sexual partnerships. The prevalence of circumcision among non-Muslim men in fishing communities of 30.7% is also lower than in the non-fishing communities.[15]

2.2 Attributes and attribute-levels

We reviewed literature and conducted qualitative interviews: 11 Focus Group Discussions (FDGs) and 6 Key Informant (KI) interviews, in August 2016 to identify health services factors that influence utilization of medical male circumcision services. We initially identified 12 influential MMC service attributes (Web Appendix A), which were narrowed to focus on the most influential to MMC decisions, and the most relevant for MMC demand creation policy or intervention design. The relative importance of the attributes to men's MMC decisions was inferred by the extent of mention in the qualitative interviews. Policy-relevance was inferred through KI interviews with MMC surgeons and community health workers involved in mobilization for MMC. Attribute levels were based on the qualitative interviews and plausibility for intervention or service design.

A final list of seven attributes and their levels included: (1) accessing MMC services at permanent versus temporary health facilities, (2) distance travelled to access MMC services (1 km, 5 km, 15 km), (3) number of week-days during which MMC services were available (1, 3 and 5 days), (4) privacy during counselling and waiting to get circumcised (complete, some, none), (5) device versus surgical circumcision, (6) incentives for getting circumcised (none, voucher and cash), and (7) price/monetary

value of incentive (a continuous variable with values greater than or equal to zero, indicating out-of-pocket payment and negative values indicating incentive payment) (Web Appendix Table B1).

2.3 Experimental design

Our experimental design approach is detailed in Web Appendix B. In February 2017, we conducted a pilot survey of 40 men to obtain priors for a Bayesian D-efficient experimental design. The final design had 36 choice scenarios in 3 blocks of 12 choice tasks each. The D-error for this design was 0.06 and required sample size of 123 respondents per block.[17] We used the pick-one response format because it was simple to implement, imposed a lower cognitive burden, and mimicked real-life decision-making.[18] A 2-alternative design with an opt out (neither) alternative, approach permitted estimation of unconditional demand and enhanced the conceptual validity of our experiment given that MMC is voluntary. An example of the choice task is shown in Figure 1.

2.4 Questionnaire

We also collected data on sociodemographic characteristics, health status, sexual behaviors, and past experiences with circumcision. Before the discrete choice experiment, we provided a verbal explanation of circumcision and a brief animated video describing the procedures of circumcision. The questionnaire was translated into Luganda, the predominant local language of the area and independently back-translated. The two translators jointly reviewed the translations to resolve discrepancies. The questionnaire was programmed onto Open Data Kit (ODK) 2.0,[19] on Android tablets. Each respondent was randomly allocated to one of the three choice blocks.

2.5 Survey procedures

The survey was conducted between March and April 2017 in Ntenjeru sub-country in Mukono district, which is divided into nine parishes with 111 villages and has a population of about 40,000 people, approximately 50% of whom are male.[20] We randomly selected seven villages for the study, and included self-reported heterosexual, uncircumcised, HIV-negative men aged between 18-45 years, who consented to the study. Trained community health workers identified respondents who fit the inclusion criteria. Trained research assistants administered the questionnaire in private to randomly selected respondents either at their homes or their workplaces. The interviews lasted between 60-90 minutes and included an incentive payment equivalent to US$2 per participant.

2.6 Ethical considerations

The study was approved by the Institutional Review Boards (IRB) of the University of Washington and Mbarara University of Science and Technology. The Uganda National Council for Science and Technology (UNCST) provided final clearance for the study. All study participants provided written consent. Data were encrypted and uploaded daily onto an online server at the University of Washington's Global Medicines Program.

2.7 Analytical strategy

2.7.1 Indirect utility function

Our econometric framework follows random utility theory in which utility is a latent construct composed of systematic, V and stochastic, ε components.[21, 22]

$$U_{njt} = V_{njt} + \varepsilon_{njt}$$

Systematic utility was modelled as a function of choice attributes, X_{njt} and a parameter vector, β of generic marginal utilities, and alternative specific constants (ASC):[23]

$$\begin{aligned} V_{njt} = \beta_{o,j} &+ \beta_{permhc}X_{permhc,njt} + \beta_{dist5}X_{dist5,njt} + \beta_{dist15}X_{dist15,njt} + \beta_{avail}X_{avail,njt} + \beta_{somepriv}X_{somepriv,njt} \\ &+ \beta_{nopriv}X_{nopriv,njt} + \beta_{device}X_{device,njt} + \beta_{voucher}X_{voucher,njt} \\ &+ \Big(\beta_{pricenone}\big(X_{none,njt} = 1\big) + \beta_{pricevoucher}\big(X_{voucher,njt} = 1\big) \\ &+ \beta_{pricecash}\big(X_{cash,njt} = 1\big)\Big)X_{price} \end{aligned}$$

$\beta_{0,j}$ for $j = \{1, 2\}$ were normalized to zero to allow for identification so that $\beta_{0,neither}$ can be interpreted as the baseline preference to opt-out of circumcision. This structural model allowed for the marginal utility of price to depend on whether an option was presented as an out-of-pocket payment (a positive price) or an incentive payment (a negative price). We used indicator variables for type of incentive in the price interactions, which allowed us to recover three estimates of marginal utility of price, i.e. $\beta_{pricenone}$, the marginal utility of out-of-pocket payment, $\beta_{pricevoucher}$, the marginal utility of a voucher incentive payment, and $\beta_{pricecash}$ the marginal utility of a cash incentive payment.

2.7.2 Econometric estimations

First, we estimated conditional logit (CL) model,[22] that assumes individuals have the same parameter vector, β. We, then, estimated panel mixed logit (MIXL) and latent class logit (LC) models that incorporate random preference heterogeneity i.e., these models assume that each individual or group of individuals has their own parameter vector, β_n which is drawn from a mixing distribution with density $f(\beta|\Omega)$. In the MIXL, $f(\beta|\Omega)$ was specified to follow a multivariate normal mixing distribution with mean parameter vector, $\bar{\boldsymbol{\beta}}$ and covariance matrix, Σ.[24] The MIXL was estimated by maximum simulated likelihood,[25] using 2000 Modified Latin Hypercube Sampling (MLHS) draws.[26] In the LC model, $f(\beta|\Omega)$ was specified as discrete i.e., that respondents belong to separate classes with homogeneous utility coefficients, β_q.[27] Class membership which is unobserved to the analyst was modelled using a multinomial logit, with utility of class membership, a linear function of age, education level, income, and residence (urban versus rural).

2.7.3 Policy simulations

We examined the potential effects of five policy proposals on the potential uptake of MMC. Descriptions of the policy options as attributes in our choice experiment are shown in Web Appendix Table C1. As was the predominant practice in the study area, the initial state was set to surgical circumcision services only available at permanent health facilities. We then examined the demand effects of five post policy states: (1) introduction of outreach services where circumcision was performed by surgical methods, (2) an option of a device circumcision option at permanent health facilities, (3) introduction of both outreach services where circumcision was performed by surgical methods and a choice of device circumcision option at permanent health facilities (i.e. 2, and 3 above), (4) providing cash incentives for device and surgical circumcision at permanent health facilities--assuming a cash incentive equivalent to US$12 would be provided if circumcision was performed using a device, and US$8 if circumcision was performed surgically and (5) introduction of both outreach services where circumcision was performed by surgical methods and providing cash incentives for device and surgical circumcision at permanent health facilities. The opt-out option was available in both initial and post-policy states for all comparisons, reflecting the voluntary nature of the MMC (Web Appendix Table C2). Using this approach, we were able to project the realizable demand for circumcision by observing how different policies affect the probability of choosing the opt-out option, and how individuals self-select into different options depending on their preferences.

We used the estimated parameters from the different model specifications to calculate the predicted probability of choosing different circumcision options. For predictions from the CL model this involved a straightforward calculation of choice probabilities using the logit function. For predictions from models which incorporated random preference heterogeneity, we calculated a vector of unconditional choice probabilities for each individual by averaging over the distribution of the random parameters. This method of obtaining choice probabilities is consistent with the interpretation that randomness of parameters captures taste differences in the population, as opposed to measurement error.[28] To capture measurement error, we used the resulting individual unconditional choice probability vectors, to probabilistically allocate a chosen alternative, summed choice indicators to obtain number of times each alternative was chosen and divided by number of individuals to calculate the average demand.

To enhance the realism of our policy analysis, we followed methods suggested by Train,[25] and implemented by others,[29-31] to recalibrate our models such that the probability of choosing circumcision in the initial state matched the estimated prevalence of uncircumcised men in fishing communities in Uganda of approximately 30.7%.[15]

The experimental design was generated in Ngene v1.1.2 (ChoiceMetrics Ltd) [22]. All econometric models were coded and estimated in R using the Apollo 0.0.9 suite of functions.[32] Policy simulations were also performed in R. Additional details of the econometric approach and policy simulations are provided in Web Appendix C. Data and codes are available at https://github.com/lubingas/MMC-Demand.

3 Results

3.1 Descriptive summary

We interviewed a total of 406 respondents. We did not collect information on those who were approached but decline to take part in the survey. All respondent who agreed to take part in the survey gave complete responses to all questions. Characteristics are summarized in Table 1. The mean (SD) age and years of schooling were 27.0 (6.7) and 7.0 (3.2) years respectively. The median monthly income was US$26.7. The majority lived in urban areas (64%), and a half (50%) were married. Most participants belonged to the Baganda tribe (67%), were Catholic (48%), and worked in fishing or fishing related businesses (38%).

3.2 Econometric estimations

Results of the CL and MIXL (as mean and standard deviations) models are shown in Table 2. Preferences for all attributes were directionally consistent with our prior hypotheses. Mean attribute preferences in the MIXL model were directionally similar to, albeit numerically higher than their corresponding CL estimates, except for the coefficient on $\beta_{o,neither}$ which was not statistically significantly from zero in the MIXL model. Standard deviations for all preference parameters were statistically significant ($p < 0.05$).

The 3-class model had the lowest BIC (Web Appendix Table D1). Preferences estimates are shown in Table 5. Individuals in class 3 exhibit a preference pattern similar to the CL model. The ASC was not significant for individuals in classes 1 and 2. Individuals in class 2 had a strong preference for device circumcision (3.195; $p < 0.001$), a preference for moving moderately further to access services (0.800, $p < 0.05$), and were only sensitive to out-of-pocket payment. By contrast, those in class 1 were characterized by strong preferences for permanent health facilities (3.260; $p < 0.001$) and incentives (voucher: 1.874; $p < 0.001$, and cash: 1.534; $p < 0.001$), although they were not sensitive to the amount of incentive offered. They had a strong dislike for device circumcision (-4.703; $p < 0.001$), the strongest preference for a higher number of weekdays of service availability and disliked longer distances to access services. Class membership was predicted by education level and place of residence (urban versus rural). Those who had completed at least a primary education were more likely to belong to class 2 compared to classes 1 and 3. Those residing in urban areas were more likely to belong to class 3 compared to classes 1 and 2. Most respondents were predicted to belong to class 3 (47.5%).

3.3 Policy simulations

Choice probabilities from the policy simulations are shown in Figure 2, panel A for the CL model. Addition of outreach services would result in 18% choosing these services by individuals substituting away from the opt out and surgery options (from 69% to 56% and 30% to 25% respectively). Fifteen percent (15%) would choose device circumcision if it were introduced, while introduction of both outreach services and device circumcision would result in 16% and 13% choosing these services respectively. Addition of incentives for device and surgical circumcision would lower probability of opt-out (from 69% to 42%) and increases in probability of choosing both surgical circumcision to 35%, and device circumcision to 23%. If all options were available in the policy mix, 37% would still opt-out. Incentives for surgery would not alter the predicted uptake of surgical circumcision, but 20% would choose device circumcision, and 12% would opt for surgery at an outreach center.

Predictions from the MIXL model are shown in Figure 2, panel B. Introduction of outreach services would result in 38% of individuals choosing this option, by individuals substituting away from the opt out option (from 69% to 44%), and from surgical circumcision at hospitals (31% to 18%). Introduction of device circumcision would result in 29% of individuals choosing this option, by substituting away from the opt out option (from 69% to 50%) and surgical circumcision (from

31% to 20%). A policy mix where device and surgical circumcision options were available at health facilities, together with outreach services would result in 30% choosing outreach services, 23% choosing device circumcision, and reductions in surgical circumcision in hospitals from 31% to 14% and the opt-out option from 69% to 32%. Cash incentives for device and surgical circumcision at hospitals would lower percentage of men opting out to approximately 7% largely driven by an increase to approximately 61% in those choosing device circumcision.

Predictions from the LC model are shown in Figure 2 panel C for the individual classes. The predicted uptake patterns we observed in class 3 were consistent with those from the CL model. We predicted a large increase in the probability of choosing device circumcision (73% and 72%) for individuals in class 2 if device circumcision was added to the policy mix, but a modest impact on uptake in (from 41% to 40%) if a cash incentive was provided, largely driven by an increase in uptake of device circumcision (39% and 38%). In class 1, we predicted a slight increase (7%) in the probability of choosing outreach services if they were added to the policy mix, and no increase in the probability of device circumcision. For these individuals, only the addition of incentives appreciably increased the probability of circumcision driven almost exclusively by an increase in the probability of choosing surgical circumcision (72% and 70%). Averaging over the classes, cash incentives were predicted to lead to the largest increase in uptake of circumcision (figure 2, panel D)

4 Discussion

4.1 Interpretation

Our choice experiment assessed three policy options that could influence the demand for MMC: service delivery models, the introduction of device circumcision, and potential out-of-pocket cost and incentives payments for circumcision. MMC services are mostly provided either at static (fixed) health facilities or as outreach services, or some combination of both.[12] We captured trade-offs between three attributes that characterize these service delivery models: permanency of the facility, distance to access services, and availability of MMC services whenever they were sought. Of these, permanency of the health facility was the most highly valued attribute, and service availability was the least valued. In our qualitative interviews, the importance of permanent health facilities was driven primarily by fear of procedure-related complications and the need to have readily accessible help. The infrequent availability of services was of less concern probably because men could tailor their schedules to match the days that services were provided. Distance was mostly a concern for those who lived far away from MMC service points.

Circumcision devices have been promoted for their potential to resolve implementation challenges and appeal to men.[33] However, we found that men, on average, disliked device circumcision. Several attributes of devices may not appeal to men, in particular, the requirement for tetanus immunizations and multiple clinic visits. Current evidence indicates a high risk of tetanus with device circumcisions.[34] The WHO recommends immunization with a tetanus-toxoid-containing vaccine, implying that men would require at least four clinic-visits--two for vaccination, 1 for device placement and 1 for device removal, likely creating a significant barrier to device circumcision.

Incentives were valued components of the hypothetical MMC services. In particularly cash incentives, have the potential to generate demand for MMC. Price was an important predictor of choice: sensitivity to price varied depending on whether individuals were faced with an out-of-pocket payment or would receive an incentive payment. Respondents were only sensitive to incentive payments, with the estimates higher for voucher payments. The marginal utility distributions indicate that most individuals are likely to be slightly more sensitive to voucher payments than both out-of-pocket payment and cash incentives. The high mean marginal utility for cash payments suggests that there could be outliers who are unusually sensitive to cash payments.

There was significant heterogeneity in the ASC with a distribution that suggests a substantial proportion of individuals either who do not like circumcision, or whose preferences were well described by the attributes in our experiment (with ASC would be ≥ 0). The MIXL model also suggests substantial heterogeneity exists in preferences for key policy variables: permanency of health facilities, device circumcision, cash incentives and price (and the respective interactions indicating the type of incentive).

The LC model revealed three distinct classes of individuals. The majority of individuals (47.5% in class 3) either would like to get circumcised, or our experiment did not capture all the attributes that matter to them as indicated by a negative and significant ASC. These individuals responded to changes in attributes of the MMC services in a moderate and mostly predictable way. It may be difficult to design services specific to these individuals based on our study because we likely have not fully characterized the attributes that drive their choices. However, the key decision drivers in these individuals were the availability of services at permanency of health facilities and incentives; they were also sensitive to the incentive payments but not out-of-pocket payments. Individuals in class 2 (15.5%) had a clear preference for device circumcision and were only sensitive to out-of-pocket payments. For these, the focus should be on providing device circumcision, at minimal out-of-pocket cost. Similarly, our experiment captured all the decision drivers for individuals in class 1. They expressed strong preferences for circumcision services at permanent health facilities, performed by surgical methods. They also had strong preferences for incentives but were insensitive to the value of the incentive payment. For these, the focus should be on providing surgical MMC services at permanent health facilities close to where they live, as well as some form of incentive, irrespective of the amount.

The policy analysis indicated that cash incentives for device and surgical circumcision at permanent health facilities is, probably, the most likely to lead to the largest increase in uptake, although their potential policy effects were highly heterogeneous. We identified individuals (class 2) in whom the introduction of device circumcision at permanent health facilities may lead to the largest increase in uptake even in the presence of cash incentives. Indeed, incentives could have the paradoxical effect of dis-incentivizing circumcision because individuals are probably suspicious about the motivations of circumcision service providers. Some participants in our FGDs believed that their foreskins were being sold onwards, for instance to make cosmetics. This either could lead to a desire for incentives or could reinforce this belief and hence dis-incentivize circumcision. Individuals in class 1 may be much more responsive to demand creation programs that utilize cash incentives for surgical circumcision at permanent health facilities.

Further analyses should examine the benefit-cost profile of different demand creation strategies. For instance, our models predict only modest impacts of introducing outreach services on uptake of MMC. The average cost (in US$ 2012) of circumcision in surgical outreach camps ranges from $61 to $72 for more remote locations,[35] suggesting that such a program may not be worth its cost. The introduction of device circumcision appreciably increased uptake in class 2 (15.5% of the population) and only moderately increased uptake in class 3 (47.5% of the population), especially when combined with a cash incentive. Given the estimated average cost of providing this service at health facilities in Uganda is $30.55,[36] it may not be worth its cost, unless it is appropriately targeted to these groups. Provision of cash incentives is a potentially high-value demand creation strategy, although as we have shown, for individuals in class 2, this may actually disincentivize uptake of circumcision.

4.2 Strengths and limitations

We followed best practices for the development of choice experimental surveys,[14, 37] including the identification of relevant attributes and attribute levels using qualitative methods. However, our findings should be interpreted in light of several limitations. Our sample was drawn from a single sub-county in Uganda, limiting the generalizability of our findings. The length of the survey and complex nature of the questions likely imposed a high cognitive burden on the respondents and may have induced non-compensatory heuristics in evaluating the choice tasks.[38] Given that our analytical framework assumes compensatory decision rules, our results may be biased. Device circumcision was a relatively new approach in the community: only a few men had prior knowledge about it. We provided a verbal explanation of, and a brief video describing the procedure before the choice experiment.

Preferences in stated choice experiments may not reflect actual preferences in real life.[39] We excluded important attributes that may influence demand for MMC for HIV prevention, for instance gender of the provider, HIV testing requirements and facility waiting times. To the extent that these are correlated with included attributes, our marginal utility estimates may be biased.[40] We mitigated this by asking respondents to assume these attributes were the same across all choice options.

4.3 Implications for policy

Our study suggests that, where resources are limited, policymakers should continue to prioritize the provision of MMC services at permanent health facilities, using surgical methods of circumcision. The introduction of devices may be challenging, likely requiring physical improvements in the devices themselves, and associated circumcision and pain management techniques. Enhancing the acceptability of device circumcision may also require training covering personal hygiene and pain management. Although controversial for a voluntary procedure, policymakers should also consider the use of voucher and cash incentives to increase the utilization of MMC services. The projections in our policy analysis are based on modest $12 and $8 cash incentives for device and surgical circumcision respectively. It is possible to increase these amounts which could increase demand and still maintain a favorable benefit-cost ratio. Our policy analysis indicates that, offering a policy mix that considers heterogeneous preferences in the population is likely to result in higher overall uptake of MMC.

Our analyses of heterogeneity in preferences and demand effects support the continued implementation of targeted MMC outreach services, specifically to the more educated perhaps because of competing demands on their time, and to those who reside in rural areas perhaps because of challenges in travelling to permanent health facilities. Our analysis also suggests a potential role for targeting the device method of circumcision towards more educated men, perhaps because of better knowledge, or better ability to manage pain or complications. The patterns of preferences for incentives and price we observed in our LC model suggest that, for individuals in class 2, who are insensitive to the type of incentive but respond to the out-of-pocket payment for MMC, policymakers could focus on ensuring the availability of low-cost MMC services. Individuals in class 1, who are sensitive to the type of incentive but are insensitive to both the out-of-pocket payment and the amount of incentive, would likely require some form of incentive, although the amount does not matter.

5 Acknowledgements

(See Title Page for Acknowledgements)

6 Declaration of conflicting interest

The Author(s) declare(s) that there is no conflict of interest.

7 References

1. Mills E, Cooper C, Anema A, Guyatt G. Male circumcision for the prevention of heterosexually acquired HIV infection: a meta-analysis of randomized trials involving 11,050 men. *HIV Med*. 2008; 9(6):332-5.

2. Njeuhmeli E, Forsythe S, Reed J, Opuni M, Bollinger L, Heard N, et al. Voluntary medical male circumcision: modeling the impact and cost of expanding male circumcision for HIV prevention in eastern and southern Africa. *PLoS Med*. 2011; 8(11):e1001132.

3. World Health Organization. WHO Progress Brief - Voluntary Medical Male Circumcision for HIV prevention in priority countries of East and Southern Africa - June 2016 2016. Available from: http://apps.who.int/iris/bitstream/10665/246174/1/WHO-HIV-2016.14-eng.pdf Accessed: February 12 2017

4. Auvert B, Marseille E, Korenromp EL, Lloyd-Smith J, Sitta R, Taljaard D, et al. Estimating the resources needed and savings anticipated from roll-out of adult male circumcision in Sub-Saharan Africa. *PLoS One*. 2008; 3(8):e2679.

5. Bollinger LA, Stover J, Musuka G, Fidzani B, Moeti T, Busang L. The cost and impact of male circumcision on HIV/AIDS in Botswana. *J Int AIDS Soc*. 2009; 12:7.

6. Gray RH, Li X, Kigozi G, Serwadda D, Nalugoda F, Watya S, et al. The impact of male circumcision on HIV incidence and cost per infection prevented: a stochastic simulation model from Rakai, Uganda. *AIDS*. 2007; 21(7):845-50.

7. Long EF, Stavert RR. Portfolios of biomedical HIV interventions in South Africa: a cost-effectiveness analysis. *J Gen Intern Med*. 2013; 28(10):1294-301.

8. Djimeu WE. Scoping report on interventions for increasing the demand for voluntary medical male circumcision: Washington (DC): International Initiative for Impact Evaluation (3IE). 2013. Available from: http://www.3ieimpact.org/media/filer/2013/03/22/white_paper__vmmc.pdf Accessed: April 12 2016

9. Chinkhumba J, Godlonton S, Thornton R. The Demand for Medical Male Circumcision. *Am Econ J-Appl Econ*. 2014; 6(2):152-77.

10. Thirumurthy H, Masters SH, Rao S, Bronson MA, Lanham M, Omanga E, et al. Effect of providing conditional economic compensation on uptake of voluntary medical male circumcision in Kenya: a randomized clinical trial. *J Am Med Assoc*. 2014; 312(7):703-11.

11. Padian NS, Buve A, Balkus J, Serwadda D, Cates W, Jr. Biomedical interventions to prevent HIV infection: evidence, challenges, and way forward. *Lancet*. 2008; 372(9638):585-99.

12. Ledikwe JH, Nyanga RO, Hagon J, Grignon JS, Mpofu M, Semo BW. Scaling-up voluntary medical male circumcision - what have we learned? *HIV AIDS (Auckl)*. 2014; 6:139-46.

13. Sgaier SK, Reed JB, Sundaram M, Brown A, Djimeu E, Ridzon R. Interventions to Drive Uptake of Voluntary Medical Male Circumcision-A Collection of Impact Evaluation Evidence. *J Acquir Immune Defic Syndr*. 2016; 72 Suppl 4:S257-s61.

14. Lancsar E, Louviere J. Conducting discrete choice experiments to inform healthcare decision making: a user's guide. *Pharmacoeconomics*. 2008; 26(8):661-77.

15. Chang LW, Grabowski MK, Ssekubugu R, Nalugoda F, Kigozi G, Nantume B, et al. Heterogeneity of the HIV epidemic in agrarian, trading, and fishing communities in Rakai, Uganda: an observational epidemiological study. *Lancet HIV*. 2016; 3(8):e388-96.

16. Kamali A, Nsubuga RN, Ruzagira E, Bahemuka U, Asiki G, Price MA, et al. Heterogeneity of HIV incidence: a comparative analysis between fishing communities and in a neighbouring rural general population, Uganda, and implications for HIV control. *Sex Transm Infect*. 2016; 92(6):447-54.

17. Rose JM, Bliemer MCJ. Sample size requirements for stated choice experiments. *Transportation*. 2013; 40(5):1021-41.

18. Louviere JJ, Hensher DA, Swait JD. Stated Choice Methods: Analysis and Applications. Cambridge, UK: Cambridge University Press 2000.

19. Brunette W, Sundt M, Dell N, Chaudhri R, Breit N, Borriello G. Open Data Kit 2.0: Expanding and Refining Information Services for Developing Regions 2013. Available from: http://dl.acm.org/citation.cfm?id=2444790 Accessed: January 01 2017

20. Uganda Bureau of Statistics. National Population and Housing Census 2014: Provisional Results 2014. Available from: http://www.ubos.org/onlinefiles/uploads/ubos/NPHC/NPHC%202014%20PROVISIONAL%20RESULTS%20REPORT.pdf Accessed: June 14, 2017

21. Manski CF. The structure of random utility models. *Theor Decis*. 1977; 8(3):229-54.

22. McFadden D. Conditional logit analysis of qualitative choice behavior. In: Zarembka P, ed. *Frontiers in Econometrics*. New York: Academic Press 1973.

23. Lancaster KJ. A New Approach to Consumer Theory. *J Polit Econ*. 1966; 74(2):132-57.

24. McFadden D, Train K. Mixed MNL models for discrete response. *J Appl Economet*. 2000; 15(5):447-70.

25. Train K. Discrete choice methods with simulation. New York, USA: Cambridge University Press 2009.

26. Hess S, Train KE, Polak JW. On the use of a Modified Latin Hypercube Sampling (MLHS) method in the estimation of a Mixed Logit Model for vehicle choice. *Transport Res B-Meth*. 2006; 40(2):147-63.

27. Greene WH, Hensher DA. A latent class model for discrete choice analysis: contrasts with mixed logit. *Transport Res B-Meth*. 2003; 37(8):681-98.

28. Herriges JA, Phaneuf DJ. Inducing Patterns of Correlation and Substitution in Repeated Logit Models of Recreation Demand. *Am J Agr Econ*. 2002; 84(4):1076-90.

29. Buckell J, Hess S. Stubbing out hypothetical bias: improving tobacco market predictions by combining stated and revealed preference data. *J Health Econ*. 2019; 65:93-102.

30. Fiebig DG, Knox S, Viney R, Haas M, Street DJ. Preferences for new and existing contraceptive products. *Health Econ*. 2011; 20 Suppl 1:35-52.

31. Sivey P, Scott A, Witt J, Joyce C, Humphreys J. Junior doctors' preferences for specialty choice. *J Health Econ*. 2012; 31(6):813-23.

32. Hess S, Palma D. Apollo: A flexible, powerful and customisable freeware package for choice model estimation and application. *J Choice Model*. 2019; 32:100170.

33. Tobian AA, Reed J, Njeuhmeli E. An evidence-based analysis of voluntary medical male circumcision devices. *Nat Rev Urol*. 2016; 13(5):295.

34. World Health Organization. Tetanus and voluntary medical male circumcision: risk according to circumcision method and risk mitigation. Report of the WHO Technical Advisory Group on Innovations in Male Circumcision 2016. Available from: https://www.malecircumcision.org/file/61936/download?token=ev4nWK9i Accessed: June 19 2017

35. Larson B, Tindikahwa A, Mwidu G, Kibuuka H, Magala F. How much does it cost to improve access to voluntary medical male circumcision among high-risk, low-income communities in Uganda? *PLoS One*. 2015; 10(3):e0119484.

36. Duffy K, Galukande M, Wooding N, Dea M, Coutinho A. Reach and cost-effectiveness of the PrePex device for safe male circumcision in Uganda. *PLoS One*. 2013; 8(5):e63134.

37. Coast J, Al-Janabi H, Sutton EJ, Horrocks SA, Vosper AJ, Swancutt DR, et al. Using qualitative methods for attribute development for discrete choice experiments: issues and recommendations. *Health Econ*. 2012; 21(6):730-41.

38. Nguyen TC, Robinson J, Whitty JA, Kaneko S, Chinh NT. Attribute non-attendance in discrete choice experiments: A case study in a developing country. *Econ Anal Policy*. 2015; 47:22-33.

39. Lancsar E, Swait J. Reconceptualising the external validity of discrete choice experiments. *Pharmacoeconomics*. 2014; 32(10):951-65.

40. Witt J, Scott A, Osborne RH. Designing choice experiments with many attributes. An application to setting priorities for orthopaedic waiting lists. *Health Econ*. 2009; 18(6):681-96.

Tables

Table 1: Demographics summary (N = 406)

Variable	Value
Age, mean (sd)	27.01 (6.69)
Years of schooling, mean (sd)	6.97 (3.18)
Net monthly income[a] in USD, median	26.67
	N (%)
Net monthly income[a] above $60	347 (85%)
Lives in urban area	258 (64%)
Marital status	
Married	205 (50%)
Never married	150 (37%)
Other marital status	51 (13%)
Muganda	274 (67%)
Religion	
Catholic	194 (48%)
Protestant	155 (38%)
Other religion	57 (14%)
Occupation – fishing/fishing related	154 (38%)

[a] income net of expenditure

Table 2: Marginal utility estimates from conditional (CL) and mixed logit (MIXL) models

Attribute	**CL**	**MIXL**	
	β (se)	$\bar{\beta}$ (se)	σ (se)
Alternative specific constant ($neither$)	-1.497*** (0.148)	-0.475 (0.496)	4.072*** (0.734)
Type of health facility			
Temporary health facility		Ref	
Permanent health facility	0.811*** (0.083)	3.860*** (0.511)	4.747*** (0.857)
Distance (in km) to health facility			
1		Ref	
5	-0.176* (0.086)	-0.724* (0.347)	1.807** (0.656)
15	-0.223** (0.082)	-1.278*** (0.354)	1.643** (0.552)
Number of week-days for circumcision	0.073*** (0.012)	0.357*** (0.046)	0.436*** (0.076)
Privacy of counselling and waiting			
By yourself		Ref	
Men of your age only	-0.094* (0.045)	-0.505* (0.196)	1.929*** (0.395)
All age groups together	-0.154*** (0.081)	-0.549* (0.221)	1.769*** (0.377)
Method of circumcision			
Surgical circumcision		Ref	
Device circumcision	-0.541*** (0.081)	-2.900*** (0.456)	7.124*** (1.143)
Incentive			
None		Ref	
Voucher	0.160† (0.091)	1.490*** (0.424)	5.161*** (0.866)
Cash	0.415*** (0.115)	2.499*** (0.607)	5.451*** (0.963)
Out-of-pocket payment	-0.018 (0.018)	-0.002 (0.064)	0.794*** (0.139)
Voucher payment	-0.035** (0.013)	-0.124* (0.049)	0.422*** (0.091)
Cash payment	-0.028* (0.013)	-0.137* (0.06)	0.416*** (0.078)
Number of parameters	13	104	
LL	-3703.1	-2505.0	
AIC	7432.2	5218.0	
BIC	7516.6	5893.1	

β: parameter estimate in conditional logit model

μ: mean of random parameter in mixed logit model

σ: Standard Deviation of random parameter in mixed logit model. Significant standard deviation implies significant heterogeneity in the preference for the attribute. The sign of the can be interpreted as positive

se: standard error, LL: log-likelihood; AIC: Akaike Information Criterion; BIC: Bayesian Information Criterion

'***' p < 0.001, '**' p < 0.01, '*' p < 0.05, '†' p < 0.1

Table 3: Three-class latent class logit model

Attributes	**Class 1, β (se)**	**Class 2, β (se)**	**Class 3, β (se)**
Utility model			
Alternative specific constant (*neither*)	0.161 (0.431)	0.085 (0.856)	-1.506*** (0.259)
Type of health facility			
Temporary health facility	Ref		Ref
Permanent health facility	3.260*** (0.574)	0.535 (0.334)	1.194*** (0.158)
Distance (in km) to health facility			
1	Ref	Ref	Ref
5	-0.800** (0.276)	0.800* (0.354)	-0.279† (0.163)
15	-0.923* (0.424)	0.508† (0.304)	-0.422** (0.162)
Number of week-days for circumcision	0.271** (0.092)	-0.121† (0.073)	0.160*** (0.022)
Privacy of counselling and waiting			
By yourself	Ref	Ref	Ref
Men of your age only	-0.350 (0.312)	0.360 (0.282)	-0.168* (0.083)
All age groups together	-0.437† (0.250)	0.136 (0.193)	-0.279*** (0.077)
Method of circumcision			
Surgical circumcision	Ref	Ref	Ref
Device circumcision	-4.702*** (0.459)	3.195*** (0.295)	-0.267*** (0.081)
Incentive			
None	Ref	Ref	Ref
Voucher	1.875*** (0.445)	-1.064 (0.768)	0.299† (0.167)
Cash	1.544** (0.535)	-0.253 (0.687)	0.685*** (0.204)
Out-of-pocket payment	0.021 (0.066)	-0.293*** (0.074)	-0.004 (0.026)
Voucher payment	0.074 (0.039)	0.013 (0.079)	-0.065** (0.022)
Cash payment	-0.011 (0.044)	0.105 (0.113)	-0.059* (0.022)
Class allocation model			
Intercepts		-1.359* (0.563)	0.057 (0.413)
Age			
Less than or equal to 30 years old			
Greater than 30 years old		0.004 (0.333)	-0.106 (0.262)
Level of education			
Less than primary (< 7 years of schooling)			
Completed at least primary (≥ 7 years of schooling)		0.798* (0.320)	0.003 (0.251)
Income			
Greater than or equal to $60			
Less than $60		0.161 (0.516)	-0.526 (0.346)
Place of residence			
Rural area			
Urban area		-0.075 (0.322)	1.042*** (0.259)
Posterior class membership probability	0.370	0.155	0.475

Class 1 was the reference
se: standard error
'***' p < 0.001, '**' p < 0.01, '*' p < 0.05, '†' p < 0.1

In this part of the interview, we are going to explore some issues that will help us to understand whether and why some men choose circumcision for HIV prevention.

Safe Male Circumcision (SMC) is being promoted because it offers some protection against men acquiring HIV from women. SMC does not provide 100% protection against HIV, it compliments, abstinence, condom use and reduced number of sexual partners. There are currently two methods of circumcision: surgery and the device.

Surgery is a one-off procedure in which the surgeon will anesthetize you with an injection, cut off the fore skin and bandage the wound. You will be discharged to take care of the surgical wound at home. With the device, the surgeon will apply anesthetic cream on your penis and insert a ring-like device. You will then be discharged and return to the clinic after one week to have the ring removed. Thereafter, you take care of your wound from home. There is always a chance that you can experience infections and bleeding with both methods of circumcision. You should not have sex for about 5 to 6 weeks until the wound is healed. This period is typically 1 week longer if you are circumcised with the device. However, some people say that they prefer the appearance of the penis after circumcision with devices compared to surgery.

I will now present to you some scenarios in which we will vary the ways in which you can access SMC services. Our SMC services will be described by the methods of circumcision available, where you may get circumcised from (the type of facility and distance of the facility from your home), the number of days in a week when you will find the surgeons available at the facility, privacy and whether you will receive an “incentive” and the cost of circumcision to you. There are other characteristics of SMC services that you might consider important for you to choose circumcision. Please assume that these are the same for each of the choices. Now, please consider carefully each of these characteristics together, and decide whether you would choose to circumcise or not.

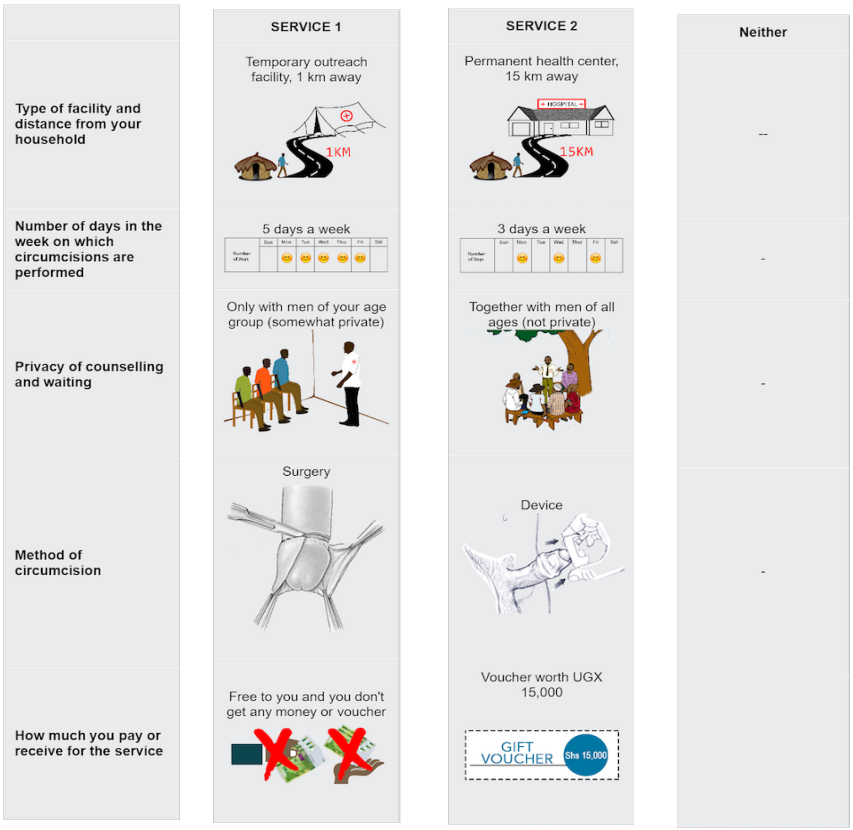

Figure 1: An example of the choice task

Figure 2. Predicted MMC uptake under different policy scenarios. Panel A shows uptake under the CL specification ($\alpha = 2.89$). Panel B shows uptake under the MIXL specification ($\alpha = 4.99$). Panel C shows class specific uptake under the LC model ($\alpha = 2.95$); for each policy the classes are ordered 1, 2 and 3 from left to right. Panel D shows uptake averaged over the posterior class membership probabilities in the LC model

Web Appendix A: Justification for the inclusion and exclusion of attributes and rationale for the attribute levels for included attributes (To be added)

Description of attribute	Description of levels	Justification of attributes and levels
Included attributes		
MMC site options	Fixed (permanent) sites – permanent structures located within existing health facilities that offer MMC services on a continuous basis Outreach sites can be permanent structures (e.g., primary clinics or schools) modified for MMC service purposes, or temporary structures to increase available space so more clients can receive VMMC services	PEPFAR best practices for MMC site operations lists three MMC site options for implementing MMC programs – fixed sites, mobile sites and outreach sites.[1] In our qualitative interviews, participants expressed varied preferences (and justifications thereof) for these sites. For example: "*Outreaches help to bring service closer, most people from far places would otherwise pay ten thousand to get to Kojja HC*" (male, circumcised, over 30 years) "*Those [outreach facilities] cannot because they do not take good care of you. In fact, they can choose to relocate after circumcising you*" (male, under 30, circumcised) We restricted our choice experiment to permanent facilities and temporary facilities because, from the user's perspective, there is no distinction between the mobile sites and outreach sites.
Distance one has to travel to access MMC services	1km 5km 15km	Long distance to health facilities is a well-recognized barrier to access to health services in general in low-income countries.[2] In our qualitative interviews, this was an often-cited barrier to accessing MMC services: "*If they hadn't come here in our community, I wouldn't have gone there. They came here to our community, educated us and then I got circumcised here. They had taken some time offering circumcision at XXX but I wouldn't go there but because they came nearer, I picked interest and went there*" (male, above 30 years, circumcised)
Number of week-days during which MMC services were available at facilities	1 3 5	Past qualitative work has shown that men who had decided to get circumcised, sometimes found that services were not available at health facilities when they eventually visited them [3]. This challenge was corroborated among the participants in our qualitative interviews: *"…ensure that the staff are available daily. Currently, it is offered on Tuesdays only. That has led to some people missing their appointments*" (male, above 30 years, uncircumcised). The levels were chosen to reflect the minimum, maximum and an arbitrary middle value, in order to maximize variability in choices
Privacy during counselling	Complete privacy – when you visit the clinic, you get counselled and you wait by yourself	Privacy (or lack-of) is a well-recognized indicator of the quality of health services from the user perspective and has been shown to impact

and while waiting to get circumcised	Some privacy - when you visit the clinic, you get counselled and you wait to get circumcised in a group of men of a similar age to you; we separate younger men from older men No privacy - when you visit the clinic, you get counselled and you wait with wait for the procedure with everyone; there is no age segregation	decisions to access health services in general and MMC specifically.[3] It is an important target for improvements in MMC service delivery. The levels reflect the fact that our FGD participants were more concerned about separation of services by age.
The method of MMC	Surgical circumcision Device circumcision	The most widely used methods of circumcision are surgical but the WHO has recently approved several circumcision devices.[4] There is interest among policy-makers in the introduction of devices for circumcision and their potential for resolving supply side challenges as well as their potential appeal among men.[5] Knowledge about circumcision devices among the participants in our qualitative interviews was minimal. However, circumcision surgeons informed us that prior to circumcision, men are educated about the relative advantages of surgical and device circumcisions, and where available, are given a choice between the two methods.
Incentives for MMC	None Voucher Cash	Incentives were mentioned extensively by participants in the FGD. In addition, although potentially controversial perhaps because the coercive undertones, given the voluntary nature of the procedure, we believe they are still important economic policy instruments, especially where there are significant opportunity costs, and intangible (psychological and socio-cultural) costs to an intervention. Incentives are normally cash, vouchers or lottery-based incentive. Lottery-based incentives were difficult to implement in the context of our choice experiment. We restricted our experiment to voucher and cash incentives because they cover the types of incentives mentioned by the FGD participants and were simple to implement in our choice experiment.
Cost/value of incentive	Incentive worth US$12 Incentive worth US$8 Incentive worth US$4 Free to you and no incentive US$0 You pay US$4 You pay US$8	Cost is a well-known barrier to accessing health services in general.[2] Indeed, for many participants in our FGDs, this was a significant barrier to MMC. Like incentives, attaching a positive cost to MMC in a setting where health services are provided freely is controversial. Some FGD participants expressed a willingness-to-pay for MMC and provided various rationalizations for the payments. The maximum amount mentioned was approximately US$9. Although the maximum was mentioned in our FGDs was US$60, we restricted out levels

		to a maximum incentive compensation of US$12 for feasibility and plausibility.
Excluded attributes		
HIV testing required prior to circumcision	-	Participants in our qualitative interviews expressed strong and varied opinions about the impact of HIV testing requirements in their decisions to get circumcised: "*what is likely to happen, when someone is told that they will test him, he is bound to get scared and give up on circumcision*" (male, below 30, uncircumcised) However, providers and policymakers suggested that HIV testing prior to circumcision was voluntary; and circumcision services were offered irrespective of whether a client had tested or not.
Health worker attitudes	-	Health worker attitudes are a well-recognized indicator of quality of health services from the user perspective and have been shown to impact decisions to access -health services in general. We excluded this attribute because across all our 11 focus groups, there was a dominant preference for good provider attitudes.
Gender of the health worker	-	Gender was identified as a barrier to MMC in past qualitative work and was corroborated by the participants in our focus group discussions (FGDs). We excluded this attribute because policymakers suggested that restricting to male surgeons was an infeasible policy option.
Waiting time	-	Waiting time is a well-recognized indicator of quality of health services from the user perspective and have been shown to impact decisions to access health services in general, and MMC specifically. In our FGDs, although waiting time was identified as important, it ultimately did not impact decisions about whether to circumcise or not, rather choices about which provider to go to for circumcision
Justifications are based on past literature and qualitative interviews conducted prior to this study		

References

1. The United States President's Emergency Plan for AIDS Relief. PEPFAR's Best Practices for Voluntary Medical Male Circumcision Site Operations. Washington, DC: The United States President's Emergency Plan for AIDS Relief 2012. Available from: https://www.usaid.gov/sites/default/files/documents/1864/pepfar_best_practice_for_vmmc_site_operations.pdf Accessed: March 12 2016

2. Musoke D, Boynton P, Butler C, Musoke MB. Health seeking behaviour and challenges in utilising health facilities in Wakiso district, Uganda. *Afr Health Sci*. 2014; 14(4):1046-55.

3. Price JE, Phiri L, Mulenga D, Hewett PC, Topp SM, Shiliya N, et al. Behavior change pathways to voluntary medical male circumcision: narrative interviews with circumcision clients in Zambia. *PLoS One*. 2014; 9(11):e111602.

4. World Health Organization. List of prequalified male circumcision devices 2015. Available from: http://www.who.int/diagnostics_laboratory/evaluations/150605_pqmc_list_prequalified_devices.pdf?ua=1 Accessed: October 13, 2015

5. Tobian AA, Reed J, Njeuhmeli E. An evidence-based analysis of voluntary medical male circumcision devices. *Nat Rev Urol*. 2016; 13(5):295.

Web Appendix B: Experimental design

Appendix Table B1: Attributes, levels, coding, variable label in model, and priors used in the generating the final experimental design

Attribute	Levels	Coding	Variable label	Hypothesis for pilot design	Priors for final design
Type of health facility	Temporary (outreach) Fixed (permanent)	Dummy	temphc (reference) permhc	 +/-	 N (0.18, 0.01)
Distance (in km) to health facility [a]	1 5 15	Dummy	dist1 (reference) dist5 dist15	 - - -	 N (-0.03, 0.009) N (-0.06, 0.009)
Number of days in the week on which circumcisions are performed	1, 3, 5	Linear	avail	+	N (0.05, 0.006)
Level of privacy during counselling and waiting	By yourself Men within your age group All age groups together	Dummy	verypriv (reference) somepriv nopriv	 - - -	 N (-0.13, 0.022) N (-0.15, 0.026)
Method of circumcision	Surgery Device	Dummy	surgery (reference) device	 +/-	 N (-0.61, 0.036)
Incentive	None Voucher Cash	Dummy	none (reference) voucher cash	 + + +	- N (0.39, 0.13) N (0.58, 0.19)
Cost of procedure or amount of incentive payment for procedure [b] (US$)	-12, -8, -4, 0, 4, 8	Linear [b]	price	-	N (-0.07, 0.006)

[a] if temporary health facility, then distance was 1 or 5 and if fixed facility then distance was 5 or 15

[b] if none then cost was ≤ 0 and if voucher or cash, then cost was < 0

Based on the number of attributes in our experiment, we projected that our primary econometric model would be a panel mixed logit with 24 parameters (i.e., 12 means and 12 standard deviations). This required at least 12 repeated choice tasks per respondent to satisfy the model degrees of freedom.[1] In addition, for attribute level balance, we required at least 12 choice tasks per respondent (i.e., the lowest common multiple of the number of levels per attribute that also satisfied the model degrees of freedom).[2]

We generated a D-efficient experiment in Ngene v1.1.2 (ChoiceMetrics Ltd).[3] First, we generated a preliminary design using small priors (±0.0001), with the sign indicating our prior hypotheses about the directionality of the effect (Appendix Table B1: column 5). When unsure of the sign, we used a prior of zero. We applied design restrictions to enhance the plausibility of the choice scenarios.[4] If an alternative had the attribute “temporary health facility”, the distance was either 1km or 5km, and if it was “permanent health facility” then distance was either 5km or 15km. If an alternative had “no incentive”, then the price attribute was greater than or equal to zero (indicating the alternative was either free or had a positive cost), and if the incentive attribute was either “voucher” or “cash”, then the price attribute was less than 0, indicating a negative cost.

In February 2017, we conducted a pilot survey of 40 men. We estimated a panel conditional logit model and used the parameter estimates and standard errors (Appendix Table B1: column 6) as Bayesian priors

for the final design. The use of Bayesian priors permits the generation of a design that relies less on the accuracy of the priors.[3] The final design assumed a panel conditional logit model because finding designs for a panel mixed logit model was computationally difficult. Bleimer and Rose,[1] show that efficient designs for panel conditional logit models are also efficient enough for panel mixed logit models. The final design had 36 choice scenarios in 3 blocks of 12 choice tasks each. The D-error for this design was 0.06, and required sample size of 123 respondents per block.[5] The code snippet below summarizes the Ngene code that generated our experimental design, and Appendix Table B2 shows the final experimental design.

Appendix Figure B1: Ngene® code to generate the final experimental design

```
Design
;alts = alt1*, alt2*, none
;rows = 36
;block = 3
;eff = (mnl,d,mean)
;rdraws = gauss(5)
;bdraws = halton(100)
;rep = 500

;cond:
if(alt1.incentive=0, alt1.price>=0),
if(alt2.incentive=0, alt2.price>=0),

if(alt1.incentive=[1,2], alt1.price<0),
if(alt2.incentive=[1,2], alt2.price<0),

if(alt1.facility=0, alt1.distance<=5),
if(alt2.facility=0, alt2.distance<=5),

if(alt1.facility=1, alt1.distance>=5),
if(alt2.facility=1, alt2.distance>=5),

if(alt1.facility=0, alt1.available>3),
if(alt2.facility=0, alt2.available>3)

;model:
U(alt1)  =   permhc.dummy[(n,0.18,0.01)]*facility[0,1] +
             dist.dummy[(n,-0.03,0.009)|(n,-0.06,0.009)]*distance[1,5,15] +
             avail[(n,0.05,0.0057)]*available[1,3,5] +
             device.dummy[n,(n,-0.61,0.036),(n,0.2,0.01)]*device[0,1] +
             priv.dummy[(n,-0.13,0.022)|(n,-0.15,0.026)]*privacy[0,1,2] +
             incentive.dummy[(n,0.39,0.13)|(n,0.58,0.19)]*incentive[0,1,2] +
             price[(n,-0.07,0.006)]*price[-12,-8,-4,0,4,8] /

U(alt2)  =   fac*facility +
             dist*distance +
             avail*available +
             meth*method +
             priv*privacy +
             inc*incentive +
             pr*price /

U(none)  =   neither[(n,-4.1,0.04)]

$
```

Appendix Table B2: Final experimental design

task	facility1	distance1	available1	method1	privacy1	incentive1	price1	facility2	distance2	available2	method2	privacy2	incentive2	price2	block
1	0	1	5	0	1	0	0	1	15	3	1	2	1	-4	1
2	1	5	5	1	1	0	8	1	15	1	0	2	1	-12	1
3	1	5	3	0	1	2	-12	0	5	5	1	2	0	8	1
4	1	15	5	0	0	1	-12	1	5	1	1	1	2	-4	1
5	0	5	5	0	1	2	-12	1	5	3	1	2	0	8	1
6	1	15	3	0	0	1	-8	0	1	5	1	1	2	-8	1
7	1	5	1	0	2	2	-12	1	15	5	1	1	1	-4	1
8	1	5	3	1	2	1	-8	0	5	5	0	1	0	4	1
9	0	5	5	1	0	0	8	1	5	3	0	2	2	-12	1
10	1	15	3	1	2	0	8	1	5	3	0	0	1	-12	1
11	1	15	1	0	1	1	-4	1	5	5	1	0	0	0	1
12	1	5	1	1	1	0	4	1	15	5	0	0	2	-8	1
1	1	15	1	0	2	2	-12	1	5	5	1	0	0	8	2
2	0	1	5	1	0	2	-8	1	15	1	0	2	1	-8	2
3	1	15	3	1	0	2	-8	0	1	5	0	1	1	-8	2
4	1	15	1	1	0	1	-4	1	5	5	0	2	2	-12	2
5	1	5	1	1	2	0	0	0	5	5	0	1	2	-4	2
6	0	1	5	0	2	1	-8	1	15	3	1	0	0	4	2
7	1	15	5	1	1	2	-8	1	5	1	0	2	0	4	2
8	0	5	5	1	1	0	0	1	5	3	0	0	1	-4	2
9	0	1	5	1	2	0	4	1	15	3	0	1	2	-8	2
10	1	15	5	0	0	1	-12	0	1	5	1	1	2	-4	2
11	1	5	5	1	2	2	-4	1	15	1	0	0	1	-12	2
12	1	5	5	0	0	2	-4	1	15	1	1	1	0	0	2
1	0	5	5	0	2	1	-4	1	5	1	1	0	2	-12	3
2	1	15	3	0	1	1	-12	0	1	5	1	0	2	-4	3
3	1	5	3	1	2	0	8	0	5	5	0	0	1	-12	3
4	1	5	3	0	1	1	-12	0	5	5	1	2	0	8	3
5	1	15	1	1	1	2	-4	0	1	5	0	2	0	0	3
6	1	15	1	1	0	2	-8	1	5	5	0	1	0	4	3
7	0	1	5	0	0	0	4	1	15	5	1	1	1	-8	3
8	1	5	1	1	0	1	-8	1	15	5	0	2	2	-8	3
9	1	5	5	0	1	1	-4	1	15	1	1	0	2	-12	3
10	1	5	3	0	0	0	4	1	15	3	1	2	1	-8	3
11	1	15	5	1	2	0	0	1	5	1	0	0	1	-4	3
12	0	5	5	0	2	2	-4	1	5	3	1	1	0	0	3

References

1. Bliemer MCJ, Rose JM. Construction of experimental designs for mixed logit models allowing for correlation across choice observations. *Transport Res B-Meth*. 2010; 44(6):720-34.

2. Louviere JJ, Hensher DA, Swait JD. Stated Choice Methods: Analysis and Applications. Cambridge, UK: Cambridge University Press 2000.

3. ChoiceMetrics. Ngene 1.1.2 User Manual and Reference Guide 2014. Available from: https://dl.dropboxusercontent.com/u/9406880/NgeneManual112.pdf Accessed: November 13 2016

4. Reed Johnson F, Lancsar E, Marshall D, Kilambi V, Muhlbacher A, Regier DA, et al. Constructing experimental designs for discrete-choice experiments: report of the ISPOR Conjoint Analysis Experimental Design Good Research Practices Task Force. *Value Health*. 2013; 16(1):3-13.

5. Rose JM, Bliemer MCJ. Sample size requirements for stated choice experiments. *Transportation*. 2013; 40(5):1021-41.

Web Appendix C: Analytical strategy

Econometric approach

Individuals choose the alternative that maximizes their utility. Assuming that stochastic utility ε_{njt} is independently and identically Gumbel distributed over decision maker, choice scenario and alternative, the probability of choosing option i in choice scenario t is the logit function.

In the conditional logit (CL) model,[1] individual choice probabilities were computed as a product of the logit function over the 12 repeated choice scenarios. Model parameters were estimated by maximizing the log-likelihood function below.

$$LL(\beta) = \sum_{n=1}^{N} \log\left[\prod_{t=1}^{12} \frac{e^{X_{nit}\beta}}{\sum_{j=1}^{3} e^{X_{njt}\beta}}\right]$$

In models that incorporate random preference heterogeneity. conditional on β_n the probability of the observed sequence of choices is the logit function, and unconditional choice probabilities are obtained by integrating or averaging the logit function over the mixing density, $f(\beta|\Omega)$. In the MIXL, $f(\beta|\Omega)$ was specified to follow a multivariate normal mixing distribution with a mean parameter vector, $\bar{\boldsymbol{\beta}}$ and covariance matrix, Σ.[2] Model parameters were estimated by maximizing the log-likelihood function below [3].

$$LL(\Omega) = \sum_{n=1}^{N} \log\left[\int_{\beta} \prod_{t=1}^{12} \frac{e^{X_{nit}\beta_n}}{\sum_{j=1}^{3} e^{X_{njt}\beta_n}} f(\beta|\Omega)\, d\beta\right]$$

The log-likelihood was approximated by maximum simulated likelihood,[3] using 2000 Modified Latin Hypercube Sampling (MLHS) draws per respondent and random coefficient.[4] We specified all utility parameters as random and allowed for correlation by estimating the components of the lower-triangular Cholesky factorization, L of the covariance matrix, Σ. Standard deviations were recovered by computing the diagonal of the covariance matrix as LL'. Standard errors of the standard deviations were computed using the delta method.

The latent class logit model assumed that respondent, *n* belonged to one of Q separate classes with probability, $\pi_{n,q}$ in which the utility coefficients were homogeneous, β_q. Model parameters were estimated by maximizing the log-likelihood function below:[5]

$$LL(\beta_q) = \sum_{n=1}^{N} \log\left[\sum_{q=1}^{Q} \pi_{n,q} \prod_{t=1}^{12} \frac{e^{X_{nit}\beta_q}}{\sum_{j=1}^{3} e^{X_{njt}\beta_q}}\right]$$

Class membership was modelled using a multinomial logit where utility of class membership was a linear function of age, education (defined by years of schooling), income (above and below the poverty line of US$60 per month), and residence in an urban versus a rural area, in addition to a constant. Parameters for one of the classes were set to zero to allow identification of the multinomial logit model. We estimated LC models ranging from 2 to 5 classes and selected the model that minimized the Bayesian Information Criterion (BIC).

Policy simulations

For predictions from models which incorporated random preference heterogeneity, we calculated a vector of unconditional choice probabilities for each individual by integrating conditional choice probabilities over the distribution of the random parameters as below:

$$\mathbb{E}\boldsymbol{P}(\beta)_n = \int_{\beta} \frac{e^{x_i\beta}}{\sum_{j=1}^{J} e^{x_j\beta}} f\left(\beta\middle|\widehat{\Omega}\right) d\beta$$

In the MIXL we applied simulation methods using 2000 MLHS draws to approximate the unconditional choice probabilities for each individual. For each individual n, we drew a parameter vector β_n from the distribution $f\left(\beta\middle|\widehat{\Omega}\right)$, labelled β_r, calculated the conditional choice probability vector, repeated this $R = 2000$ times, and averaged the result to obtain the unconditional choice probabilities.

$$\mathbb{E}\boldsymbol{P}(\beta)_n \approx \frac{1}{R}\sum_{r=1}^{R} \frac{e^{x_i\beta_r}}{\sum_{j=1}^{J} e^{x_j\beta_r}}$$

In the LC model, the unconditional choice probabilities were obtained by weighting the conditional choice probability vector by the individual posterior class membership probabilities.

$$\mathbb{E}\boldsymbol{P}(\beta)_n \approx \sum_{q=1}^{Q} \pi_{n,q} \frac{e^{X_i\beta_q}}{\sum_{j=1}^{J} e^{X_j\beta_q}}$$

To enhance the realism of our policy analysis, we adjusted the ASC, $\beta_{o,neither}$ by adding a constant, α and searched iteratively for a value that allowed us to match the observed prevalence of circumcision of 30.7%. This was straightforward for the CL model. For the MIXL and LC models, an iterative procedure was applied to solve for the equation below:

$$P\left(SURG\middle|X_{SURG}, X_{OPT-OUT}, \widehat{\Omega}, \alpha\right) = \int_{\beta} \frac{e^{X_{SURG}\beta_n}}{e^{\alpha+\beta_{0,neither,n}} + e^{X_{SuRG}\beta_n}} f\left(\beta\middle|\widehat{\Omega}\right) d\beta = P\left(\widehat{SURG}\right)$$

where X_{SURG} is a vector of attributes levels describing the surgical circumcision at health facilities (see Table 2), $X_{OPT-OUT}$ is only described by the ASC and $P\left(\widehat{SURG}\right) = 30.7\%$. For the MIXL model, this involved shifting the distribution of the $\beta_{o,neither}$ by α through simulation using 2000 MLHS draws to integrate over the mixing density $f\left(\beta\middle|\widehat{\Omega}\right)$. For the LC model, we iteratively searched for a value of α (the same across classes), weighting the class-specific choice probabilities by individual posterior class membership probabilities.

Appendix Table C1: Policy scenarios

				Incentives	
	Surgical circumcision	Outreach service	Device circumcision	Device circumcision	Surgical circumcision
Type of health facility	Permanent	Temporary	Permanent	Permanent	Permanent
Distance (in km) to health facility	15	1	15	15	15
Number of days in the week on which circumcisions are performed	2	5	2	2	2
Level of privacy during counselling and waiting	All age groups together	Men within your age group	All age groups together	All age groups together	All age groups together
Method of circumcision	Surgery	Surgery	Device	Device	Surgery
Incentive	None	None	None	Cash	Cash

Cost of procedure or amount of incentive payment (US$)	Free	Free	Free	-12	-8

Table C2: Definition of pre- and post-policy states

No.	Current policy mix	Potential future policy mix
1	Opt-out + surgical circumcision	Opt-out + surgical circumcision + outreach service
2	Opt-out + surgical circumcision	Opt-out + surgical circumcision + device circumcision
3	Opt-out + surgical circumcision	Opt-out + surgical circumcision + device circumcision + outreach service
4	Opt-out + surgical circumcision	Opt-out + incentives (surgical circumcision + device circumcision)
5	Opt-out + surgical circumcision	Opt-out + incentives (surgical circumcision + device circumcision) + outreach

References

1. McFadden D. Conditional logit analysis of qualitative choice behavior. In: Zarembka P, ed. *Frontiers in Econometrics*. New York: Academic Press 1973.

2. McFadden D, Train K. Mixed MNL models for discrete response. *J Appl Economet*. 2000; 15(5):447-70.

3. Train K. Discrete choice methods with simulation. New York, USA: Cambridge University Press 2009.

4. Hess S, Train KE, Polak JW. On the use of a Modified Latin Hypercube Sampling (MLHS) method in the estimation of a Mixed Logit Model for vehicle choice. *Transport Res B-Meth*. 2006; 40(2):147-63.

5. Greene WH, Hensher DA. A latent class model for discrete choice analysis: contrasts with mixed logit. *Transport Res B-Meth*. 2003; 37(8):681-98.

Web Appendix D: Results

Table D1: Latent class modelling results

Number of classes	Number of parameters	Log likelihood	AIC	BIC
2	31	-3060.97	6183.93	6385.16
3	49	-2751.27	5600.54	5918.61
4	67	-2687.26	5508.52	5943.44
5	85	-2629.10	5428.20	5979.96