Using mathematical models for health economic analyses

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Outline

- Introduction to modeling
- Infectious disease modeling
  - Introduction; R0
- How models can be used to estimate health outcomes
  - Example: Potential impact of ART for prevention
  - What study data can you use to parameterize models
- Decision tree primer
- When to use which model

An introduction to Mathematical Models

- Framework for understanding and communicating infectious disease
- Explicit assumptions help delineate which parameters are based on evidence
- Quantitative or qualitative results are compared with observed or experimental data
- Validated models can be used to estimate the potential impact of interventions (e.g. ART for prevention)

Garnett, G. P. (2002). Sex Transm Infect 78(1): 7-12.

Models in health economic analyses

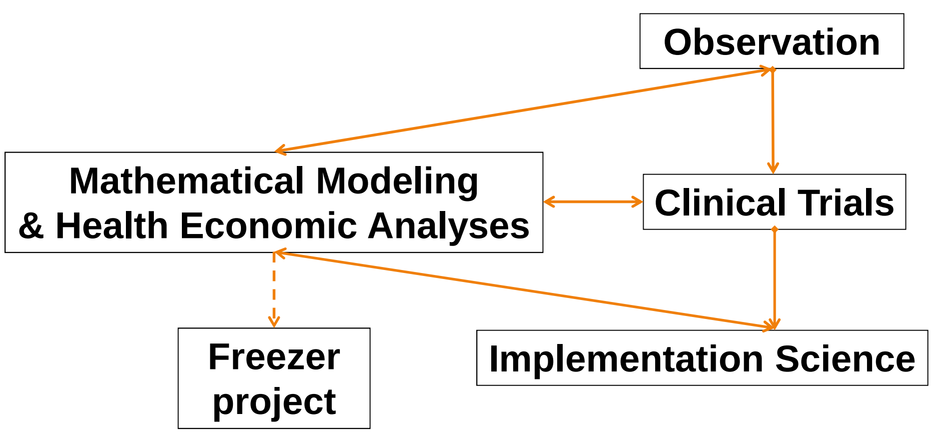
- Used to structure the economic question and compare all relevant alternatives
- Extrapolate beyond observed data
- Link intermediate and final endpoints
- Generalize results to other settings/patient groups
- Synthesize evidence to simulate comparisons where RCTs don't exist
- Indicate the need for further research

HERC short course, Oxford, 2012

Types of models

- Static models
- Dynamic models
  - Force of infection can change over time
  - Includes herd immunity
- Both static and dynamic models can be either deterministic or stochastic (constrained random variables)
- Choice of model depends on scientific question

Where do models fit in the path from discovery to implementation?



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The basic and effective reproductive numbers

R_0 The Basic Reproductive Number - The number of new infections caused by one infection in an entirely susceptible population

R_t The Effective Reproductive Number - The number of new infections caused by one infection at a given time

$$R_0 = D \cdot C \cdot \beta$$

- D: **Mean length of time infectious**
- C: **Rate at which sexual contact occurs**
- β: **Likelihood of transmission on a sexual contact**

$$R_t = R_0 \cdot x$$

- x: **Proportion of contacts susceptible -Vaccination**

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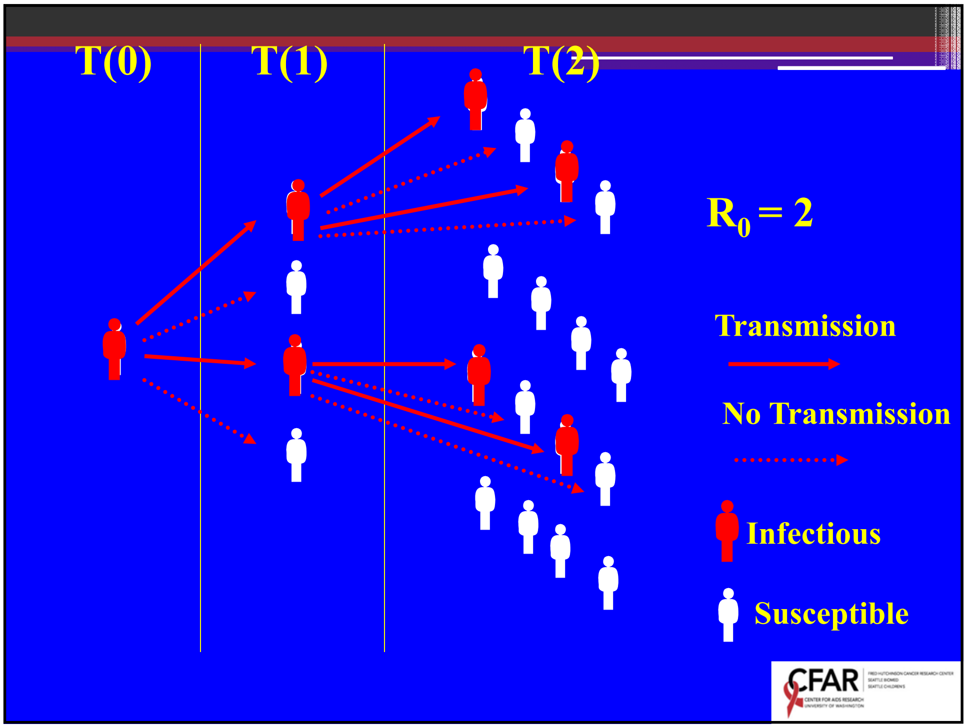

T(0)
T(1)
T(2)
R0 = 2
Transmission
No Transmission
Infectious
Susceptible
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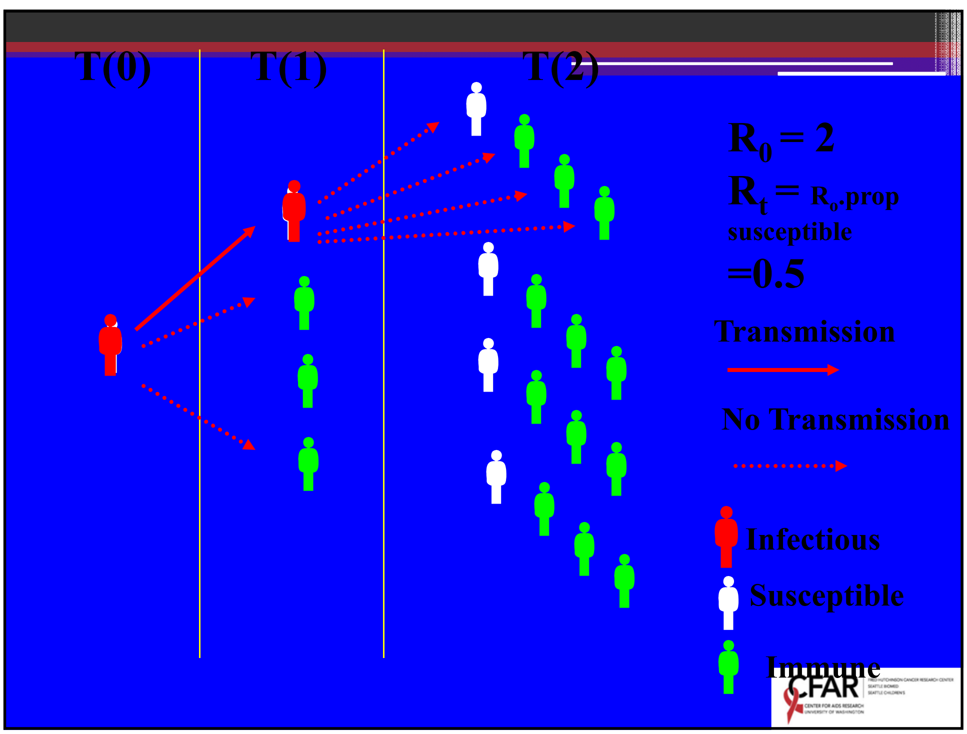

T(0)
T(1)
T(2)
R0 = 2
Rt = Ro.prop susceptible =0.5
Transmission
No Transmission
Infectious
Susceptible
Immune
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Models demonstrate potential impact of interventions

Universal voluntary HIV testing with immediate antiretroviral therapy as a strategy for elimination of HIV transmission: a mathematical model

Reuben M Granich, Charles F Gilks, Christopher Dye, Kevin M De Cock, Brian G Williams

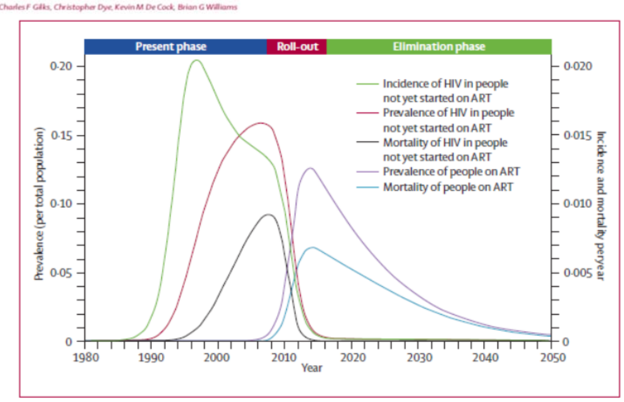

***Figure 5:* Time trends resulting from application of universal voluntary HIV testing and immediate ART strategy for people who test HIV positive, in combination with other adult prevention interventions that reduce incidence by 40%**

The programme implementation start date is arbitrarily set as immediate, with coverage increasing logistically to 50% by 2012 and 90% by 2016.

Models can estimate potential impact of health programs

Treating our way out of the HIV pandemic: could we, would we, should we? **Geoffrey P Garnett, Rebecca F Baggaley*

- "HIV prevention is easy in theory – the practice is hard."
- Need intensive HIV testing and robust linkages to care, even among people who feel well
- Strategies need to be effective and cost-effective

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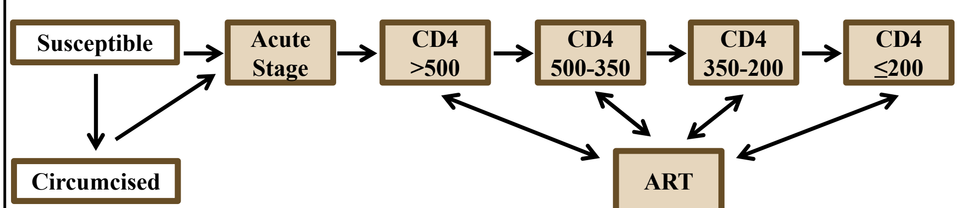
ART Model: Structure

- Mathematical model to evaluate ART scale-up



- Realistic assumptions regarding testing and ART coverage

Ying, R, et. al. Lancet HIV

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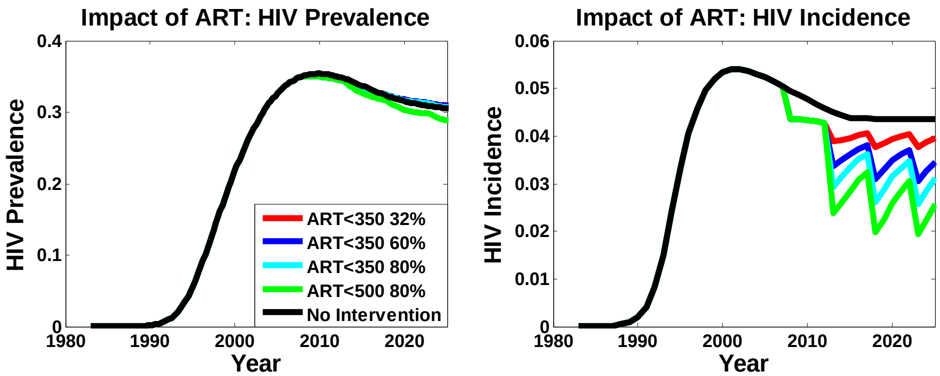
ART Model: Results



Roger Ying, ISSTDR 2013

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Cost-effectiveness

	Change in HIV incidence*	Change in HIV prevalence*	ICER per infection averted	ICER per death averted	ICER per QALY gained
Home HTC: ART for 48% of all HIV-positive people	–33·8%	–4·7%	Dominated†	$3290	$860
Home HTC plus CD4: additional ART for CD4 count 350–500 cells per µL	–40·6%	–6·7%	Dominated†	$4070	$900
Home HTC plus high viral load: additional ART for viral load >10 000 copies per mL	–51·6%	–12·1%	$2960	$5020	$1710

Results are shown for a 10 year time period of 2015–25 with a 6% annual dropout from ART care. Costs and effectiveness are discounted by 3% annually. ICER=incremental cost-effectiveness ratio. QALY=quality-adjusted life-year. HTC=home HIV testing and counselling. ART=antiretroviral therapy. *Relative to a "no ART" counterfactual. †A dominated strategy is more costly and less effective or more costly and less cost-effective than a combination of other interventions.

Table 3: **Effectiveness and cost-effectiveness of ART uptake from home HTC with varying ART initiation guidelines**

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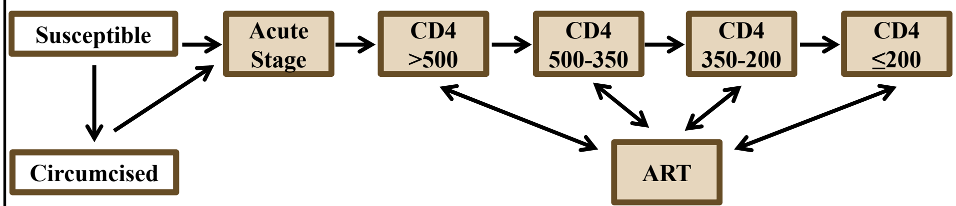
What data do we need for models?

- Demographics
- Mixing patterns
- Natural history
- Transmission probability
- Factors that change susceptibility
- Factors that change infectiousness
- Effectiveness of interventions
- Engagement in health care

What study data can you use to parameterize models?



- Country specific demographics
- Distribution of CD4 count and viral load
- Intervention (including treatment) coverage and efficacy
- Factors that impact on HIV transmission: viral load, gender, circumcision status, co-infection status

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What cost-effectiveness research question are you interested in?

- What is:
  - the intervention?
  - the comparator?
- What outcome measures are appropriate?
- How will you evaluate intervention benefits?
- How will you measure program costs?
- Will you adjust for changes in direct medical costs resulting from the intervention?
- Can you sketch a tree that portrays the consequences of the intervention and its comparator?

James Kahn, UCSF

CEA Example A – Research Questions

Cost-effectiveness of a mobile camp for adult male circumcision in rural Zambia

- *RQ1:* What is the cost of delivering adult male circumcision per 100 clients circumcised in this mobile camp, compared with no circumcision?
- *RQ2:* How many HIV infections and disability-adjusted life years (DALYs) will be averted per 100 individuals circumcised, in this population, over twenty years?
- *RQ3:* What is the incremental cost per DALY averted in this population?

CEA Example A – RQ1

Cost-effectiveness of a mobile camp for adult male circumcision in rural Zambia

- *RQ1:* What is the cost of delivering adult male circumcision per 100 clients circumcised in this mobile camp, compared with no circumcision?

Brief methods: Review program financial and service records for 12-month period, to quantify resources used, associated costs, and clients served.

CEA Example A – RQ2

Cost-effectiveness of a mobile camp for adult male circumcision in rural Zambia

- *RQ2:* How many HIV infections and disability-adjusted life years (DALYs) will be averted per 100 individuals circumcised, in this population, over twenty years?

Brief methods: Build a decision analysis model incorporating HIV epidemic projections with and without circumcision.

CEA Example A – RQ3

Cost-effectiveness of a mobile camp for adult male circumcision in rural Zambia

- *RQ3:* What is the incremental cost per DALY averted in this population?

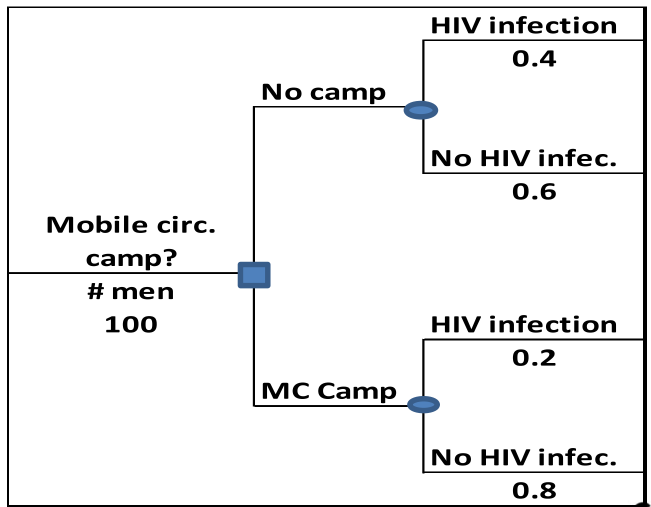
Brief methods: Calculate the incremental cost-effectiveness ratio (ICER), with net costs (program costs adjusted for changes in future HIV medical care costs) in the numerator, and DALYs averted in the denominator.

Introducing decision trees

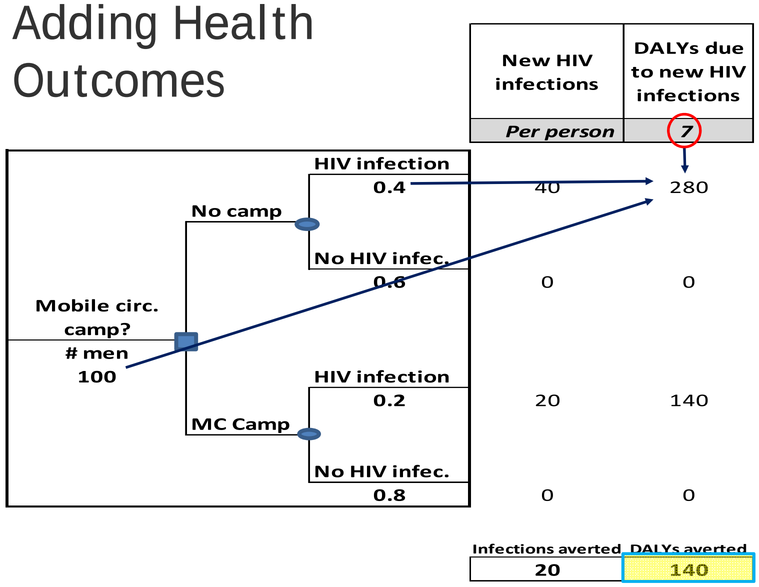
- Graphically portrays the decision & its effects
- Three major components:
  - The action options (the decision) under consideration.
  - The probabilistic mix of consequences for each option.
  - The value of health and cost outcomes for each consequence.
- Calculates the "expected value" for health and cost outcomes for each option, as the weighted mean for the mix of consequences.

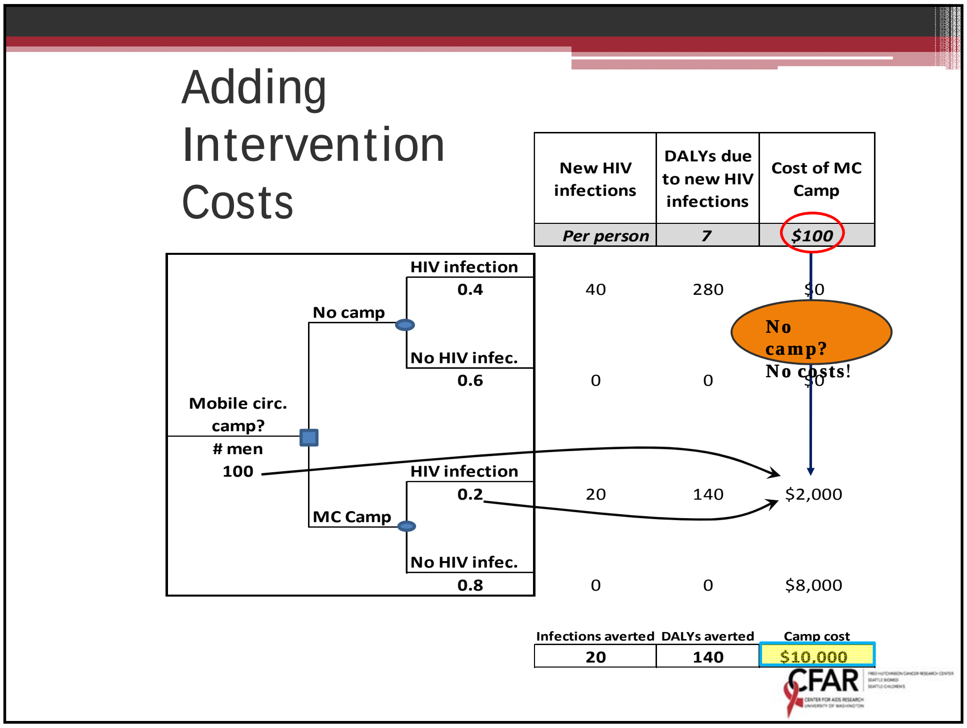
A Basic Decision Tree

Voluntary adult male circumcision for HIV prevention in rural Kenya



Adding Health Outcomes




Adding Intervention Costs
New HIV infections
DALYs due to new HIV infections
Cost of MC Camp
Per person
7
$100
HIV infection
0.4
No camp
No HIV infec.
0.6
Mobile circ. camp?
men
100
HIV infection
0.2
MC Camp
No HIV infec.
0.8
40
280
$0
0
0
$0
No camp? No costs!
20
140
$2,000
0
0
$8,000
Infections averted
DALYs averted
Camp cost
20
140
$10,000
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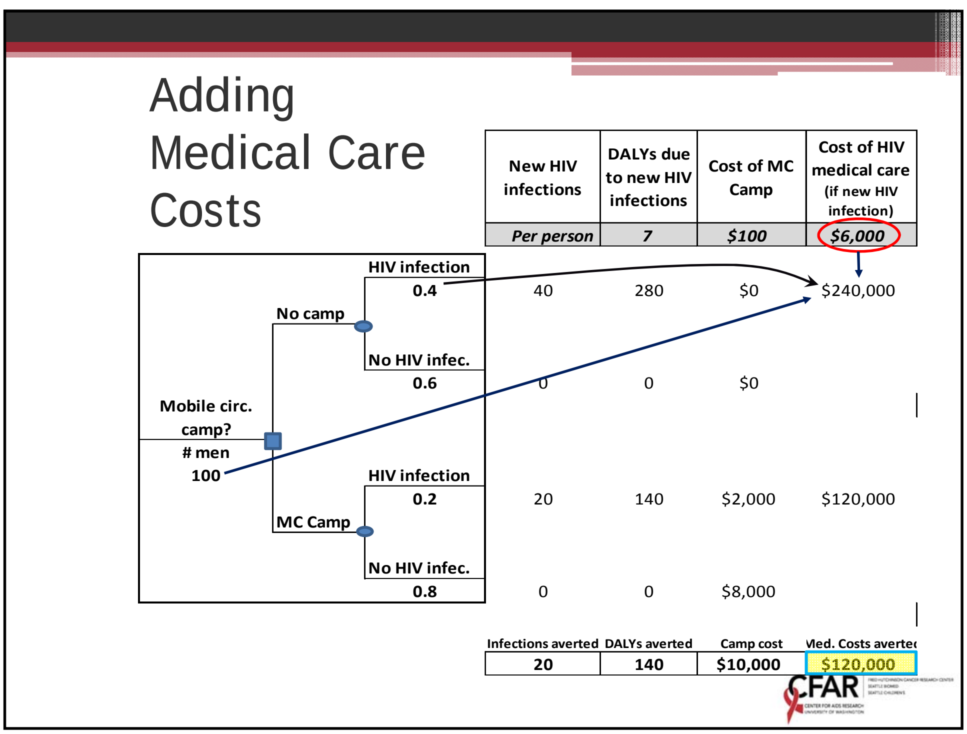
Adding Medical Care Costs
New HIV infections
DALYs due to new HIV infections
Cost of MC Camp
Cost of HIV medical care (if new HIV infection)
Per person
7
$100
$6,000
HIV infection
0.4
No camp
No HIV infec.
0.6
Mobile circ. camp?
men
100
HIV infection
0.2
MC Camp
No HIV infec.
0.8
40
280
$0
$240,000
0
0
$0
20
140
$2,000
$120,000
0
0
$8,000
Infections averted
DALYs averted
Camp cost
Med. Costs averted
20
140
$10,000
$120,000
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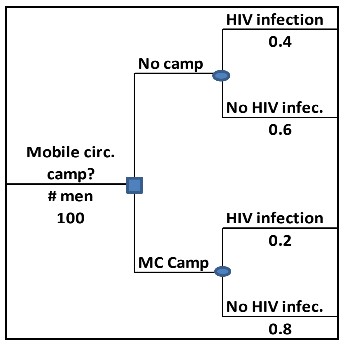
And Finally – Results!

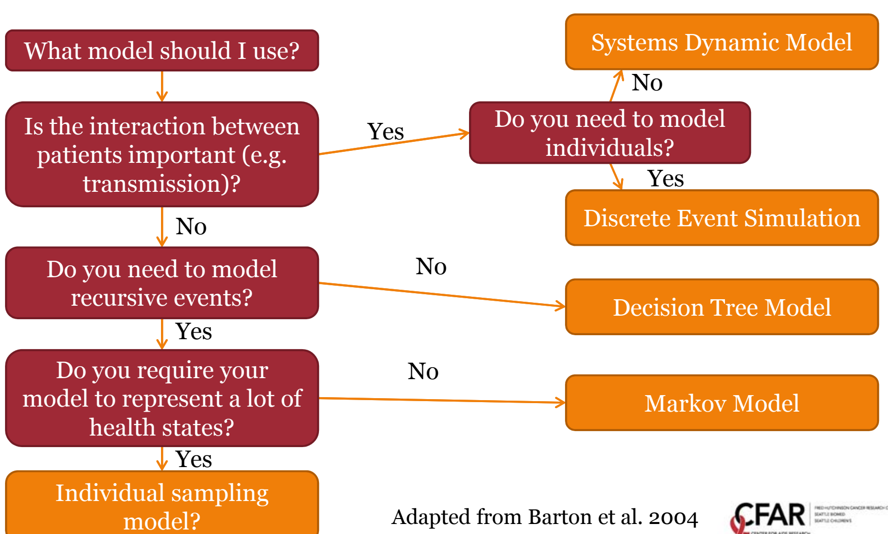


	New HIV infections	DALYs due to new HIV infections	Cost of MC Camp	Cost of HIV medical care (if new HIV infection)	Total cost
Per person	*7*	*$100*	*$6,000*		
No camp – HIV infection (0.4)	40	280	$0	$240,000	$240,000
No camp – No HIV infec. (0.6)	0	0	$0		$0
No camp total					$240,000
MC Camp – HIV infection (0.2)	20	140	$2,000	$120,000	$122,000
MC Camp – No HIV infec. (0.8)	0	0	$8,000		$8,000
MC Camp total					$130,000

Infections averted	DALYs averted	Camp cost	Med. Costs averted	Net costs
20	140	$10,000	$120,000	($110,000)

ICER ($/DALY averted): Dominant

How to choose the appropriate model for health outcomes



Adapted from Barton et al. 2004

Summary

- Infectious disease modeling is a useful tool
- Modeling can be used to estimate health outcomes
- Study data can be used to parameterize models
- Consulting with a health economist and/or modeler will help with choosing the most appropriate model to answer your question

Thank you

- CFAR website: http://depts.washington.edu/cfar/
- Ruanne Barnabas: rbarnaba@uw.edu

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