Global estimates for the lifetime cost of managing HIV

Huynh Tran[a,b], Kanwal Saleem[c], Megumi Lim[d], Eric P.F. Chow[a,b,d], Christopher K. Fairley[a,b], Fern Terris-Prestholt[e] and Jason J. Ong[a,b,d,f]

See related paper on page 1311

Objective: There are an estimated 38 million people with HIV (PWH), with significant economic consequences. We aimed to collate global lifetime costs for managing HIV.

Design: We conducted a systematic review (PROSPERO: CRD42020184490) using five databases from 1999 to 2019.

Methods: Studies were included if they reported primary data on lifetime costs for PWH. Two reviewers independently assessed the titles and abstracts, and data were extracted from full texts: lifetime cost, year of currency, country of currency, discount rate, time horizon, perspective, method used to estimate cost and cost items included. Descriptive statistics were used to summarize the discounted lifetime costs [2019 United States dollars (USD)].

Results: Of the 505 studies found, 260 full texts were examined and 75 included. Fifty (67%) studies were from high-income, 22 (29%) from middle-income and three (4%) from low-income countries. Of the 65 studies, which reported study perspective, 45 (69%) were healthcare provider and the remainder were societal. The median lifetime costs for managing HIV differed according to: country income level: $5221 [interquartile range (IQR)]: 2978–11 177) for low-income to $377 820 (IQR: 260 176–541 430) for high-income; study perspective: $189 230 (IQR: 14 794–424 069) for healthcare provider, to $508 804 (IQR: 174 781–812 418) for societal; and decision model: $190 255 (IQR: 13 588–429 772) for Markov cohort, to $283 905 (IQR: 10 558–453 779) for microsimulation models.

Conclusion: Estimating the lifetime costs of managing HIV is useful for budgetary planning and to ensure HIV management is affordable for all. Furthermore, HIV prevention strategies need to be strengthened to avert these high costs of managing HIV.

AIDS 2021, **35**:1273–1281

Keywords: cost, health economics, HIV, systematic review

Introduction

People living with HIV have seen dramatic improvements in life expectancy and reductions in morbidity since HIV first came to medical attention in the early 1980s [1–3]. Antiretroviral therapy (ART) has revolutionized the management of people with HIV (PWH). AIDS has shifted from what once was a fatal disease to now being a highly treatable chronic condition, becoming a condition people die with, rather than die from [4,5].

ART initiation using $CD4^+$ cell count criteria has evolved since the late 1990s, at a time when drugs were expensive, less robust, with considerable side effects, and where the risk of resistance was high [6]. However, with ART becoming more affordable and less toxic, the

[a]Central Clinical School, Monash University, [b]Melbourne Sexual Health Centre, The Alfred, [c]Department of Paediatrics, [d]Melbourne School of Population and Global Health, University of Melbourne, Melbourne, Australia, [e]Department of Global Health, and [f]Department of Clinical Research, London School of Hygiene and Tropical Medicine, London, England, United Kingdom.

Correspondence to Jason J. Ong, 580 Swanston Street, Carlton, VIC 3053, Australia.

Tel: +61 3 9341 6200; e-mail: Jason.Ong@monash.edu; Jason.Ong@lshtm.ac.uk
Received: 22 December 2020; revised: 5 March 2021; accepted: 15 March 2021.

DOI:10.1097/QAD.0000000000002887

decision to commence treatment regardless of $CD4^+$ cell counts is supported worldwide [6]. This is reflected in the WHO guidelines over time, in which the recommended $CD4^+$ cell count for initiation of ART rose from less than 200 cells/μl in 2002, to less than 350 cells/μl in 2010, to less than 500 cells/μl in 2013 [7]. The latest WHO guidelines in 2015 recommend commencing ART in all PWH regardless of $CD4^+$ cell count, as evidence shows the clinical and preventive benefits of starting ART early at high $CD4^+$ cell counts now outweigh their minimal risks [6,7].

These advances in HIV management impact the lifetime costs associated with HIV as patients are starting ART earlier and living longer [3,8]. Estimating an accurate lifetime cost of managing HIV is vital for policy makers who are involved in future planning and decision making to ensure quality HIV treatment is cost effective and affordable for all [8]. Thus, it is important that lifetime costs are calculated accurately and consistently to draw true conclusions regarding the economic burden of HIV, and to be able to compare lifetime costs of HIV around the world.

To our knowledge, there have been no reviews that synthesized the global estimates of lifetime cost of managing HIV over time. In this review, we aimed to examine the published literature from 1999 onwards to compare the lifetime costs for a patient living with HIV in countries globally, and describe the methodologies used to estimate these costs.

Methods

Search strategy and selection criteria

We searched databases PubMed, EconLit, Web of Science: Core Collection, Embase via Ovid and Global Health Cost Consortium [9] on 23 January 2020. The MeSH search terms used were related to 'HIV', 'cost*', 'econ*' and 'lifetime'. When searching on the Global Health Cost Consortium database, we limited our review to 'HIV', 'Treatment and Care' and 'Adult ART'. We also restricted the language of studies to English. Our search strategy is shown in Appendix 1, http://links.lww.com/QAD/C75. The inclusion criteria were, any study published from 1999 onwards, and contained information about lifetime costs related to HIV. We excluded studies related to the costs of paediatric HIV management as these are quite different from adult HIV management costs and will be a subject of future research. Titles and abstracts were independently assessed for eligibility by at least two reviewers (T.H., M.L. and K.S.). Another reviewer (J.O.) resolved any discrepancies. This systematic review has been registered at the International Prospective Register of Systematic Reviews (PROSPERO: CRD42020184490).

Data analysis

An extraction file was created in Microsoft Excel, to collate the following information: lifetime cost of HIV, age at which lifetime cost estimate begins, year of currency, country of currency, country, discount rate, time horizon, sensitivity analyses performed, perspective, methods used to estimate cost, model used to estimate lifetime cost and cost items included. Data extraction was conducted by three reviewers (T.H., M.L. and KS), and a fourth reviewer (J.O.) resolved any discrepancies. The quality of the study was assessed using the criteria from the methods section of the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist [10], with an average score of 7.5 (range 5–10) (Supplementary Table 3, http://links.lww.com/QAD/C75).

To ensure consistency of comparison for the lifetime cost, we converted all currencies to United States dollars (USD) using OFX Historical Exchange Rates [11]. We then inflated costs to 2019 using the relevant consumer price indices [12]. For studies that reported multiple estimates of lifetime costs, we used the average of the lowest and highest estimates in our model. For studies, which had two price years for their lifetime cost, for example, 2018/2019, we used the latest year for the conversion and inflation. We classified the study country income level into high, upper middle, lower middle or low income using The World Bank classification [13]. We categorized the studies into healthcare provider (only costs incurred by the health provider), societal (includes the full range of social opportunity costs including productivity losses) and modified societal perspective (which may exclude some individual costs) based on what the study reported. If no perspective was reported, the study was categorized into an unknown perspective. We also categorized the decision models as cohort (based on populations), microsimulation (based on individuals) or other.

Descriptive statistics were used to summarize the lifetime costs, including box plots to visualize the impact of the country income level, study perspective, decision model on the resultant lifetime cost of HIV. Costs were converted to a log scale in the box plots. We used the Kruskal–Wallis test to determine if there was a statistically significant difference between the groups described above. We also examined for significant changes in price over time using a linear regression model. We defined a *P* value of less than 0.05 as statistically significant. All statistical analysis was performed using STATA version 16 (StataCorp. 2019. *Stata Statistical Software: Release 16*. College Station, Texas, USA: StataCorp LLC). This review is reported as per PRISMA guidelines.

Results

Seventy-five studies were included in the analysis, where information on estimated lifetime costs and economic

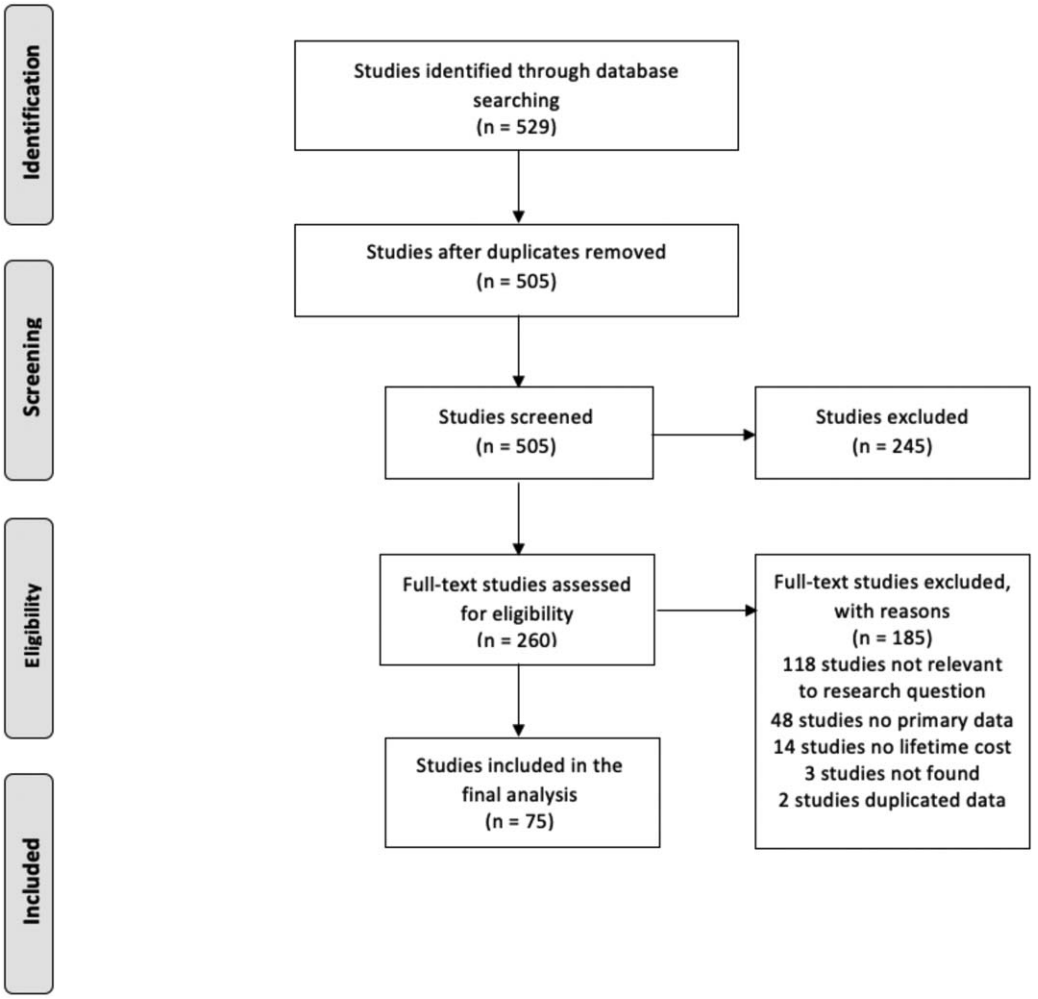

Fig. 1. PRISMA flow chart.

models used in informing these estimates were extracted (Fig. 1).

Lifetime costs according to country income level

Of 75 studies, 50 (66.7%) were from high-income countries, 15 (20.0%) from upper middle-income countries, seven (9.3%) from lower middle-income countries and three (4.0%) from low-income countries. There were statistically significant differences ($P < 0.0001$) between the median lifetime cost for managing HIV in a high-income country ($377 820; IQR: 260 176–541 430), upper middle-income country ($10 558; IQR: 8011–16 944) and low middle-income country ($3693; IQR: 3344.50–10 859). There were only three studies from low-income countries; all were from sub-Saharan Africa ($2978 [14], $11 177 [15] and $5221 [16]). There were statistically significant differences between the cost in high-income countries compared with all other country income levels ($P < 0.0001$); but not between upper middle-income countries compared with lower middle-income countries ($P = 0.053$) and low-income countries ($P = 0.214$); nor with lower middle-income compared with low-income countries ($P = 0.73$). The wide variations of lifetime costs may be explained by the differences in a country's health systems including the cost of ART, which makes up a large proportion of a patient's lifetime cost [3]. Even within the same income-country level, we can see that ART can differ greatly. For example, in the high-income country level, ART can range from 53.6 [17] to 81.3% [18] of a lifetime cost. We did not find any statistically significant increase in costs over the years for high-income countries ($1836/year, $P = 0.77$), middle-income countries ($3489/year, $P = 0.091$) or low-income countries ($2359/year, $P = 0.171$) (Fig. 2).

Lifetime costs according to study perspective

Supplementary Table 1, http://links.lww.com/QAD/C75 summarizes the lifetime costs, study perspective, income-country category and costs items for the included studies. Of the 65 studies, which explicitly stated their study perspective, 45 (69.2%) took a healthcare provider perspective, eight (12.3%) took a modified societal perspective and 12 (18.5%) took a societal perspective. The median lifetime cost was $189 230 (IQR: 14 794–424 069) for studies using a health provider perspective,

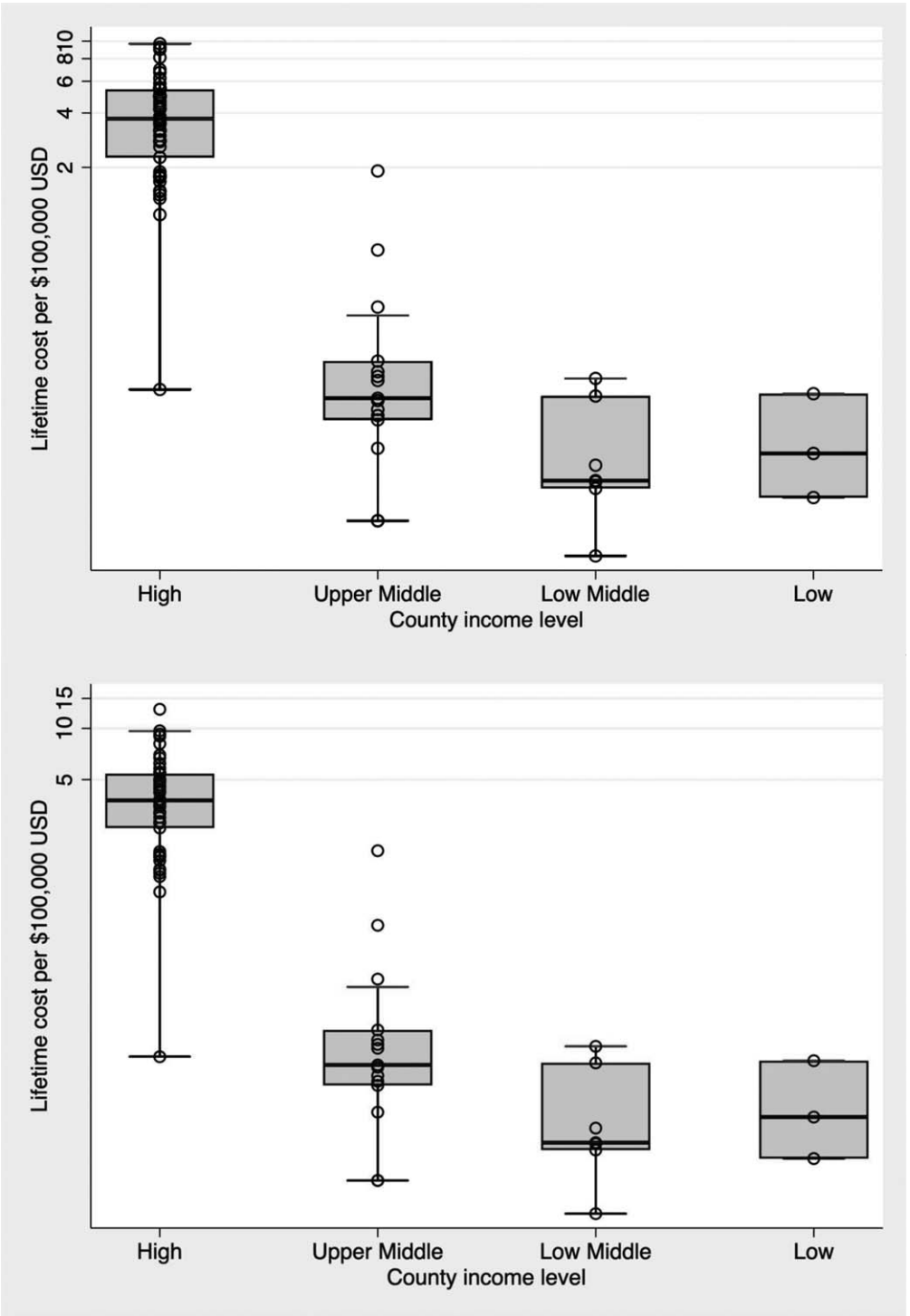

Fig. 2. Lifetime cost of managing HIV according to country income level.

$12 694 (IQR: 8217–196 746) for modified societal, $508 804 (IQR: 174 781–812 418) for societal and $318 644 (IQR: 5221–453 779) for unknown perspective. There were a statistically significant difference between studies adopting a healthcare provider perspective compared with societal ($P = 0.036$) but not modified societal ($P = 0.056$). There was also a difference between modified societal compared with societal ($P = 0.017$). Whenever we examined the cost items included within each study perspective, we found that they varied significantly (Supplementary Table 1, http://links.lww.com/QAD/C75). For example, we expect those who use a societal perspective to include productivity loss but only 50% (6/12) of these studies explicitly mentioned collecting costs

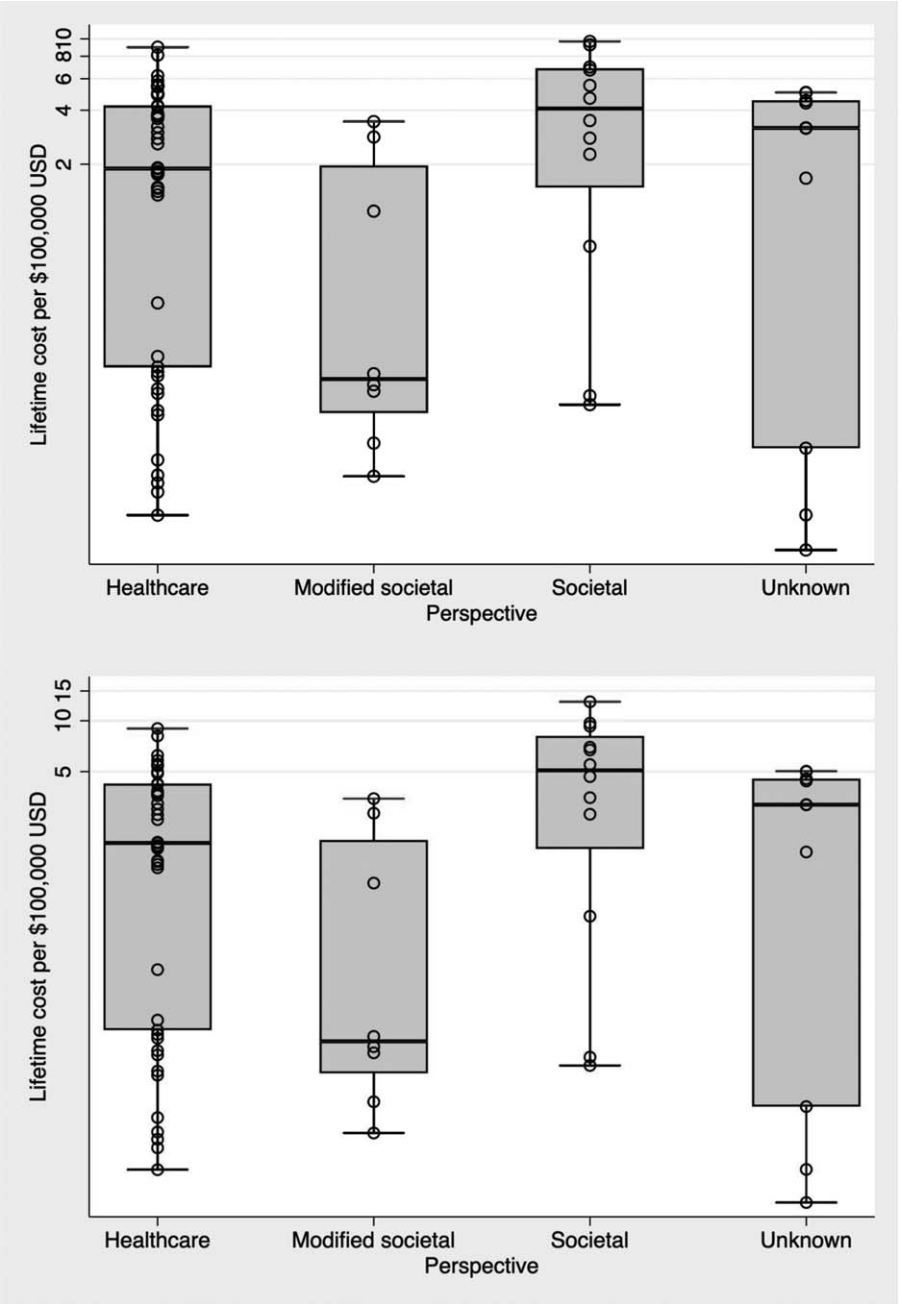

Fig. 3. Box plot of the lifetime cost (log-scale) of managing HIV according to study perspective.

related to productivity loss. It is also noteworthy that many studies did not completely report all cost items included in their analysis (Fig. 3).

Decision models used to estimate lifetime costs

Supplementary Table 2, http://links.lww.com/QAD/C75 presents a summary of methodologies of the included studies by costing and modelling approaches, decision model types, sensitivity analyses and whether $CD4^+$ status was accounted for. Of 75 studies, 64 (85%) used Markov models; among these 64 studies, 32 (50%) state-transition cohort models, 31 (48%) microsimulation models and one (1.6%) dynamic Markov model. Of 31 microsimulation models, 18 used the Cost-Effectiveness of Preventing AIDS Complications (CEPAC) model and four the Anti-Retroviral Analysis by Monte Carlo Individual Simulation (ARAMIS) model. Of the remaining 11 studies, two were discrete event simulation (DES) models, one an econometric model, one a decision tree, four mathematical simulation models and three studies were unclear on which models they used.

The median lifetime costs for PWH differed according to the decision model: $283 905 (IQR: 10 558–453 779) for

Table 1. Lifetime costs for people with HIV by country income level and models.

Country income level	Model used	Number of studies	Median (2019 USD)	IQR (2019 USD)	Min (2019 USD)	Max (2019 USD)
High-income	Cohort	22	355 577	182 661–502 763	109 586	927 428
S	Micro-simulation	19	383 168	318 023–500 311	11 807	671 301
	Others	9	467 148	227 220–623 668	141 148	968 025
Upper middle-income	Cohort	5	13 236	9140–13 941	8462	191 221
	Micro-simulation	7	10 588	8011–16 944	5576	337 112
	Others	3	2219		2211	69 786
Lower middle-income	Cohort	3	4494		3644	10 859
	Micro-simulation	4	3519		1414	13 582
Low-income	Cohort	2			5221	11 177
	Micro-simulation	1	2978			

IQR, interquartile range; USD, United States dollars.

microsimulation models, \$190 225 (IQR: 13 588–429 772) for Markov cohort and \$321 340 (IQR: 102 336–761 714) for other model types. There were no statistically significant differences between studies using Markov cohort compared with microsimulation models ($P = 0.773$) or other ($P = 0.510$); and micro-simulation models compared with other ($P = 0.244$). Table 1 further disaggregates the lifetime costs according to the country income level and model used. The choice to use cohort or microsimulation models did not significantly change lifetime costs across all country income levels (Fig. 4).

Future comorbidity associated with HIV

Whilst many studies acknowledged that HIV-related chronic comorbidities may arise, very few studies actually accounted for comorbidity associated with HIV, particularly those associated with an ageing population. From a health system planning perspective, it is not only the direct costs of the disease that are considered but also the costs of comorbidities and even unrelated future medical costs that may be incurred by not dying from HIV, and living longer. Several studies considered the link between HIV and cardiovascular disease within their lifetime cost [19–21]; however, each performed different calculations. One incorporated the costs of a 1.5-fold to 2-fold increased relative risk of cardiovascular disease compared with the general population in their model [19]. Another used the Framingham equation to predict coronary heart disease and stroke, and accounted for this within 'care of chronic disease' costs [20]. Finally, one calculated a monthly weighted mean cost of acute myocardial infarction (40%) and hypokinetic cardiomyopathy (60%) based on 'expert opinion' [21]. Another approach included the cost of medications for comorbidity [22] where 15% of the total lifetime costs were related to chronic disease medications, opportunistic infection prophylaxis and treatment medications.

Lifetime costs according to patient subpopulation

Only three of 75 studies reported lifetime costs by subpopulation. This approach was taken by Brogan *et al.* [21], who identified key cost differences between heterosexuals, MSM and people who inject drugs (PWID) [21]. The lifetime costs (USD 2019) were \$461 952, \$575 972 and \$635 663, respectively, with the most costly group being people who inject drugs. Ong *et al.* identified cost differences between heterosexuals, MSM and PWID, but found different results to Brogan *et al.* [21,22]. The lifetime costs were \$267 448 for heterosexuals, \$279 947 for MSM and \$180 225 for PWID [21], with the most costly group being MSM. Populations vulnerable to HIV acquisition can also be stratified by skin colour, ethnicity and gender. Ethnic minority populations are more likely to have delayed diagnosis, and are less likely to engage with treatment services [23,24]. Schackman *et al.* provides estimates from 15 subpopulations: MSM, male and female PWID, male and female heterosexuals and ethnic groups of white, black or Hispanic [22]. By disaggregating the data, Schackman highlighted the discrepancies in lifetime costs between subpopulations, with the greatest difference seen in Hispanic MSM with a lifetime cost (\$394 395) greater than double that of black female PWID (\$193 412) [22].

Discussion

This systematic review reported lifetime costs from 75 studies across the world for managing HIV according to country income level, study perspective and decision model; using studies published between 1999 and 2019. Though there is a need for locally derived lifetime cost estimates, our data could be used as approximations of possible ranges of costs to assist governments with budgetary planning when no local estimates exist. Given significant variations noted in the literature, we recommend a standardized methodology for measuring lifetime HIV costs to improve comparability in future studies. We noted key knowledge gaps within the literature on costs disaggregated by subpopulation and the inclusion of comorbidity associated with an ageing population of PWH.

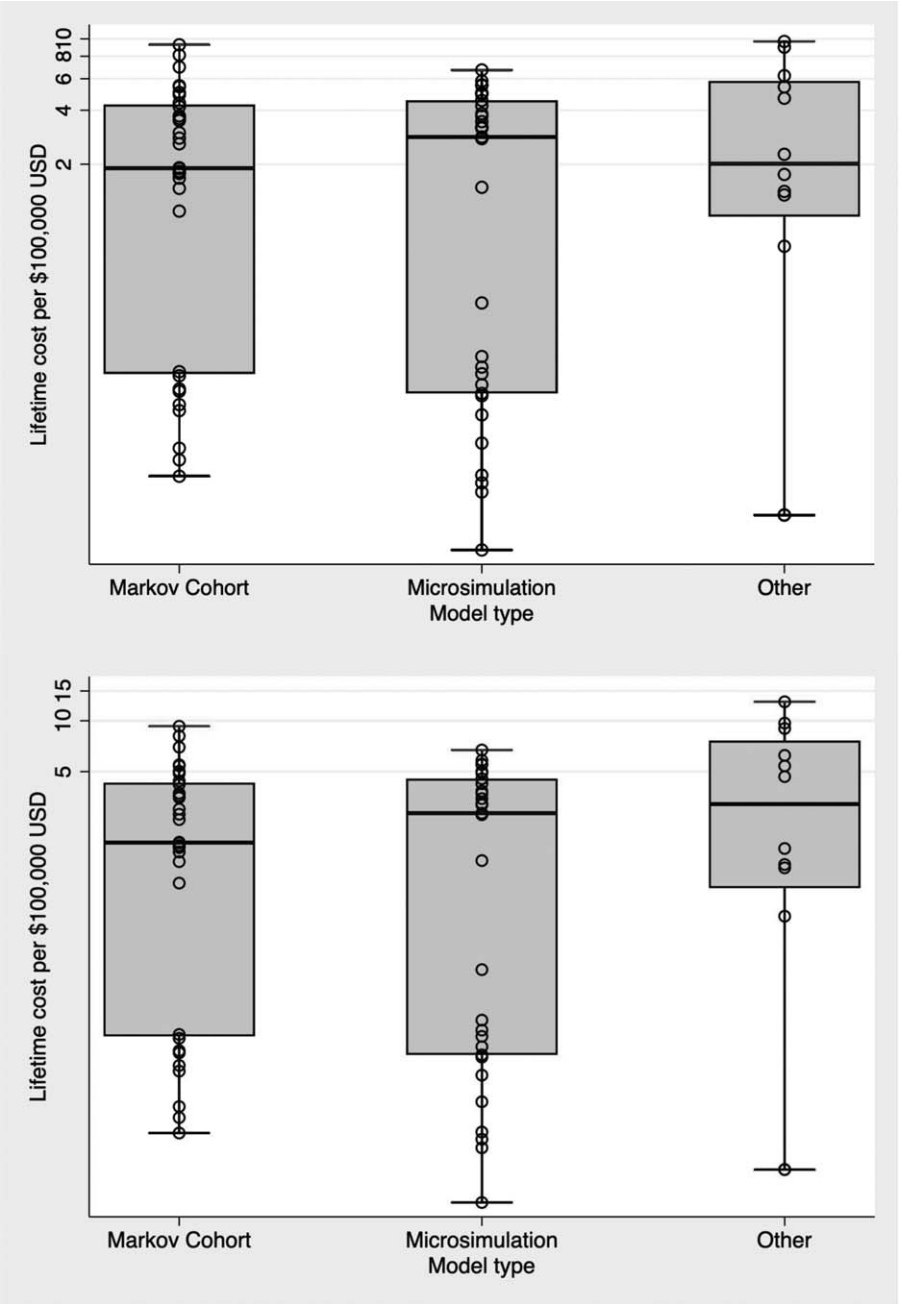

Fig. 4. Box plot of the lifetime cost of managing HIV according to decision model.

In an infection, such as HIV, which disproportionately affects certain subpopulations, it is important to consider the heterogeneity of economic impacts, which result within these subpopulations. By performing subgroup analyses on populations defined by transmission risk, sex and ethnicity, it highlights the large variation of lifetime costs in these key populations. Minority groups often experience structural and social barriers to timely access to medical care and ART [23]. And so, these vulnerable populations are more likely to be diagnosed at a more advanced disease stage, which is associated with higher healthcare utilization, and thus, higher lifetime costs [24]. Combined with the cost of an extended lifespan, managing HIV could be more expensive for high-risk individuals [24]. These racial and ethnic differences not only affect disease morbidity and mortality but also health service utilization [23]. It is important to capture these differences through subgroup analyses. We recommend that future studies disaggregate their lifetime estimates by key group within their study population. These subgroup analyses enable decision-makers to identify the groups for which treatment is costly, and helps prioritize prevention

efforts and reduce health inequities. Although there may be differences in cost according to subpopulation, we must also account for the benefit of downstream transmissions averted by a person having an undetectable viral load within that subpopulation.

There is increasing discussion that medical advancements that can prolong life should be considered when estimating the lifetime cost of a disease [25]. With HIV now regarded as a chronic disease, there are additional HIV-related comorbidities that come with ageing that might significantly affect the lifetime cost calculations for PWH. Most studies we reviewed did not include this in their estimation. Further, it may be important to consider a broad societal perspective when estimating the lifetime cost of a chronic infection, such as HIV. For a PWH, there could be significant indirect costs – opportunity and productivity costs – that may have a large impact on both the individual and society [23]. With the inclusion of the cost of managing HIV-related comorbidity – particularly with an ageing population of PWH, a more accurate and realistic estimation of lifetime cost of HIV will result [5]. This will have important implications not only for individuals but also for the healthcare systems, in relation to resource utilization, allocation and cost expenditure [24].

Even though the majority of studies adopted a healthcare provider perspective, we found that the cost items included were inconsistently measured. This matters for health system planning and for comparability of total costs between different settings. There was also an issue with transparency as it was often unclear as to which cost items were included, and how they were calculated. Thus, we recommend that a standardized checklist of cost items from a broad societal perspective be adopted for future studies, with clear disclosure on cost items included and how they were derived. HIV-costing guidelines has already been developed by Joint United Nations Programme on HIV/AIDS [26], and the Global Health Cost Consortium provides guidance for estimating the unit costs of a health intervention [27] but there is no consensus on how to estimate the lifetime costs for managing HIV. Having a standardized methodology would ensure consistency within the literature, and ensure accurate and realistic lifetime costs for HIV disease globally.

As HIV is a complex disease, which requires lifelong management, it is important to use a decision model that captures the key relevant events in a patients' lifetime. The dominant decision model used was a Markov cohort model (32 of 75 studies) that classified health states based on $CD4^+$ cell count status, which seems appropriate, as long as readers are aware of the assumption of the memoryless property of Markov models [28]. The second most predominant type of model (31 of 75 studies) was the microsimulation models (most commonly the CEPAC model), which can account for the history of a simulated individual. Although choosing a Markov cohort model or microsimulation approach have different strengths and limitations [29], interestingly, we did not find significant differences in the estimation of lifetime costs according to the decision model used; but estimates using microsimulation models had less variation compared with cohort models. We found one study, which used a decision tree model [30]. Over the course of a lifetime, a person experiences numerous clinical conditions that may recur, as well as be uncertain in nature; so a decision tree might not be the right tool for interventions to treat for such conditions because of the complexity and inconvenience of representing all probable sequences of events over the entire course of a person's lifetime (or alternative time horizon).

To our knowledge, this is the first attempt to provide an overview of the large number of studies reporting lifetime cost for PWH. This allowed us to understand the strengths and limitations in the literature and to provide direction for future studies, for example, the need for disaggregated data by subpopulation. Our study should be read in light of some limitations. First, there is the potential for publication bias as we could not access any unpublished data from pharmaceutical companies, which were submitted to funding bodies that could contain economic models estimating lifetime costs. It is unclear the impact this would have on our findings. Second, there was large heterogeneity in the methods used for estimating lifetime costs, precluding the use of meta-analysis methods. Thus, we present the data using descriptive statistics instead. Third, the models included in our review do not take into account the treatment costs of secondary transmission averted by treating the index case – they only examine the lifetime cost of managing HIV in the index case. Therefore, although the cost of managing HIV may be relatively expensive compared with noncommunicable diseases, there is an added benefit of averting secondary transmissions when an index patient has undetectable HIV viral load; this is not presently captured within the metric of lifetime HIV costs. This additional benefit should be accounted for in economic evaluations of HIV programs.

In conclusion, we found variations in the estimation of lifetime costs of managing HIV, which could be accounted partly by country income level, study perspective and variations in cost items included. Although decision models have different strengths and limitations, lifetime costs were not sensitive to the decision model used. There was a paucity of studies that disaggregated lifetime costs by subpopulation and inconsistencies in the inclusion of comorbidity for the aging HIV population. There is a need for a standardized methodology to allow comparability of lifetime costs of HIV globally. We recommend future studies disaggregate data by subpopulation and suggest the inclusion of non-HIV-related costs associated with ageing and comorbidity

(at least as a sensitivity analysis), to determine a more accurate cost of managing HIV.

Acknowledgements

Authorship: J.J.O. designed the research study. J.J.O., H.T., K.S. and M.L. performed the research and analysed the data. H.T., K.S., M.L., E.C., C.F., F.T.P., J.J.O. wrote the article.

Funding: J.J.O., C.F.K. and E.P.F. are supported by the Australian National Health and Medical Research Council Fellowship grants (GNT1104781, GNT1172900 and GNT1172873, respectively).

Conflicts of interest

There are no conflicts of interest.

Meeting where data was presented: Australasian Sexual Health and HIV Conference 2020 (Virtual), 16–20 November 2020.

References

1. Palmer C. **HIV treatments and highly active antiretroviral therapy.** *Aust Prescr* 2003; **26**:59–61.
2. Peng S, Tafazzoli A, Dorman E, Rosenblatt L, Villasis-Keever A, Sorensen S. **Cost-effectiveness of DTG + ABC/3TC versus EFV/TDF/FTC for first-line treatment of HIV-1 in the United States.** *J Med Econ* 2015; **18**:763–776.
3. Nakagawa F, Miners A, Smith CJ, Simmons R, Lodwick RK, Cambiano V, *et al*. **Projected lifetime healthcare costs associated with HIV infection.** *PLoS One* 2015; **10**:e0125018.
4. Walensky RP, Paltiel AD, Losina E, Mercincavage LM, Schackman BR, Sax PE, *et al*. **The Survival Benefits of AIDS Treatment in the United States.** *J Infect Dis* 2006; **194**:11–19.
5. Braithwaite RS, Justice AC, Chang CC, Fusco JS, Raffanti SR, Wong JB, Roberts MS. **Estimating the proportion of patients infected with HIV who will die of comorbid diseases.** *Am J Med* 2005; **118**:890–898.
6. Ford N, Meintjes G, Vitoria M, Greene G, Chiller T. **The evolving role of CD4 cell counts in HIV care.** *Curr Opin HIV AIDS* 2017; **12**:123–128.
7. Organization WH. *Guideline on when to start antiretroviral therapy and on preexposure prophylaxis for HIV*.Geneva; 2015.
8. Schackman BR, Gebo KA, Walensky RP, Losina E, Muccio T, Sax PE, *et al*. **The lifetime cost of current human immunodeficiency virus care in the United States.** *Med Care* 2006; **44**:990–997.
9. Consortium GHC. Welcome to the Unit Cost Study Repository: Global Health Cost Consortium; 2020. Available at: https://ghcosting.org/pages/data/ucsr/app/. [Accessed 6 March 2021]
10. CHEERS Checklist - Items to include when reporting economic evaluations of health interventions 2013. Available at: https://www.equator-network.org/wp-content/uploads/2013/04/Revised-CHEERS-Checklist-Oct13.pdf. [Accessed 6 March 2021]
11. OFX. Historical Exchange Rates: UKForex Ltd; 2020 [cited 2020. Available at: https://www.ofx.com/en-gb/forex-news/historical-exchange-rates/. [Accessed 6 March 2021]
12. Fund IM. IMF Data - Access to Macroeconomic & Financial Data: International Monetary Fund; 2020 [updated 2020. Available at: https://data.imf.org/?sk=4C514D48-B6BA-49ED-8AB9-52B0C1A0179B&sId=1409151240976. [Accessed 6 March 2021]
13. Rissel C, Heywood W, de Visser RO, Simpson JM, Grulich AE, Badcock PB, *et al*. **First vaginal intercourse and oral sex among a representative sample of Australian adults: the Second Australian Study of Health and Relationships.** *Sex Health* 2014; **11**:406–415.
14. Hyle EP, Jani IV, Lehe J, Su AE, Wood R, Quevedo J, *et al*. **The clinical and economic impact of point-of-care CD4 testing in mozambique and other resource-limited settings: a cost-effectiveness analysis.** *PLoS Med* 2014; **11**:e1001725.
15. Uthman RT, Sutton AJ, Jackson LJ, Uthman OA. **Does directly administered antiretroviral therapy represent good value for money in sub-Saharan Africa? A cost-utility and value of information analysis.** *PLoS One* 2018; **13**:e0191465.
16. Sempa J, Ssennono M, Kuznik A, Lamorde M, Sowinski S, Semeere A, *et al*. **Cost-effectiveness of early initiation of first-line combination antiretroviral therapy in Uganda.** *BMC Public Health* 2012; **12**:736.
17. Triant VA. **Cardiovascular disease and HIV infection.** *Curr HIV/AIDS Rep* 2013; **10**:199–206.
18. Moreno Guillen S, Losa Garcia JE, Berenguer Berenguer J, Martinez Sesmero JM, Cenoz Gomis S, Graefenhain R, *et al*. **Cost-utility analysis of the fixed-dose combination of dolutegravir/abacavir/lamivudine as initial treatment of HIV+ patients in Spain.** *Farm Hosp* 2017; **41**:601–610.
19. Restelli U, Rizzardini G, Antinori A, Lazzarin A, Bonfanti M, Bonfanti P, *et al*. **Cost-effectiveness analysis of dolutegravir plus backbone compared with raltegravir plus backbone, darunavir plus ritonavir plus backbone and efavirenz/tenofovir/emtricitabine in treatment naive and experienced HIV-positive patients.** *Ther Clin Risk Manage* 2017; **13**:787–797.
20. Schackman BR, Fleishman JA, Su AE, Berkowitz BK, Moore RD, Walensky RP, *et al*. **The lifetime medical cost savings from preventing HIV in the United States.** *Med Care* 2015; **53**:293–301.
21. Brogan AJ, Talbird SE, Davis AE, Wild L, Flanagan D. **Is increased screening and early antiretroviral treatment for HIV-1 worth the investment? An analysis of the public health and economic impact of improvement in the UK.** *HIV Med* 2019; **20**:668–680.
22. Ong KJ, van Hoek AJ, Harris RJ, Figueroa J, Waters L, Chau C, *et al*. **HIV care cost in England: a cross-sectional analysis of antiretroviral treatment and the impact of generic introduction.** *HIV Med* 2019; **20**:377–391.
23. van Baal P, Morton A, Meltzer D, Brouwer W. **Future unrelated medical costs need to be considered in cost effectiveness analysis.** *Eur J Health Econ* 2019; **20**:1–5.
24. Kumaranayake LP, J. Goodman, H. Mills, A. Walker, D. Costing Guidelines for HIV Prevention Strategies Geneva, Switzerland: UNAIDS; 2000. Available at: https://data.unaids.org/publications/irc-pub05/jc412-costguidel_en.pdf. [Accessed 6 March 2021]
25. Rosen JPW, Bollinger L. Guidelines for costing of social and behavior change health interventions. Washington DC: Population Council: Breakthrough RESEARCH; 2019.Available at: https://breakthroughactionandresearch.org/wp-content/uploads/2019/10/guidelines-for-costing-sbc-interventions.pdf. [Accessed 6 March 2021]
26. Vassall A. Reference case for estimating the costs of global health services and interventions: Global Health Cost Consortium; 2017. Available at: https://ghcosting.org/pages/standards/reference_case. [Accessed 6 March 2021]
27. Briggs A, Sculpher M. **An introduction to Markov modelling for economic evaluation.** *Pharmacoeconomics* 1998; **13**:397–409.
28. Kuehne F, Chancellor J, Mollon P, Weinstein M, Powderly W. **Microsimulation or cohort modelling? A comparative case study in HIV infection**. *iHEA 6th World Congress on Health Economics*, Copenhagen, 8-11 July 2007. Available at: https://www.researchgate.net/publication/228210404_Microsimulation_or_Cohort_Modelling_A_Comparative_Case_Study_in_HIV_Infection [Accessed 23 March 2021]
29. Simpson KN, Pei PP, Moeller J, Baran RW, Dietz B, Woodward W, *et al*. **Lopinavir/ritonavir versus darunavir plus ritonavir for HIV infection: a cost-effectiveness analysis for the United States.** *Pharmacoeconomics* 2013; **31**:427–444.
30. Peng S, Tafazzoli A, Dorman E, Rosenblatt L, Villasis-Keever A, Sorensen S. **Cost-effectiveness of DTG + ABC/3TC versus EFV/TDF/FTC for first-line treatment of HIV-1 in the United States.** *J Med Econ* 2015; **18**:763–776.