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Costs and cost-effectiveness of HIV counselling and testing modalities in Southern Mozambique

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Abstract

Objective: Despite the high HIV associated burden, Mozambique lacks data on HIV counselling and testing (HCT) costs. To help guide national HIV/AIDS programs, we estimated the cost per test for voluntary counselling and testing (VCT) from the patient's perspective and the costs per person tested and per HIV-positive individual linked to care to the healthcare provider for VCT, provider-initiated counselling and testing (PICT) and home-based testing (HBT). We also assessed the cost-effectiveness of these strategies for linking patients to care.

Methods: Data from a cohort study conducted in the Manhica District were used to derive costs and linkage-to-care outcomes of the three HCT strategies. A decision tree was used to model HCT costs according to the likelihood of HCT linking individuals to care and to obtain the incremental cost-effectiveness ratios (ICERs) of PICT and HBT with VCT as the comparator. Sensitivity analyses were performed to assess robustness of base-case findings.

Findings: Based on costs and valuations in 2015, average and median VCT costs to the patient per individual tested were US\$1.34 and US\$1.08, respectively. Costs per individual tested were greatest for HBT (US\$11.07), followed by VCT (US\$7.79), and PICT (US\$7.14). The costs per HIV-positive individual linked to care followed a similar trend. PICT was not cost-effective in comparison with VCT at a willingness-to-accept threshold of US\$4.53, but only marginally given a corresponding base-case ICER of US\$4.15, while HBT was dominated, with higher costs and lower impact than VCT. Base-case results for the comparison between PICT and VCT presented great uncertainty, whereas findings for HBT were robust.

Conclusion: PICT and VCT are likely equally cost-effective in Manhica. We recommend that VCT be offered as the predominant HCT strategy in Mozambique, but expansion of PICT could be considered in limited-resource areas. HBT without facilitated linkage or reduced costs is unlikely to be cost-effective.

Keywords: Acquired immunodeficiency syndrome, Mozambique, Cost-benefit analysis, Decision trees, Uncertainty, Counseling, Health resources

Introduction

Timely HIV diagnosis and linkage to care are essential for improved HIV outcomes [1] but are generally not achieved across sub-Saharan Africa (SSA) [2, 3]. Haber et al. showed that in Kwazulu-Natal, the transition from receiving an HIV-positive diagnosis to care is the weakest in the HIV care continuum [4]. A systematic review

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reported that, among HIV diagnosed individuals, only one-third of ART-eligible patients were receiving treatment [5]. Cost-effective HIV counselling and testing (HCT) strategies are needed to link more people living with HIV (PLHIV) to care. Few cost-effectiveness analyses (CEAs) on HCT strategies examining linkage to care as an outcome have been conducted, although existing reports have indicated that facility-based strategies are likely more cost-effective than community-based strategies [6, 7].

In Mozambique, where the adult HIV prevalence is among the highest in the world, only 61% PLHIV know their HIV status, and 54% are receiving ART [8]. At the time of this study, Mozambique did not have universal HIV testing [9]. In the country, community-based strategies such as home-based testing (HBT) are infrequently offered [10]. Voluntary counselling and testing (VCT), initiated by the patient at the health facility, has been a mainstay for HCT while provider-initiated counselling and testing (PICT) is the standard approach for healthcare services [9]. In Mozambique as well as in other settings with high burden HIV, PICT lacks optimization strategies in order to reach its full potential [11]. A recent cohort study conducted in Manhiça District found that VCT was associated with the greatest proportion of PLHIV linked to care, followed by PICT and HBT [12]. Importantly, the study procedures did not influence the linkage-to-care beyond the HCT and facility-based referral.

Economic evidence in relation to costs and cost-effectiveness of these HCT strategies in linking PLHIV to care is lacking. By drawing on prospective data from the Manhiça cohort study [12], we estimate the costs of providing HCT strategies in Mozambique and examine the cost-effectiveness of PICT and HBT compared to VCT for initiating linkage to care. In doing so, we compared the level of engagement each HCT strategy entails against the outcome.

In the literature, unit costs of HCT strategies from the provider's perspective are derived from program costs and usually reported as average cost per person tested and/or average cost per HIV-positive individual identified. The former is more relevant for our study and shall be examined in detail for VCT, PICT, and HBT. Estimates of unit costs per person tested vary. For example, VCT costs in Kenya, Swaziland, Tanzania, and Uganda were reported to be US\$8.27–US\$28.93 [13–17], and PICT costs were lower (US\$5.71–US\$11.68) [13–15]. In Kenya, South Africa, and Uganda, several studies reported HBT costs ranging from US\$5.00 to US\$29.00 per client tested, similar to the range reported for VCT [14, 15, 18–20]. Importantly, costs are not directly comparable across studies because the underlying assumptions and contexts

may differ. Findings from our study can help inform policymakers on effective yet affordable national-level HCT that could help identify more PLHIV and link them to care in Mozambique.

Methods

Manhiça cohort study

In 2012, HIV prevalence and incidence in Manhiça district were estimated to be 40% and 3.6 infections/100 person-years, respectively [21, 22]. The Manhiça cohort study enrolled 1122 participants with a new HIV-positive diagnosis (May 2014–June 2015), following routine VCT and outpatient PICT at the Manhiça District Hospital and door-to-door HBT by trained healthcare workers (Appendix 1). VCT and PICT resulted in significantly higher proportions of PLHIV linked to care, defined as enrollment in care at the reference district hospital and with a CD4 count registered within the first 3 months after HIV diagnosis, than HBT. Nonetheless, HBT reached a distinct population living in extreme poverty who were in greatest need for facilitated linkage interventions. Details of the study methods and procedures have been described elsewhere [12].

Cost estimate methods

We employed a micro-costing (bottom-up) approach [23] to estimate the financial and economic costs of HCT provision incurred in the cohort study from the provider's perspective. As VCT and PICT were routinely offered to the public at the time of the study, estimated costs were referenced from routine health system costs. HBT-associated costs were assessed separately as HBT was not a routine testing strategy. Nevertheless, we examined only recurrent costs and not start-up costs for HBT as there was already an existing structure for carrying out door-to-door interventions e.g. community vaccination.

To determine financial costs, we processed data on capital (e.g. buildings, equipment, and vehicles) and recurrent (personnel, supplies, test-kits, and transport) costs collected May 2014–June 2015. We utilized time and motion data to determine the financial costs of personnel and transport. Time data tracked the time taken by counsellors to travel to and between participants' houses during HBT and to conduct each counselling session either at the District Hospital or at each participant's house. On the other hand, motion data included travelling speeds to determine fuel costs. We did not include training costs because HCT in the cohort study was provided by healthcare workers who were not specially trained.

The cost per VCT attendance from the patient's perspective was determined by a similar micro-costing approach using self-reported explicit costs and implicit costs. Implicit costs were calculated by valuing the

patients' time spent travelling to and waiting at the VCT facility using the average monthly minimum wage in Mozambique, expressed as an hourly wage and assuming an average of 176 work hours (22 days \times 8 h/day) per month. We assumed patients would not incur any additional costs for HBT and PICT.

Data sources

A questionnaire was used to elicit demographic information (Appendix 2). From the patient's perspective, data were collected from patients accessing VCT by using a specific questionnaire (Appendix 3). From the provider perspective, data were collected from VCT, HBT, and PICT using a separate questionnaire (Appendix 4). Some of the provider resources used (e.g. time to perform the test) were collected for all patients receiving the test (as their HIV status was not known a priori), but only HIV-positive patients were retained for ethical reasons. Where information on costs was not available through questionnaires (e.g. building, furniture, and operation and maintenance costs), we approximated them as a percentage of total recurrent costs based on results from a study by Mwenge et al. [24] in Malawi and Zimbabwe, which share similar sociodemographic and economic profiles as Mozambique [25, 26].

Data analysis

For cost estimate analysis, we included data on all individuals who tested HIV positive ($n=1277$), including non-enrolled individuals ($n=155$) who had received a HIV-positive test result previously in a concomitant study. These 155 patients were tested using the same procedure as with the other participants in the main cohort study and were included in our sample size. Of the 1277 patients, 350 were enrolled from VCT and were included in cost estimates from the patients' perspective. Time data for the following variables were highly negatively skewed due to measurement errors during data collection: travelling to individual houses, performing the test, waiting for test results, and explaining the results. We deemed the 85th percentile to be an appropriate upper limit to capture a reasonable proportion of these data without including outlying values, replacing observations above this percentile with the value at the 85th percentile. All data analyses were conducted using Microsoft Excel 2016 (V.16.14.1) and Stata (V.13.1: Stata Corporation).

We performed descriptive statistical analysis to compute mean (with standard deviation) and median (with maximum and minimum ranges) costs per person tested positive from both the patient's and provider's perspective. All costs were expressed in 2015 US\$ at an exchange rate of 33.00 Mozambique New Metical (MT) per US\$ [27].

Determination of cost per individual tested

The cost of testing each individual was determined by summing costs of each individual resource, obtained by multiplying the quantities of each resource expended with their approximated unit costs (Appendix 5).

Implicit costs to patients were calculated by valuing their time spent travelling to and waiting at the VCT facility, using the average monthly minimum wage in Mozambique [28]. Capital costs were factored as a proportion of total costs. Fuel costs were calculated using motion data assuming an average travelling speed of 50 km/hour and an average fuel consumption of 0.143 L/km, based on 2013 estimates from the Global Fuel Economy Initiative [29].

Determination of HCT costs and cost-effectiveness

A decision tree model (Appendix 6) was designed for the CEA to determine cost-effectiveness ratios (CERs) and incremental cost-effectiveness ratios (ICERs). We defined effectiveness as linkage to care based on the cohort study's definition. Our primary outcome measure was incremental cost per enrolled individual linked to care. The model's time horizon of 1 year mirrored the duration of the cohort study.

The model captured all steps of the HIV care cascade for both VCT and PICT from diagnosis to retention in care after 12 months of follow-up. For HBT, the model additionally captured steps before the HCT process, from being reached through HBT to obtaining consent. One-year cumulative proportions, reported as the percentage uptake at each step of the HIV care cascade (figures reported in Appendix 1), were directly converted into conditional probabilities for parameterizing the decision tree (Table 1).

The key assumptions of the model were:

- (1) Linear, unidirectional transitions along the care cascade; uptake at each step must be conditional on the previous step;
- (2) Only early treatment uptake (≤ 3 months post-diagnosis) at each step was modelled; and.
- (3) Costs incurred for individuals who cannot be reached through or deemed ineligible for HBT are inconsequential to total program costs.

We calculated the expected average costs and linkage-to-care proportion per person tested for each HCT strategy, by summing costs and outcomes of each branch of the tree weighted by their associated probabilities of occurrence. A ratio of average costs and average expected linkage-to-care proportion was calculated to determine expected HCT linkage-to-care costs.

Table 1 Base-case inputs of parameters (probabilities and costs) for the model, their candidate distributions, and alpha–beta values characterizing those distributions (Manhiça District, Mozambique)

Model inputs	PICT	HBT	VCT	Distribution ^a	Alpha-Beta ^b	Source
Probabilities ^c						
Individual reached	–	0.752	–	β	8192–2705 (HBT)	[12]
Not known HIV-positive/not pregnant	–	0.822	–	β	6736–1456 (HBT)	[12]
Gave consent ^d	–	0.760	–	β	5116–1620 (HBT)	[12]
HIV test positive	0.312	0.072	0.119	β	1046–2305 (PICT); 369–4747 (HBT); 909–6718 (VCT)	[12]
Enrolled in study	0.404	–	0.363	β	423–623 (PICT); 330–579 (VCT)	
Enrolled in care	0.908	0.355	0.985	β	384–39 (PICT); 131–238 (HBT); 325–5 (VCT)	[12]
Attended 1st consultation	0.799	0.901	0.911	β	307–77 (PICT); 118–13 (HBT); 296–29 (VCT)	[12]
Linked to care	0.642	0.746	0.693	β	197–110 (PICT); 88–30 (HBT); 205–91 (VCT)	[12]
Costs ^e						
Average cost per test (SD), US\$	7.14 (1.30)	11.07 (3.82)	7.79 (1.30)	γ	30.3–0.235 (PICT); 8.39–1.32 (HBT); 36.1–0.216 (VCT)	Table 2

^a Candidate distribution were determined based on expert opinion and other similar studies

^b Alpha-Beta values were dependent on the type of candidate distribution. For β distribution, alpha = number of people reaching that step while beta = total number of people who completed previous step – alpha. For γ distribution, alpha = $\frac{\mu^2}{s^2}$ while beta = $\frac{s^2}{\mu}$, where μ is the mean and s² is the variance

^c These were conditional probabilities derived directly from proportions of individuals reaching each step over the number of individuals completing the previous step, as described in the cohort study

^d The probability of giving consent to be tested is a proxy to HBT uptake. Moreover, step downstream are conditional on successfully obtaining consent

^e Average costs per person tested determined for each strategy from the micro-costing analysis were fed into the model. These were assumed to be equivalent to the average cost per test

PICT provider-initiated counselling and testing, HBT home-based testing, VCT voluntary counselling and testing, SD standard deviation

$$\text{HCT cost per person linked to care} = \frac{\text{Average cost per test}}{\text{Expected proportion linked to care per test among all who were tested}}$$

Unlike the derivation of CERs, data only for enrolled individuals was used to determine ICERs to facilitate accurate comparisons of effectiveness. We determined ICERs by dividing the difference in expected costs over the difference in the expected proportion of enrolled individuals linked to care.

varied at the maximum and minimum values defined by their respective distributions (Table 1). In the PSA, we performed 2000s-order Monte-Carlo simulations and plotted each result on a cost-effectiveness plane. Cost-effectiveness acceptability curves (CEACs) were constructed to determine the cost-effectiveness threshold.

$$\text{ICER} = \frac{\text{Average cost per test (PICT/HBT)} - \text{Average cost per test (VCT)}}{\text{Expected enrolled proportion linked to care (PICT/HBT)} - \text{Expected enrolled proportion linked to care (VCT)}}$$

Sensitivity analysis

Our univariate sensitivity analysis varied key cost-related parameters within predefined sensitivity ranges (Appendix 7) to explore the robustness of results. Lacking published data, we empirically adjusted base-case values by ±20%, referencing ranges used by Mwenge et al. in their determination of HCT costs in three SSA countries [24].

We performed deterministic and probabilistic sensitivity analyses (DSA and PSA) as part of the CEA. In the DSA, probabilities and average costs per test were

Results

Costs

Costs to the provider

Base-case median costs were higher for VCT per individual tested (US\$7.82; range, US\$4.54–US\$15.14) than for PICT per individual tested (US\$7.29; range, US\$2.30–US\$14.67) but were lower than HBT per individual tested (US\$11.62; range, US\$4.32–US\$19.83; Table 2). The small difference in costs between the two facility-based strategies (VCT & PICT) can be attributed to higher personnel costs for VCT which probably resulted from a longer

Table 2 Breakdown of costs to the provider per individual tested for all 3 HCT strategies among individuals in the cohort study who tested HIV-positive

Cost item	VCT (n = 350)		PICT (n = 455)		HBT (n = 472)	
	Average cost/ person tested (SD), US\$	Median cost/ person tested (range), US\$	Average cost/ person tested (SD), US\$	Median cost/ person tested (range), US\$	Average cost/ person tested (SD), US\$	Median cost/ person tested (range), US\$
Capital costs ^a						
Building, furniture	0.25 (0.04)	0.26 (0.15–0.49)	0.23 (0.04)	0.24 (0.07–0.48)	–	–
Recurrent costs						
Personnel	3.11 (1.22)	3.12 (0.56–10.08)	2.49 (1.20)	2.62 (0.50–9.64)	3.64 (1.00)	3.80 (1.03–7.32)
Supplies	4.32 (0.00)	4.32 (4.32–4.32)	4.32 (0.35)	4.32 (4.27–4.36)	4.39 (0.57)	4.32 (3.21–9.68)
O & M ^b	0.12 (0.02)	0.12 (0.07–0.24)	0.11 (0.02)	0.12 (0.04–0.23)	–	–
Transport (fuel)	–	–	–	–	3.04 (2.82)	3.50 (0.00–7.33)
Total recurrent costs	7.55 (1.23)	7.56 (4.32–14.40)	6.91 (1.23)	7.06 (2.18–13.96)	11.07 (3.82)	11.62 (4.32–19.83)
Total costs (capital and recurrent)	7.79 (1.30)	7.82 (4.54–15.14)	7.14 (1.30)	7.29 (2.30–14.67)	11.07 (3.82)	11.62 (4.32–19.83)

All figures are reported to 2 decimal places. SD refers to standard deviation

^a This was approximated as a percentage (3.27%) of the total costs. Building and furniture costs were not annuitised

^b This was approximated as a percentage (1.65%) of the total recurrent costs

PICT provider-initiated counselling and testing, HBT home-based testing, VCT voluntary counselling and testing, SD standard deviation, O & M operation and management

time spent on HCT. As expected, HBT costed more than facility-based strategies, driven by higher personnel costs and transport costs. Like VCT and PICT costs, cost component proportions of HBT costs were almost equal: personnel (32.2%), supplies (36.6%) and transport (29.6%). Resources used are reported by HCT strategy in Appendix 8.

Costs to the patient

The median base-case total cost to the patient per VCT visit was US\$1.08 (range, US\$0.00–US\$19.58). A breakdown of total costs into explicit (median, US\$0; range US\$0–US\$18.62) and implicit costs (median, US\$0.86; range, US\$0.00–US\$4.65) showed most costs (~80%) were implicit, which reflected waiting times and traveling times to the hospital (Appendix 9).

Sensitivity analysis

Average and median costs of VCT and PICT from the provider's perspective were most sensitive to variations in operation and maintenance, and capital costs (Appendix 10). However, closer examination revealed this was largely a result of high estimates obtained from reports in Kenya and Uganda, which were unlikely to represent real costs in Mozambique [13, 14].

Although unit costs of VCT and PICT were less sensitive to test-kit prices, the large extent of overlap between them in the sensitivity analysis suggested that accurate determination of these prices is crucial, since the order

of costs could differ should assumptions change. On the other hand, HBT costs were most sensitive to the choice of percentile cut-off for the upper limit of several time-related variables. Median HBT cost was especially sensitive to the low estimate, varying from the base-case value by 41%. Base-case average and median VCT costs from the patient's perspective were generally robust (Appendix 11).

HCT costs and cost-effectiveness of HCT to link to care

Base-case results

The costs per HIV-positive individual linked to care, covering both testing and linkage cost, were estimated at US\$289.67 for VCT, US\$121.46 for PICT, and US\$643.37 for HBT (Table 3). PICT was less expensive than VCT but also resulted in a lower proportion of PLHIV linked to care. As PICT is less costly but also less efficacious than VCT, PICT ICER of US\$4.15 could be interpreted as savings per individual not linked to care. PICT falls in the low cost/worse outcome quadrant of the cost-effectiveness plane (Appendix 12). In comparison with VCT, the HBT ICER (–US\$8.57) was in the high cost/worse outcome quadrant.

Sensitivity analyses

HCT costs per individual linked to care were most sensitive to the average cost per test (Appendices 13, 14). However, within the narrower ranges elicited from the sensitivity analysis for unit costs, base-case linkage-to-care costs for VCT and PICT were robust. Unfortunately,

Table 3 Base-case results of HCT costs and cost-effectiveness comparisons between PICT & VCT and HBT & VCT

	VCT	PICT	HBT
HCT costs			
Average cost per test ^a , US\$	7.79	7.14	11.07
Expected proportion of HIV ⁺ individuals linked to care among those tested	0.0269	0.0588	0.0172
Cost per HIV ⁺ individual linked to care, US\$	289.67	121.46	643.37
Cost-effectiveness comparisons			
Effect–Expected proportion of HIV ⁺ individuals linked to care among those enrolled only	0.621	0.466	0.238
Incremental cost, US\$	–	–0.65	3.28
Incremental effect	–	–0.155	–0.383
ICER	–	4.15	–8.57 (Dominated) ^b

All costs are reported to 2 decimal places. All other figures are reported to 3 significant figures

^a Assume cost per person tested positive is equivalent to cost per test

^b A dominated scenario occurs when the comparator, in this case VCT, is less costly but more effective than HBT. HBT is said to be dominated by VCT

PICT provider-initiated counselling and testing, HBT home-based testing, VCT voluntary counselling and testing, ICER incremental cost-effectiveness ratio

there was still great uncertainty in the determined HCT costs of HBT.

Similarly, ICERs were most sensitive to unit costs per test although they too were fairly robust within the narrower ranges obtained from the sensitivity analysis for unit costs (Appendix 15). Both the DSA and PSA showed significant uncertainty in determining the cost-effectiveness of PICT in relation to VCT, notwithstanding considerations of the cost-effectiveness threshold. HBT, however, was likely a dominated strategy. The probabilistic results were similar to the deterministic findings (Fig. 1).

The interpretation of ICERs in the low cost/worse outcome quadrant for the PICT comparison is dependent on the minimum willingness-to-accept (WTA) for every individual successfully linked to care. As there was no clearly defined WTA threshold, a CEAC was constructed (Fig. 2). Since the elicited threshold of US\$4.53 was greater than the base-case and average ICER in the PSA, we concluded PICT was not cost-effective relative to VCT, although this result was only marginal. Moreover, both the DSA and PSA indicated significant uncertainty in this result. Interestingly, both strategies had almost equal likelihood of being cost-effective when the cost-effectiveness threshold was mapped on the Monte-Carlo plot (Appendix 16). A CEAC was not produced for the comparison between HBT and VCT because HBT was clearly dominated (high cost/worse outcome) at all cost-effectiveness thresholds above zero, i.e., the corresponding CEAC is a flat horizontal line at $y=0$.

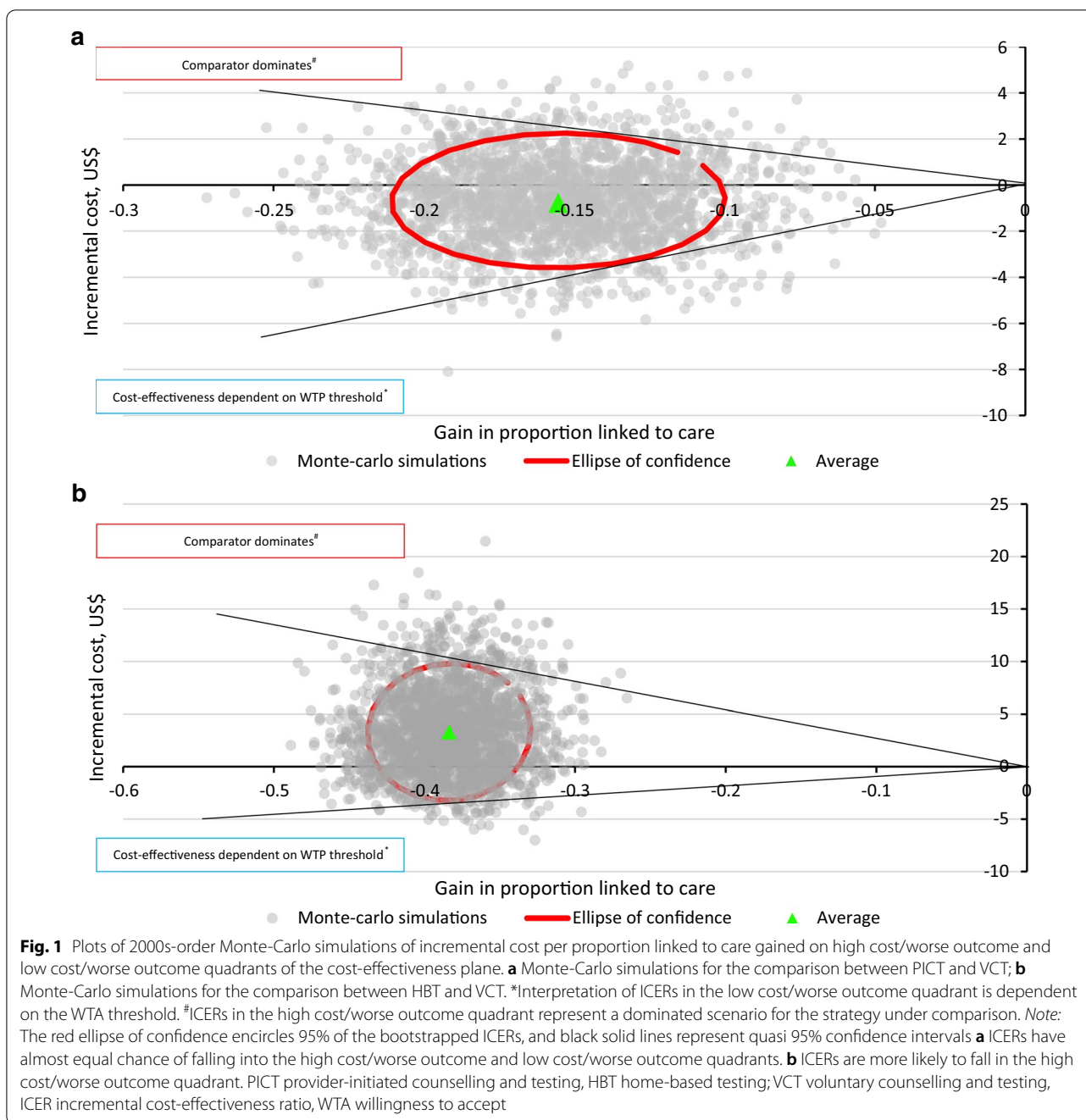
Discussion

To our knowledge, this is the first study in Mozambique to estimate costs and cost-effectiveness of VCT, PICT, and HBT. We found the median cost per VCT attendance

to be as low as US\$1.00, largely comprising implicit costs. This is commensurate with VCT prices and patients' willingness-to-pay reported elsewhere [34, 35], suggesting that the costs to patients were reasonable. However, differences in health systems, wage structure, and socioeconomic conditions between countries may lead to different valuations of explicit and implicit costs.

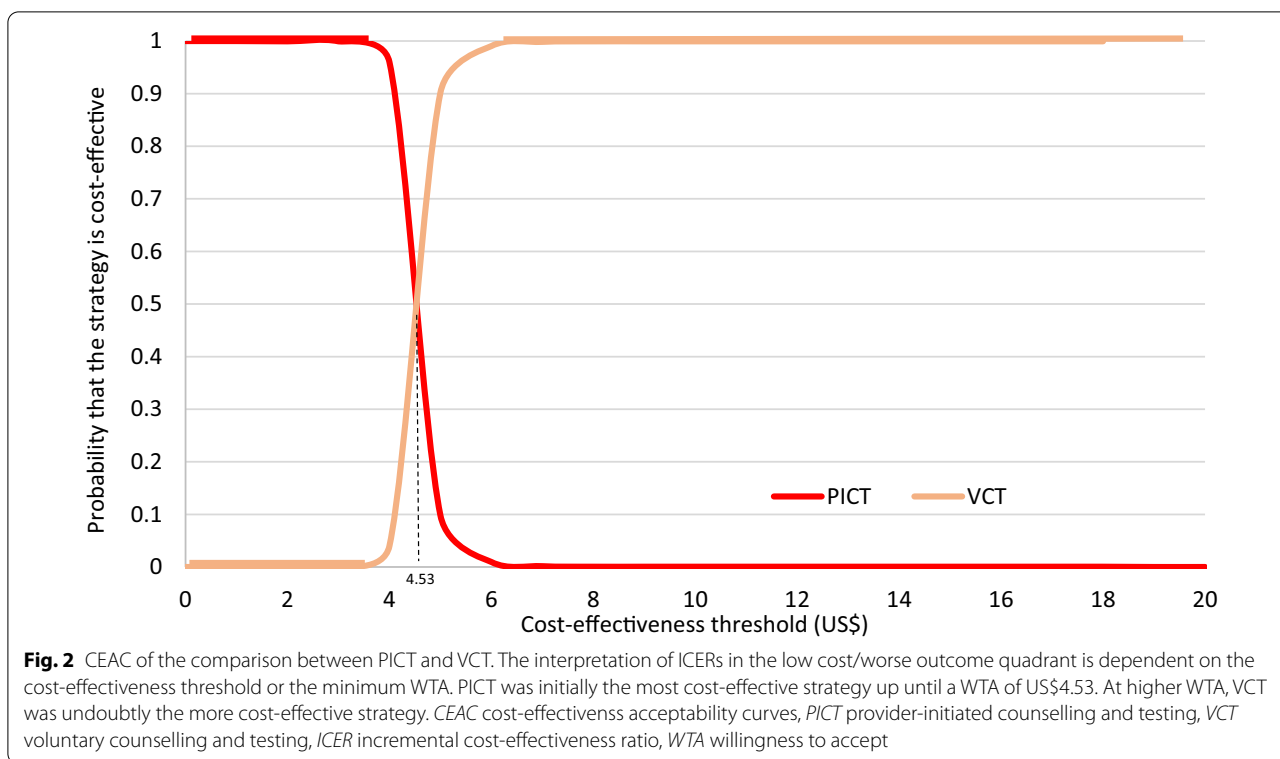
We found the average cost to the provider per individual tested and derived costs per HIV-positive patient linked to care to be greatest for HBT, followed by VCT and PICT. Both the magnitude and trend of costs elicited were mostly consistent with the available literature for neighboring SSA countries (in 2009 prices), with the exception of the study by Menzies et al. (in 2007 prices) [13–15]. Notwithstanding considerations for effectiveness, PICT is the cheapest for potential HCT scale-up in areas with inadequate coverage. However, in resource-limited Mozambique, HCT scale-up requires more than mere consideration of HCT costs as improvement of existing healthcare infrastructure and expansion of the healthcare workforce are also needed.

We found HBT to be substantially more expensive than VCT and PICT. This was not consistent with the available literature. Five studies across Uganda, Kenya, and South Africa reported HBT costs ranging from US\$5.00–US\$29.00 per client tested that were in several cases lower than reported VCT and PICT costs [14, 15, 18–20]. A difference in cost analysis approach likely accounts for this discrepancy, since reported cost estimates from a program perspective are more likely to capture economies of scale accurately, particularly for HBT. Another reason could be the numerous far-lying residential areas in Manhiça [21], which probably required substantial resources for HBT.



CEA results suggested PICT was not cost-effective to link PLHIV to care, relative to VCT; more precisely, PICT was less expensive but also less effective than VCT. However, this result was only marginal. Moreover, the lack of robustness in the base-case results of the CEA comparing PICT and VCT, coupled with the fact that PICT was consistently reported to be cheaper than VCT [13, 15] yet with almost comparable linkage-to-care proportions [6, 36], suggests a high possibility that PICT could be considered cost-effective as well, especially in areas

with limited resources. PICT could be considered for expansion and scale-up, depending on the context and available resources, in line with regional trends [37–40]. For example, in remote areas where health facilities may be understaffed, PICT could be expanded to include the general population to lower costs of HCT but still yield reasonable linkage-to-care proportions. Conversely, in areas with more resources and likely higher WTA, PICT could be limited.



As expected, HBT was more expensive and had a lower expected linkage-to-care proportion than VCT. This was consistent with several studies [19, 41–46]. However, other reports showed high linkage-to-care proportions for HBT (47.5%–70.0%) [47–51]. Although definitions of linkage to care were inconsistent in the literature, Kiene et al. highlighted an obvious but important trend: HBT programs that facilitate linkage perform better than those that do not [52]. Sharma et al.’s systematic review of 126 studies confirmed this trend, showing high linkages to care for strategies that facilitated linkages [6]. Similarly, Gilbert et al. found community-based TB and HIV integrated screening and linkage to care strategies to be cost-effective in South Africa [53]. Moreover, the Manhiça cohort study investigators also hypothesized that strategies to facilitate linkage to care were important for cost-effectiveness [12]. HBT could be cost-effective if integrated with facilitated linkage strategies.

Our study had limitations. Because data were only available for PLHIV, we modelled total program costs. The inability to determine real program costs may limit the usefulness of our findings for policymakers [54]. Moreover, the lack of methodological consistency between our study and published studies may result in overestimates and bias cost comparisons. In Mozambique, some HIV-testing costs are borne by the government and others by international donors; our study did

not distinguish between the two. In addition, analysis of costs to the provider did not include other costs, such as training, supply chain, and program management. HBT, as analyzed in this study, referred to door-to-door universal testing, and results cannot be extrapolated to other forms of community testing, such as index case testing, which is prominent in SSA testing programs.

Results from this study are hardly generalizable to other countries. Manhiça is a small, semi-rural district in Mozambique where HCT services are offered free-of-charge at district hospitals. It is unclear how the imposition of charges, like in Kenya and Tanzania [34, 35], would influence HCT uptake and linkage-to-care. The representativeness and precision of this study’s findings may also be limited since only data from a single cohort study were used, and findings are subject to limitations in that study. For example, López-Varela et al. acknowledged that attrition in linkage to care in the cohort study could have been overestimated due to poor record keeping. However, such overestimation is likely lower than in other studies because the authors used data from the Health and Disease Surveillance System [12].

Because our dataset lacked detailed cost information, we were unable to evaluate the combination of VCT with either PICT or HBT against standalone VCT. Future studies, however, could investigate such combinations

and provide information to policymakers on how best to improve existing HIV-testing policies in Mozambique.

A CEA may be unsuitable for assessing the utility of HBT to meet targets for HIV eradication. CEAs are often designed to maximize efficiency at the expense of achieving distributive equality and equity [55]. Therefore, active HCT approaches, such as HBT, are seldom favored over more passive strategies due to their high unit costs per outcome achieved. Nevertheless, such strategies play a crucial role in achieving HIV eradication. HBT might not be cost-effective but may be equitable because HBT can reach populations distinct from those reached by facility-based strategies [12]. CEAs can address health equity concerns either through an equity impact analysis or an equity trade-off analysis as introduced by Cookson et al. [56] Round et al.'s analytical framework, which uses equity weights in decision analyses, may be useful [57]. Addressing equity is relevant for HCT strategies because factors like age, sex, and socioeconomic status may result in differential rates of uptake and linkage to care [12, 58, 59].

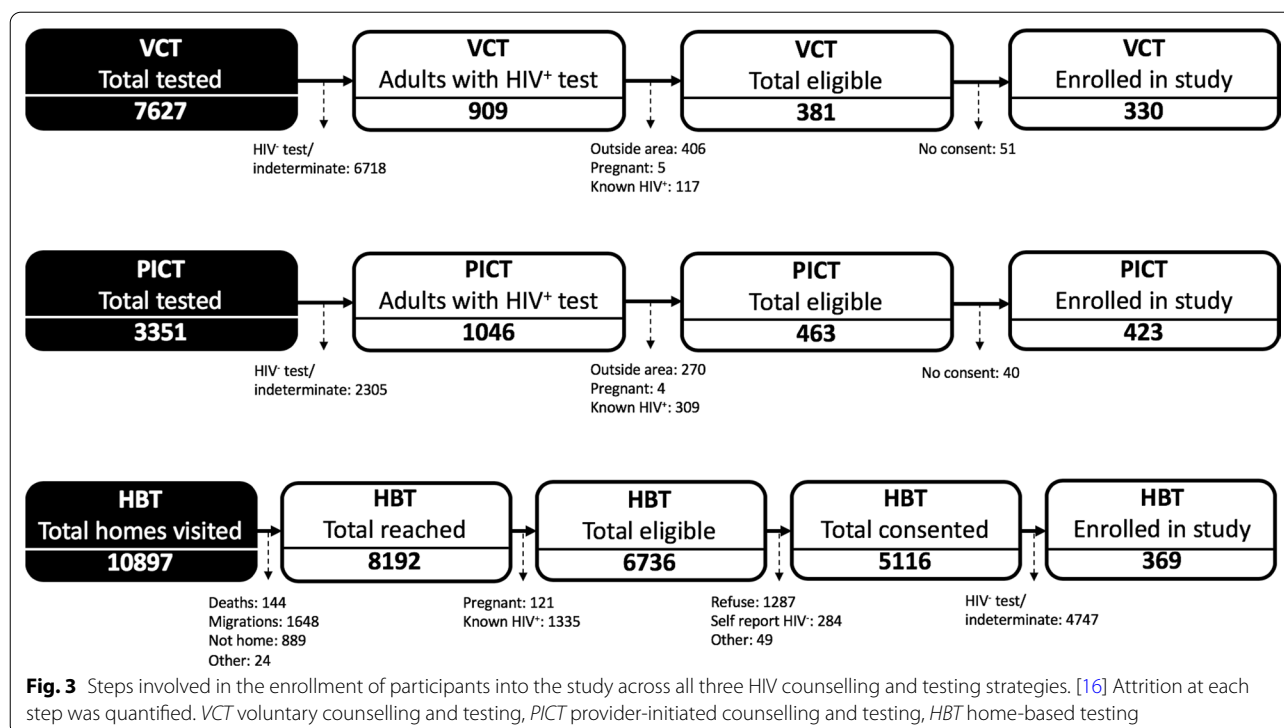
Despite these limitations, this study generates, for the first time, information for HIV healthcare policy decision making in Southern Mozambique, a setting characterized

by one of the highest community based HIV prevalences in the world (i.e., 40%). From the research perspective, this project calls for the need to test the cost-effectiveness of comprehensive home-based strategies including not only screening but also linkage to care and promotion of ART adherence. A similar combination prevention approach involving universal HIV testing and treatment has recently been assessed to be a cost-effective strategy at thresholds greater than US\$800 per DALY averted in Zambia and South Africa [60]. This may be seen as a reasonable threshold also for Mozambique, considering the traditional threshold of three times the gross domestic product (GDP) per capita and that the GDP per capita of Mozambique is just below US\$500. However, site specific studies should be carried out to obtain valuable information.

Appendices

Appendix 1: Schematic of cohort study with figures used in the economic evaluation

Numbers in Fig. 3 are used in the cohort decision model presented in Fig. 1.



Appendix 2: Copy of the questionnaire administered to study participants to elicit demographic information
 Questionnaire was administered in Portuguese.

Informação do participante	
1. Data da visita __ _ - __ _ _ - 2014	2. Sexo <input type="checkbox"/> Homen <input type="checkbox"/> Mulher
3. Idade em anos __ _	
Critérios de Inclusão	
4. Lugar de testagem: <input checked="" type="checkbox"/> UAT <input checked="" type="checkbox"/> SAAJ <input checked="" type="checkbox"/> Triagem <input checked="" type="checkbox"/> Casa <input checked="" type="checkbox"/> outro (especificar): __ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	
5. Se UATS/SAAJ referencia para testagem: <input type="checkbox"/> Voluntario <input type="checkbox"/> Referido (administrar questionário 4 só se voluntário)	
6. Se referido, lugar de referencia <input type="checkbox"/> consultas <input type="checkbox"/> PNCT <input type="checkbox"/> enfermeria <input type="checkbox"/> consulta prenatal <input type="checkbox"/> maternidad <input type="checkbox"/> CCR <input type="checkbox"/> Banco sangue <input checked="" type="checkbox"/> outro (especificar): __ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	
7. Tipo de testagem: <input type="checkbox"/> Individual <input type="checkbox"/> Familiar	
8. Se familiar, especifique a relação com o participante, o resultado do teste e se for positivo, o num TESHAM	
9. __ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ <input type="checkbox"/> Positivo <input type="checkbox"/> Negativo <input type="checkbox"/> Indeterminado Num TESHAM	
10. __ _ _ _ _	
11. __ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ <input type="checkbox"/> Positivo <input type="checkbox"/> Negativo <input type="checkbox"/> Indeterminado Num TESHAM	
12. __ _ _ _ _	
__ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ <input type="checkbox"/> Positivo <input type="checkbox"/> Negativo <input type="checkbox"/> Indeterminado Num TESHAM	
__ _ _ _ _	
Resultado do teste HIV <input type="checkbox"/> positivo <input type="checkbox"/> Negativo <input type="checkbox"/> Indeterminado	
13. Assinou o consentimento informado? <input type="checkbox"/> Sim <input type="checkbox"/> Não	
14. Se não, por qué: __ _ (1. Já conhece status HIV, 2. Recusa, 3. Fora de area de estudo, 4. Recusa do marido ou mulher, 5. Não pode vir as visitas, 6. Outra razão)	
15. Cumpre os criterios de inclusão? <input type="checkbox"/> Sim <input type="checkbox"/> Não (Test positivo, pertencer ao CS Manhíça como centro de referencia TARV, assinar consentimento informado) Se cumprir criterios, dar numero de estudo é preencher inquerito de identificação e. Se não cumprir, PARAR aqui	
16. Número de estudo TESH (colar etiqueta)	
Informação do test HIV	
17. Sabe o que é o vírus de HIV? <input type="checkbox"/> Sim <input type="checkbox"/> Não	
18. Alguma vez já fez o teste de HIV? <input type="checkbox"/> Sim <input type="checkbox"/> Não <input type="checkbox"/> Não sabe responder	
19. Se sim, quantas vezes o/a participante já fez o teste de HIV? <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> Mais de 2	
20. Quando foi a última vez que fez o teste? <input type="checkbox"/> < 6 meses <input type="checkbox"/> Entre 6 meses e 1 ano <input type="checkbox"/> >1 ano	
Preferências para testagem de HIV	
21. Onde é que o Sr/Sra. preferiria fazer o teste de HIV? <input type="checkbox"/> GATV <input type="checkbox"/> Triagem <input type="checkbox"/> Casa <input type="checkbox"/> Unidade móvil <input type="checkbox"/> Não tem preferência	
22. O Sr/Sra tem intenção de dizer o resultado ao parceiro? <input type="checkbox"/> Sim <input type="checkbox"/> Não <input type="checkbox"/> Não sabe responder <input type="checkbox"/> Não tem parceiro.	
Situação laboral	
23. Ocupação habitual : 1. Campones/pacuaria, 2. Operarios, 3. Comerciantes, 4. Mineiros, 5. Servicios, 6. Vendedor, 7. Domestico, 8. Estudante, 9. Sector de saúde, 10. Outro, __ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	
24. Deixou de fazer a sua ocupação no ultimo mes por doença. <input type="checkbox"/> Sim <input type="checkbox"/> Não	
25. Se sim, quantos dias deixou de fazer? __ _ _	
Identificação a través do DSS (Departamento de demografia)	
26. Perm_id do participante (copiar do inquerito de identificação) __ _ _ _ _ - __ _ _ _ _ - __ _ _	
27. Entrevistador: Codigo __ _ _ _ Data __ _ _ - __ _ _ _ - 2014 Assinatura _____	
28. Revisor Codigo __ _ _ _ Data __ _ _ - __ _ _ _ - 2014	

Appendix 3: Copy of the questionnaire administered to study participants to elicit cost-related information for voluntary counselling and testing (VCT) from the patient’s perspective

Questionnaire was administered in Portuguese.

General information		
1.	Date of the interview (dd / mm / yyyy)	_ _ - _ _ - _ _
2.	Study number (sticker)	<div style="border: 1px solid black; width: 100px; height: 40px; margin: 0 auto;"></div>
Costs associated with voluntary screening		
3.	How did you travel here today and how much did it cost?	<input type="checkbox"/> by Walking <input type="checkbox"/> By bus/”chapa” MZN _ _ _ _ _ _ <input type="checkbox"/> Bicycle MZN _ _ _ _ _ _ <input type="checkbox"/> Your own Car MZN _ _ _ _ _ _ <input type="checkbox"/> Autostop MZN _ _ _ _ _ _ <input type="checkbox"/> Other _____ MZN _ _ _ _ _ _
4.	How long did it take you to get here from your home?	Hours _ _ Minutes _ _ _ _
5.	How much did you spend today, while here, on?	<input type="checkbox"/> Food MZN _ _ _ _ _ _ <input type="checkbox"/> Drink MZN _ _ _ _ _ _ <input type="checkbox"/> Other _____ MZN _ _ _ _ _ _
6.	How much time have you spent at this health facility waiting for counseling?	Hours _ _ Minutes _ _
7.	How much time did the consultation last?	Hours _ _ Minutes _ _
8.	Which activities did you stop due to this consultation?	<input type="checkbox"/> Livestock <input type="checkbox"/> Agriculture / Harvesting <input type="checkbox"/> Fishing <input type="checkbox"/> Making items / Trade <input type="checkbox"/> Household activities / Children care <input type="checkbox"/> Building <input type="checkbox"/> Business <input type="checkbox"/> Short-term contract, other income-generating activities <input type="checkbox"/> Other salary-earning job <input type="checkbox"/> School <input type="checkbox"/> Other _ _ _ _ _ _ _ _ _ _
9.	Did anyone have to do your activities while you were here today?	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don’t Know
10.	Did you have to pay someone else to do your activities?	<input type="checkbox"/> Yes MZN _ _ _ _ _ _ <input type="checkbox"/> No <input type="checkbox"/> Don’t Know

Appendix 4: Copy of questionnaire used to collect time data, and data on health system resources used for voluntary counselling and testing (VCT), provider-initiated counselling and testing (PICT), or home-based testing (HBT)

1. Study number	
Information on HIV test	
2. Who is and how many staff are present at this visit?	<input type="checkbox"/> Clinical Officers N __ Clinical code __ __ <input type="checkbox"/> Nurses N __ Clinical code __ __ <input type="checkbox"/> Counsellors N __ Clinical code __ __
3. How long does it take (in minutes) during this visit to carry out the following activities?	<input type="checkbox"/> For home based visits only: how long did it take to reach the participant’s house (start counting from when the team leaves the CISM/health facility/the house of a previous participant) Start time __ __ : __ __ End time __ __ : __ __ <input type="checkbox"/> Explanation of why HIV testing is being recommended, of the voluntary nature of testing and testing procedures, and of the confidentiality of results Start time __ __ : __ __ End time __ __ : __ __ <input type="checkbox"/> Performing the rapid test (include all the steps, also the confirmatory test if needed) Start time __ __ : __ __ End time __ __ : __ __ <input type="checkbox"/> Explanation of the result and of its implications (in case of positive results, include also the explanation of the available treatment and care; in the case of indeterminate result, the explanation of the need to repeat is included) Start time __ __ : __ __ End time __ __ : __ __
4. Which materials and how much/many were used during this visit (please include also materials, such as rapid diagnostic tests, that were thrown away for any reason)?	<input type="checkbox"/> Determine® test N __ <input type="checkbox"/> Unigold® test N __ <input type="checkbox"/> Lancets N __ <input type="checkbox"/> Pairs of gloves N __ <input type="checkbox"/> Cotton N __ <input type="checkbox"/> Pairs of gloves N __ <input type="checkbox"/> Pipette N __ <input type="checkbox"/> Other _____ N __
5. Code __ __ __ signature of interviewer _____	Date __ __ - __ __ __ - __ __ __

Appendix 5: Unit costs (US\$) of various resource categories employed in the micro-cost estimate approach, along with their low and high estimates as determined from individual sources (Manhiça District, Mozambique)

Resource	Unit cost, US\$	Low estimate, US\$	High estimate, US\$	Source
Patient's perspective				
National monthly minimum wage (for agriculture and fisheries) ^a	101.35	99.04	114.56	[28]
Provider's perspective				
Determine HIV rapid test kit	1.07	0.98	1.16	[30]
Unigold HIV rapid test kit	3.18	2.59	4.79	[30]
Lancets	0.02	No data	No data	CISM private communication ^b
Gloves	0.01	No data	No data	[31]
Pipettes	0.04	No data	No data	[32]
Nurse monthly wage	792.00	No data	No data	CISM private communication ^b
Nurse assistant monthly wage	400.00	No data	No data	CISM private communication ^b
Counsellor monthly wage	258.32	No data	No data	CISM private communication ^b
Fuel, per litre ^c	1.55	1.20	1.60	[33]

All costs are reported to 2 decimal places.

^aThe monthly minimum wage for agriculture and fisheries best reflect the type of predominant economic activities in Manhiça.

^b Cost of lancets and monthly wages of nurses, nurse assistants and counsellors working at MDH were communicated privately by Centro de Investigação em de Saúde de Manhiça (CISM). No other sources of data were available to derive low and high estimates.

^c Fuel costs bases on fuel prices in 2014.

Appendix 6: A cohort decision-analytic model (decision tree) comparing HCT strategies for linking HIV-positive patients to care in Manhiça District, Mozambique
See Fig. 4

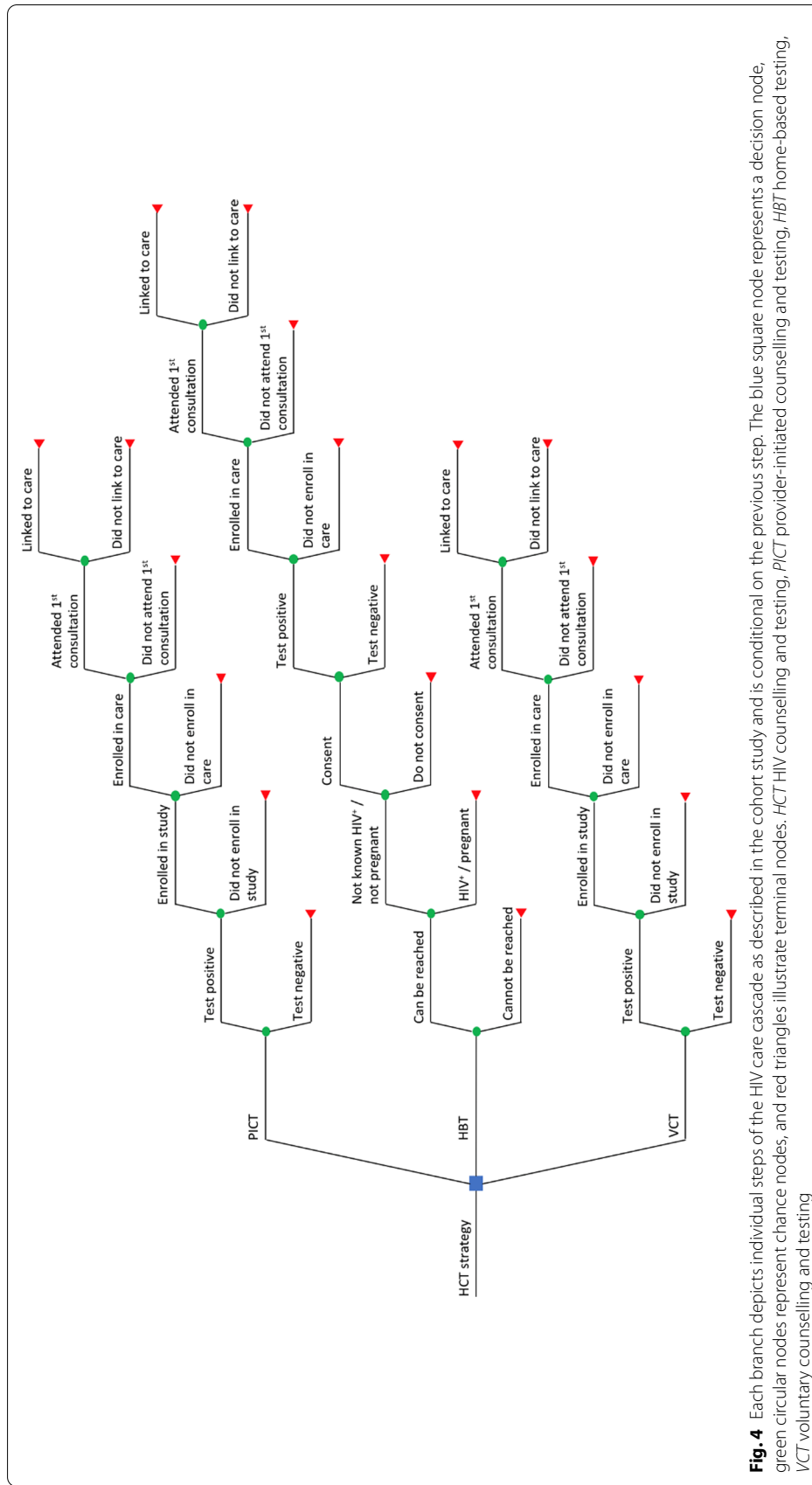


Fig. 4 Each branch depicts individual steps of the HIV care cascade as described in the cohort study and is conditional on the previous step. The blue square node represents a decision node, green circular nodes represent chance nodes, and red triangles illustrate terminal nodes. HCT HIV counselling and testing, PICT provider-initiated counselling and testing, HBT home-based testing, VCT voluntary counselling and testing

Appendix 7: Range of input values explored in the univariate sensitivity analysis for each assumption (input) made in the determination of costs per individual tested

Inputs	Input values			Source of estimates
	Base-case	Low estimate	High estimate	
Patient's perspective				
Minimum monthly wage, US\$	101.35	99.04	114.56	From Appendix 5
Monthly number of working hours	176	141 (−20%)	211 (+20%)	Empiric determination ^b
Provider's perspective				
Percentile cut-off for upper limit of variables	85th	80th	90th	Empiric determination ^b
HIV test kit prices, US\$	(Determine = 1.07; Unigold = 3.18)	(Determine = 0.98; Unigold = 2.59)	(Determine = 1.16; Unigold = 4.79)	From Appendix 5
Percentage of total costs as capital costs	3.27	3.00	14.23 ^a	[13, 14, 17, 24]
Percentage of recurrent costs as O & M costs	1.65	0.55	28.72 ^a	[13, 17, 20, 24]
Nurse monthly wage, US\$	792.00	633.60 (−20%)	950.40 (+20%)	Empiric determination ^b
Nurse assistant monthly wage, US\$	400.00	320.00 (−20%)	480.00 (+20%)	Empiric determination ^b
Counsellor monthly wage, US\$	258.32	206.66 (−20%)	309.98 (+20%)	Empiric determination ^b
2014 fuel prices, US\$/l	1.55	1.20	1.60	From Appendix 5
Travelling speed, km/h	50	40 (−20%)	60 (+20%)	Empiric determination ^b
Fuel consumption, l/km	0.143	0.114 (−20%)	0.171 (+20%)	Empiric determination ^b

^a These were ambitiously high estimates which unlikely represent true high estimates for Mozambique

^b When there were no published data for ranges, base-case values were adjusted empirically ($\pm 20\%$). Base-case values for monthly number of working hours were based on a 22-day work month and average daily working hours of 8 h/day. Base-case values for travelling speed were based on average speed limits in Manhiça O & M operation and management

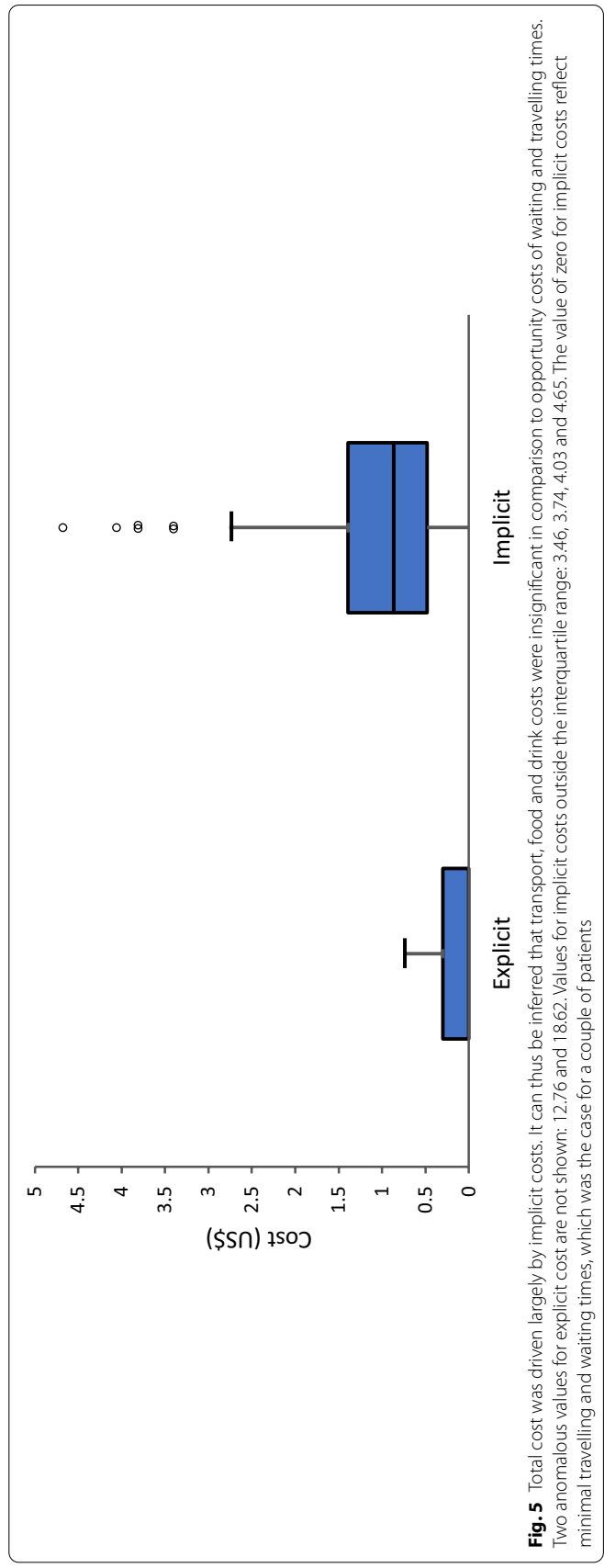
Appendix 8: Quantities of resources used in each testing modality

Testing modality	Quantity by test strategy (cost in the case of transportation, food and drinks, and others) Mean values and standard deviation are reported		
	VCT	PICT	HBT
Patient's perspective			
Transport (bus, taxi, etc.), US\$	0.19 (0.35)	—	—
Drink + Food, US\$	0 (0.25)	—	—
Waiting time (hours)	0.95 (0.94)	—	—
Travelling time (hours)	0.82 (0.71)	—	—
Any other direct cost, US\$	0.1 (1.05)	—	—
"Determine" HIV rapid test kit (number)	1 (0)	1 (0)	1.03 (0.27)
Provider's perspective			
"Unigold" HIV rapid test kit (number)	1 (0)	1 (0)	1.01 (0.12)
Lancets (number)	1 (0)	1 (0)	1.04 (0.21)
Gloves (number)	1 (0)	1(0)	1.16 (0.38)
Pipettes (number)	1 (0)	1 (0)	1 (0)
Personnel time (minutes) ^a	46.53 (12.64)	30.72 (12.60)	58.45 (15.30)
Kilometers to reach the patient	—	—	13.7 (12.75)

^a Personnel time was measured through a time and motion study. Personnel included counsellors and/or nurses and clinicians in provider-initiated counselling and testing (PICT). Personnel time includes time to reach patient (home-based testing [HBT] only), explanation, doing the test, waiting for results, and explaining the results and next steps

VCT voluntary counselling and testing

Appendix 9: Box and whiskers plot of median explicit and implicit costs of voluntary counselling and testing, in US\$, to the patient
 See Fig. 5.



Appendix 10: Sensitivity analysis of average and median costs per person tested
See Fig. 6.

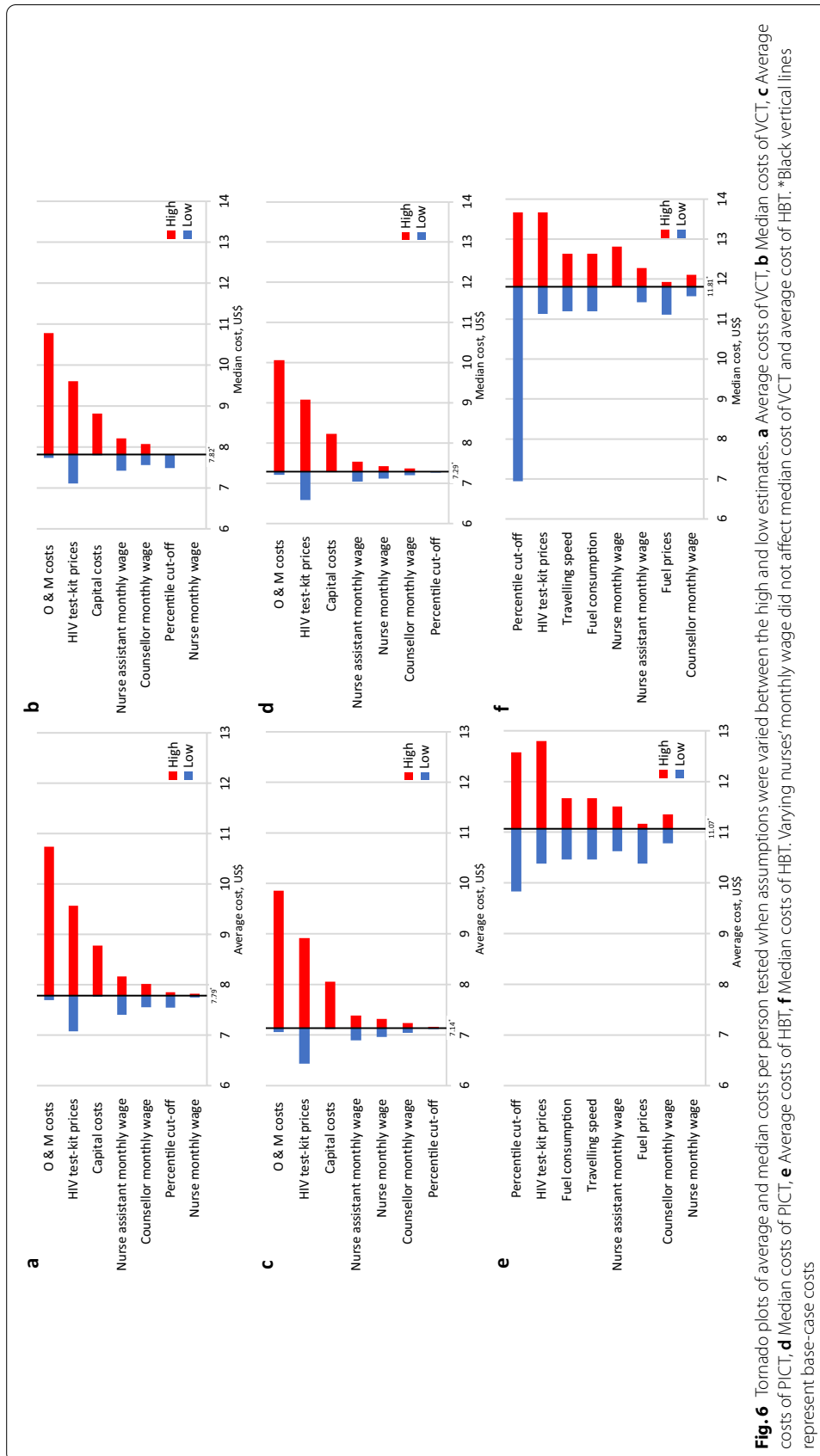


Fig. 6 Tornado plots of average and median costs per person tested when assumptions were varied between the high and low estimates. **a** Average costs of VCT, **b** Median costs of VCT, **c** Average costs of PICT, **d** Median costs of PICT, **e** Average costs of HBt, **f** Median costs of HBt. Varying nurses' monthly wage did not affect median cost of VCT and average cost of HBt. *Black vertical lines represent base-case costs

Appendix 11: Impact of varying assumptions on base-case average and median costs of VCT from the patient’s perspective among participants who tested HIV-positive

Parameter	Average cost (SD), US\$	Median cost (range), US\$
Base-case analysis	1.34 (1.46)	1.08 (0.00–19.58)
Monthly minimum wage ^a		
Low estimate = US\$99.04	1.32 (1.45)	1.07 (0.00–19.56)
High estimate = US\$114.56	1.47 (1.50)	1.19 (0.00–19.70)
Number of working hours per month ^a		
Low estimate = 141 h	1.59 (1.55)	1.32 (0.00–19.82)
High estimate = 211 h	1.17 (1.40)	0.96 (0.00–19.42)

All costs are reported to 2 decimal places. SD refers to standard deviation

^a The monthly minimum wage and number of working hours per month in the base-case analysis was US\$101.35 and 176 h respectively
VCT voluntary counselling and testing, SD standard deviation

Appendix 12: Cost-effectiveness plane depicting the four quadrants in which ICERs may reside

See Fig. 7.

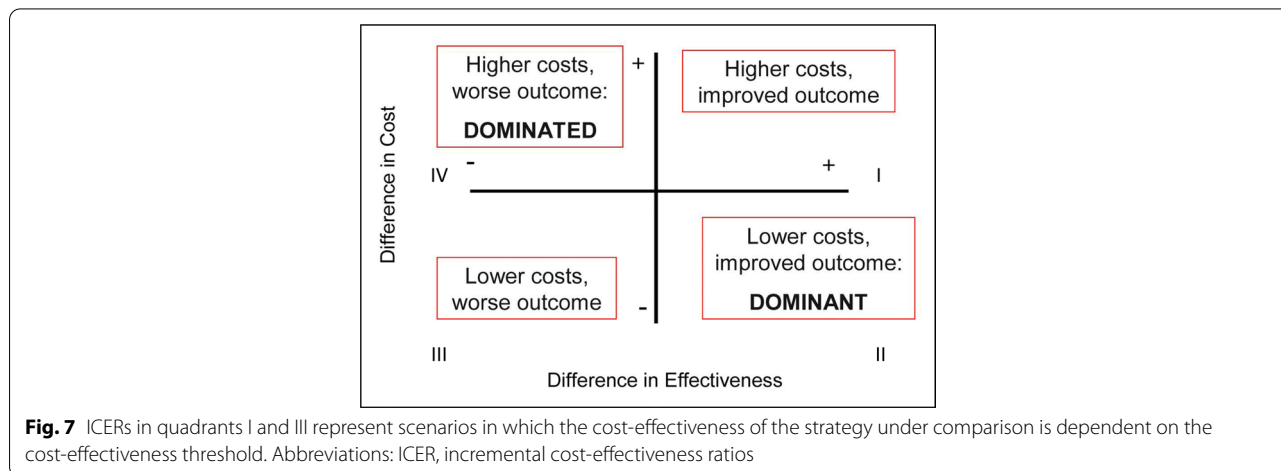
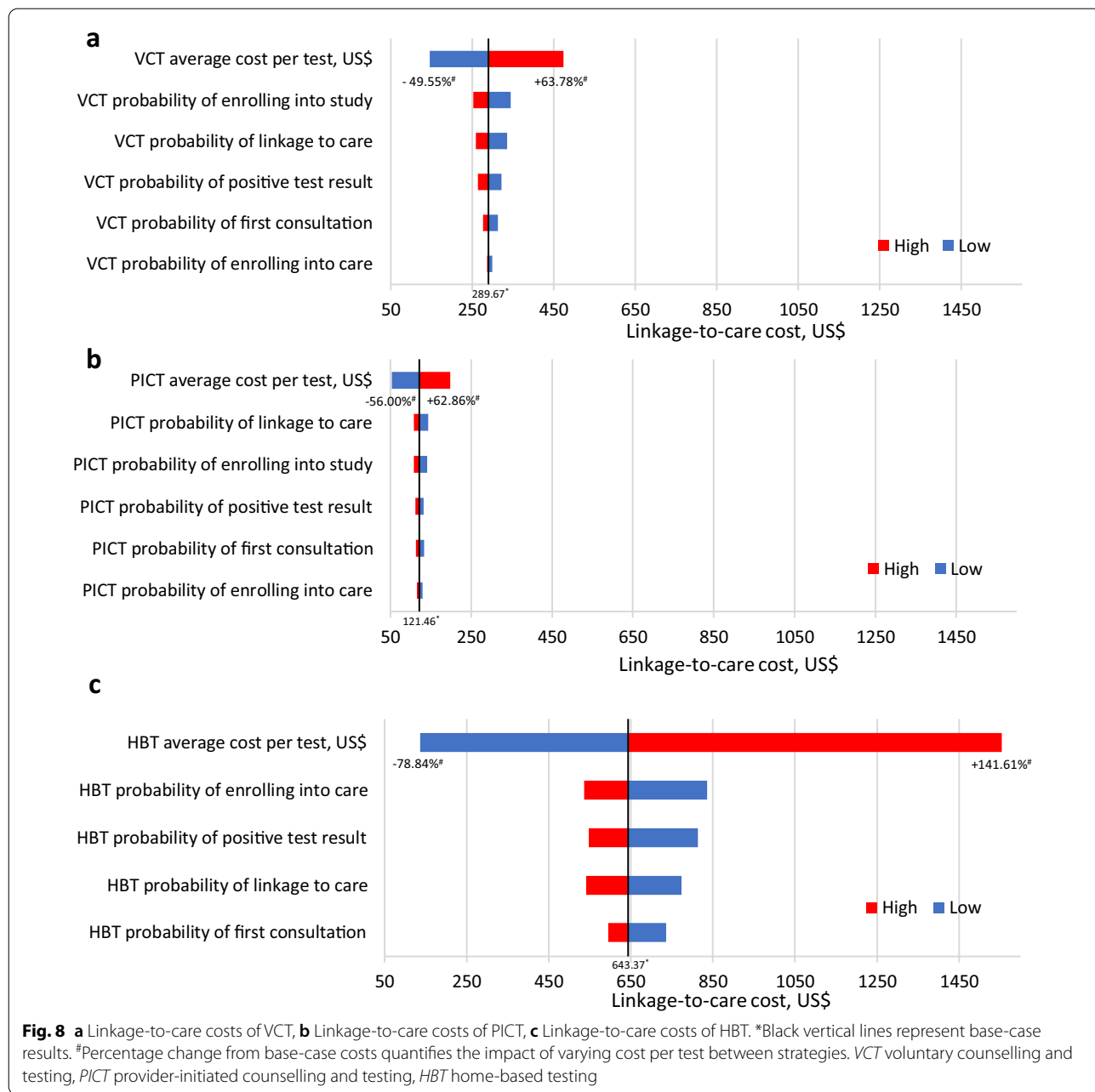


Fig. 7 ICERs in quadrants I and III represent scenarios in which the cost-effectiveness of the strategy under comparison is dependent on the cost-effectiveness threshold. Abbreviations: ICER, incremental cost-effectiveness ratios

Appendix 13: Tornado plots illustrating fluctuations in linkage-to-care costs between the minimum (low) and maximum (high) values of individual model parameters in the univariate sensitivity analysis

See Fig. 8.



Appendix 14: Impact of varying probabilities and costs used to parameterise the decision tree on linkage-to-care costs of VCT, PICT, and HBT from the provider's perspective, US\$

Model parameters	VCT		PICT		HBT	
	Min parameter value ^a	Max parameter value ^a	Min parameter value ^a	Max parameter value ^a	Min parameter value ^a	Max parameter value ^a
Probabilities						
Positive test result	322.24 (+11.24%)	263.38 (-9.08%)	132.47 (+9.06%)	111.79 (-7.96%)	813.86 (+14.40%)	547.15 (-7.53%)
Enrolled into study	344.07 (+18.78%)	251.99 (-13.01%)	141.39 (+16.41%)	107.69 (-11.34%)	-	-
Enrolled into care	298.50 (+3.05%)	285.88 (-1.31%)	130.18 (+7.18%)	116.06 (-4.45%)	835.64 (+20.24%)	535.66 (-15.97%)
Attended first consultation	312.83 (+8.00%)	276.09 (-4.69%)	133.15 (+9.62%)	112.75 (-7.17%)	736.03 (+26.50%)	594.93 (-14.96%)
Linked to care	335.18 (+15.71%)	258.26 (-10.84%)	143.59 (+18.22%)	107.47 (-11.52%)	773.58 (+29.88%)	540.62 (-16.74%)
Costs						
VCT	146.14 (-49.55%)	474.41 (+63.78%)	-	-	-	-
PICT	-	-	53.45 (-56.00%)	197.81 (+62.86%)	-	-
HBT	-	-	-	-	136.11 (-78.84%)	1554.44 (+141.61%)

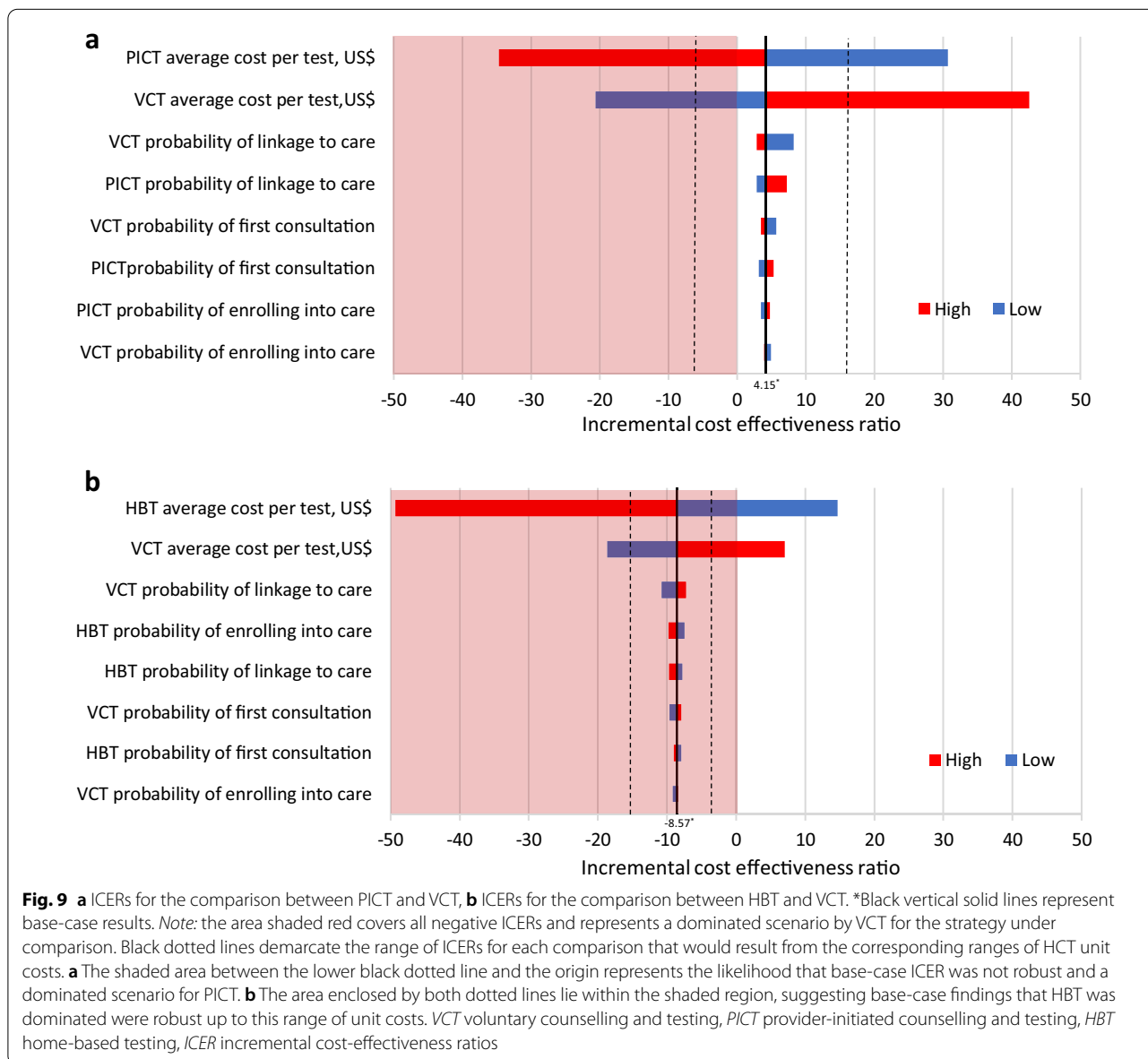
All figures are reported to 2 decimal places. Percentages in parentheses denote the percentage change from base-case linkage-to-care costs for strategy

^a Minimum and maximum parameter values as tabulated in Table 2

VCT voluntary counselling and testing, PICT provider-initiated counselling and testing, HBT home-based testing

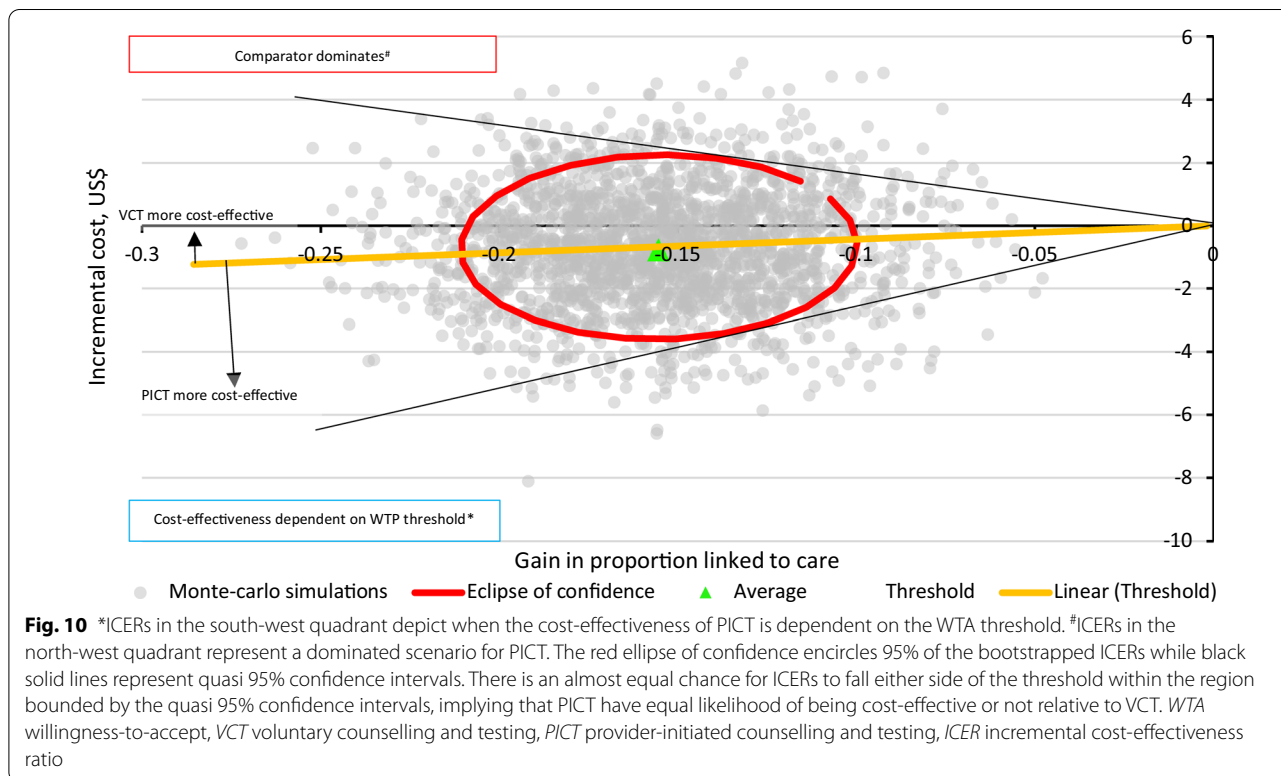
Appendix 15: Tornado plots illustrating fluctuations in ICERs between the minimum (low) and maximum (high) values of individual model parameters in univariate sensitivity analysis

See Fig. 9.



Appendix 16: Mapping the WTA threshold on the Monte-Carlo plot for the comparison between PICT and VCT

See Fig. 10.



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Author contributions

JHC cleaned the data, performed the economic analysis, and was also a major contributor in writing the manuscript. RT and ES provided guidance on the method of data analysis. All authors read and approved the final manuscript.

Funding

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Mozambican National Bioethics Committee and the Institutional Review Boards at the Hospital Clinic of Barcelona (Spain) and the Manhiça Health Research Centre. It was also reviewed according to Centers for Disease Control and Prevention (CDC) human research protection procedures and was determined to be research; however, CDC was not engaged directly with research participants. The purpose of the main study was explained to participants, and written informed consent was obtained.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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