COST-EFFECTIVENESS OF ADULT HEARING SCREENING IN THE US

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DISCLOSURES

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- No conflicts of interest

PRESENTATION OBJECTIVES

1. Decision modeling is a quantitative method that can inform health policy
2. Hearing loss is prevalent, undertreated, and significantly impacts quality of life, physical, and mental health
3. Yearly hearing screening of persons 55+ is likely a cost-effective intervention in the US

AGENDA:

1. CEA and Decision Analysis
2. Hearing loss in the United States
3. DeciBHAL development
4. Adult hearing screening CEA

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DECISION ANALYSIS

Decision analysis is a quantitative, probabilistic method for modeling problems under situations of uncertainty

Goal: clarify dynamics and trade-offs involved in selecting one strategy from a set of alternatives

Formal decision analysis is most helpful for important, unique, complex, non-urgent, and high-stakes decisions

COST-EFFECTIVENESS ANALYSIS

- Cost-effectiveness analysis (CEA) is a methodology for evaluating the tradeoffs between health benefits and costs
  - Meant to aid in decision making
- Costs and measures of effectiveness are collected for each alternative

Incremental Cost-effectiveness Ratio (ICER):

$$\frac{Cost_{new} - Cost_{old}}{Benefit_{new} - Benefit_{old}}$$

COST-EFFECTIVENESS ANALYSIS

- Cost-effectiveness analy (CEA) is a met dology eval g the tradeoffs betwee sts
  - M g

CE /= cheap!

- Costs ar d mea res o ffectiveness are collected for ea h alternative

Incremental Cost-effectiveness Ratio (ICER):

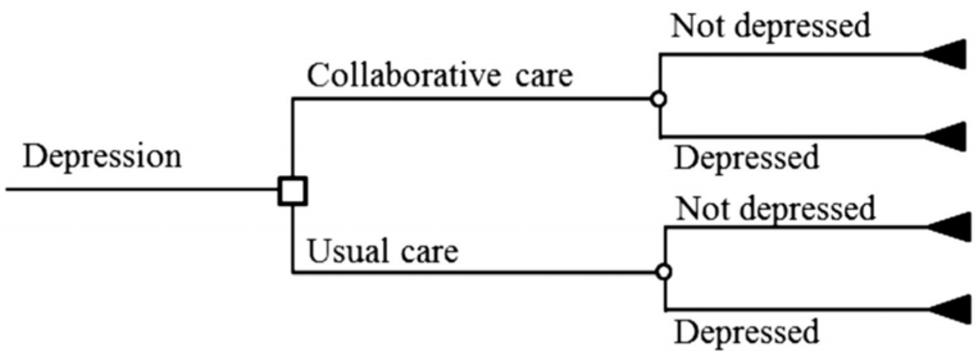
$$\frac{Cost_{new} - Cost_{old}}{Benefit_{new} - Benefit_{old}}$$

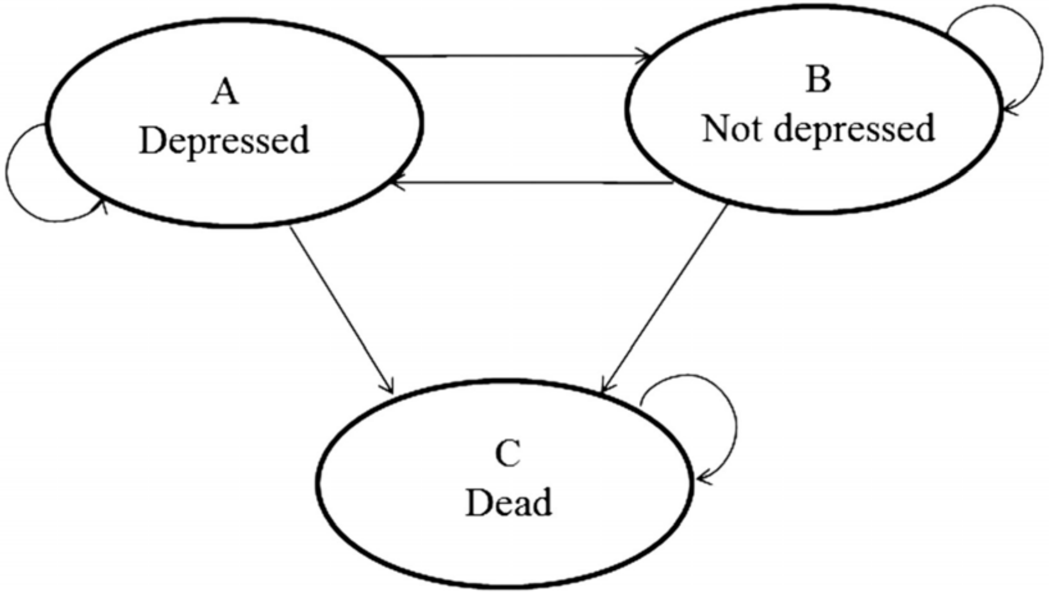
DECISION MODELS

- Schematic representation of all the clinically important outcomes of a decision
  - Computes average outcomes (costs, quality-adjusted life-years, etc.) for alternatives
- Necessarily a simplification of reality: requires assumptions
- Require parameterization from data sources (published or unpublished)

TYPES OF DECISION MODELS

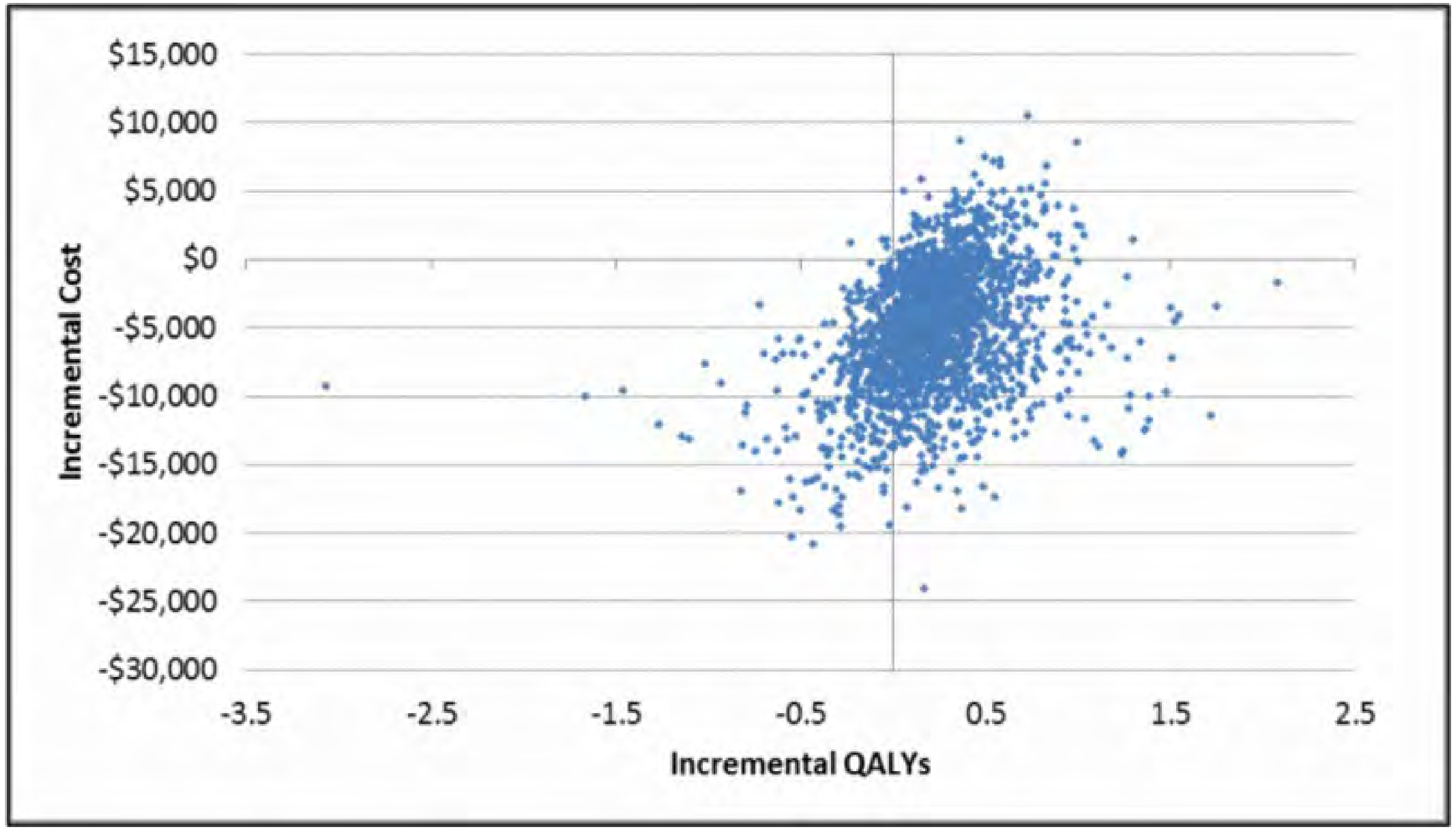
- Tree Diagram
  - Most simple, underlies many other models
- Markov Cohort Model
  - Transition between health states, incorporates *time*
- Microsimulation (Monte Carlo) Model
  - Similar to Markov, but each patient is simulated individually
- Discrete Event Simulation
  - More flexible use of time





SENSITIVITY ANALYSIS

- Critical to a decision analysis
- Deterministic: change model input parameters to pre-determined values
  - One-way (change cost to low/high values)
  - Multi-way (change cost to high and efficacy to low, “worst case”)
- Probabilistic: assign distributions to model inputs; each “run” pulls from distributions independently

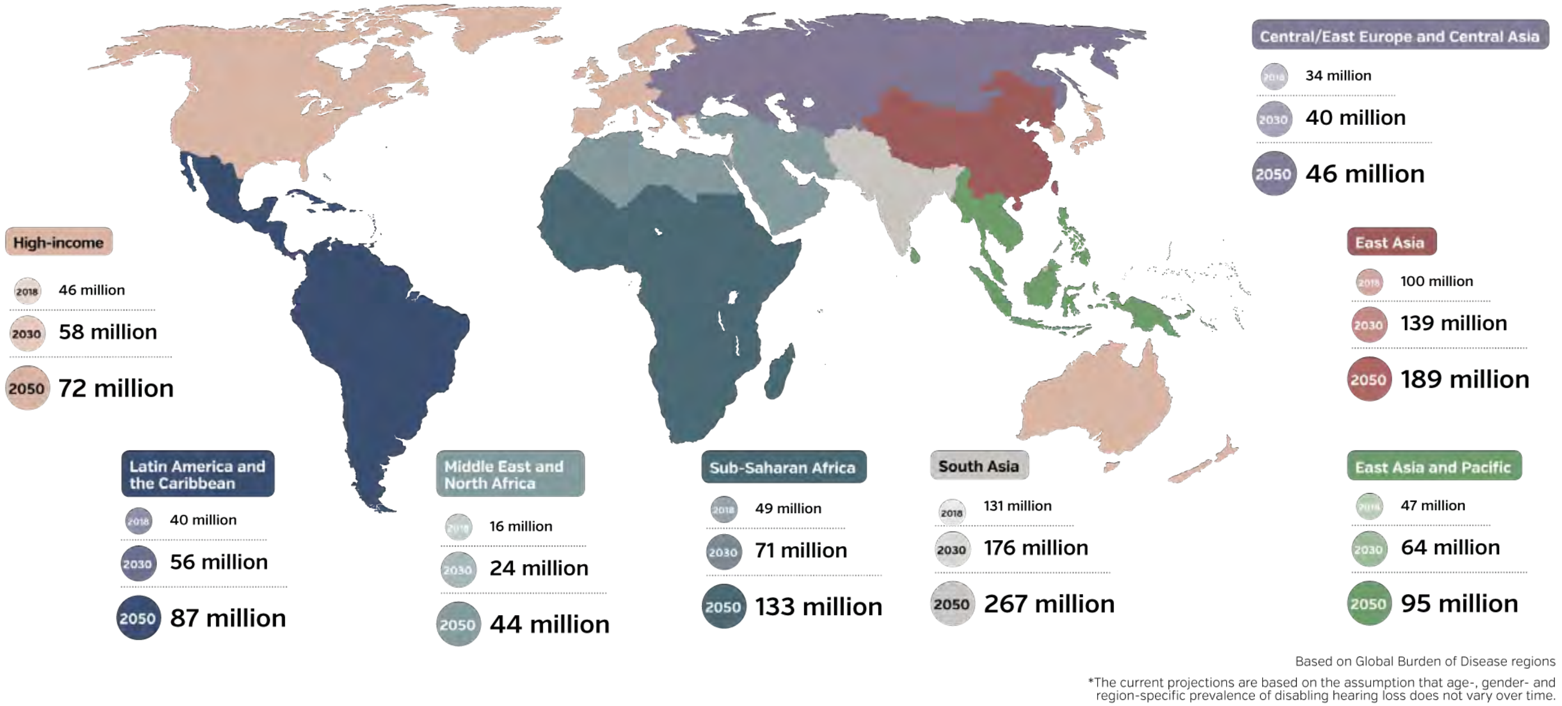


AGENDA:

1. CEA and Decision Analysis
2. Introduction
3. DeciBHAL development
4. Adult hearing screening CEA

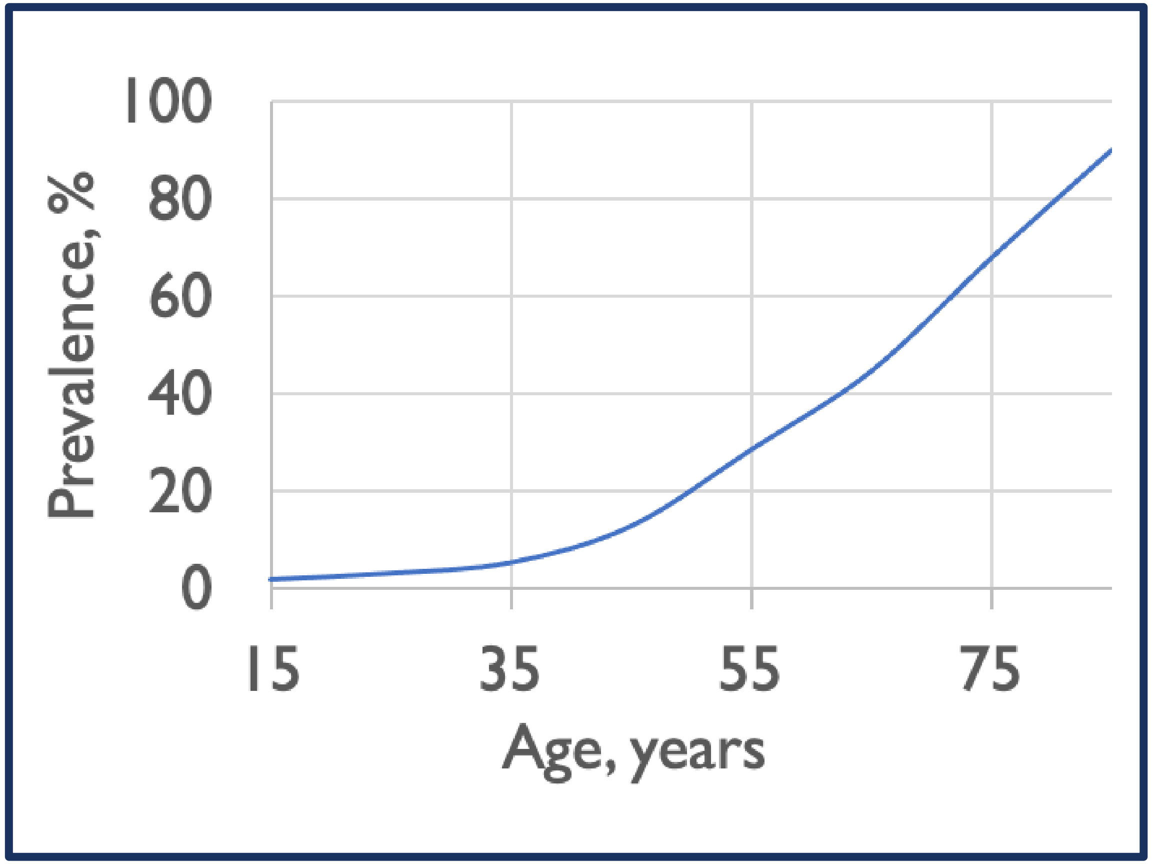
BACKGROUND

- Hearing loss is the 4th leading cause of years lived with disability worldwide[1]
- Significant barrier to human communication and fulfillment
- Associated with increased falls, hospitalization and dementia risk[1]
- Economic burden >$700B/year[2]



[1]Wilson 2017, [2]WHO 2021

HEARING LOSS IN THE US



- 1/3 of US adults over the age of 60 have hearing loss
- 80% of US adults with hearing loss do not receive beneficial treatment
- Improves quality of life utility by 10-15%
- RR of incidence dementia 1.2-1.4
- Recent RCT showed HAs slowed cognitive decline in those most at risk

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SYSTEMATIC REVIEW OF MODELS

- Large body of literature with many high-quality studies identified
- Gaps remain in evaluation of hearing health care interventions in LMIC, across the lifespan and etiologies
- Uncertainty around utility values and how to best incorporate indirect economic effects

- Next steps for Commission to synthesize high quality modeling frameworks to assess optimal global scale-up strategies

OBJECTIVE

Development and validation of DeciBHAL-US: A novel microsimulation model of hearing loss across the lifespan in the United States

Ethan D. Borre,[a,b] Evan R. Myers,[c] Judy R. Dubno,[d] Gerard M. O'Donoghue,[e] Mohamed M. Diab,[f] Susan D. Emmett,[f,g] James E. Saunders,[h] Carolina Der,[i] Catherine M. McMahon,[j] Danah Younis,[b] Howard W. Francis,[g] Debara L. Tucci,[k] Blake S. Wilson,[f,g,l,m] Osondu Ogbuoji,[b,f,n] and Gillian D. Sanders Schmidler[a,b,o,*]

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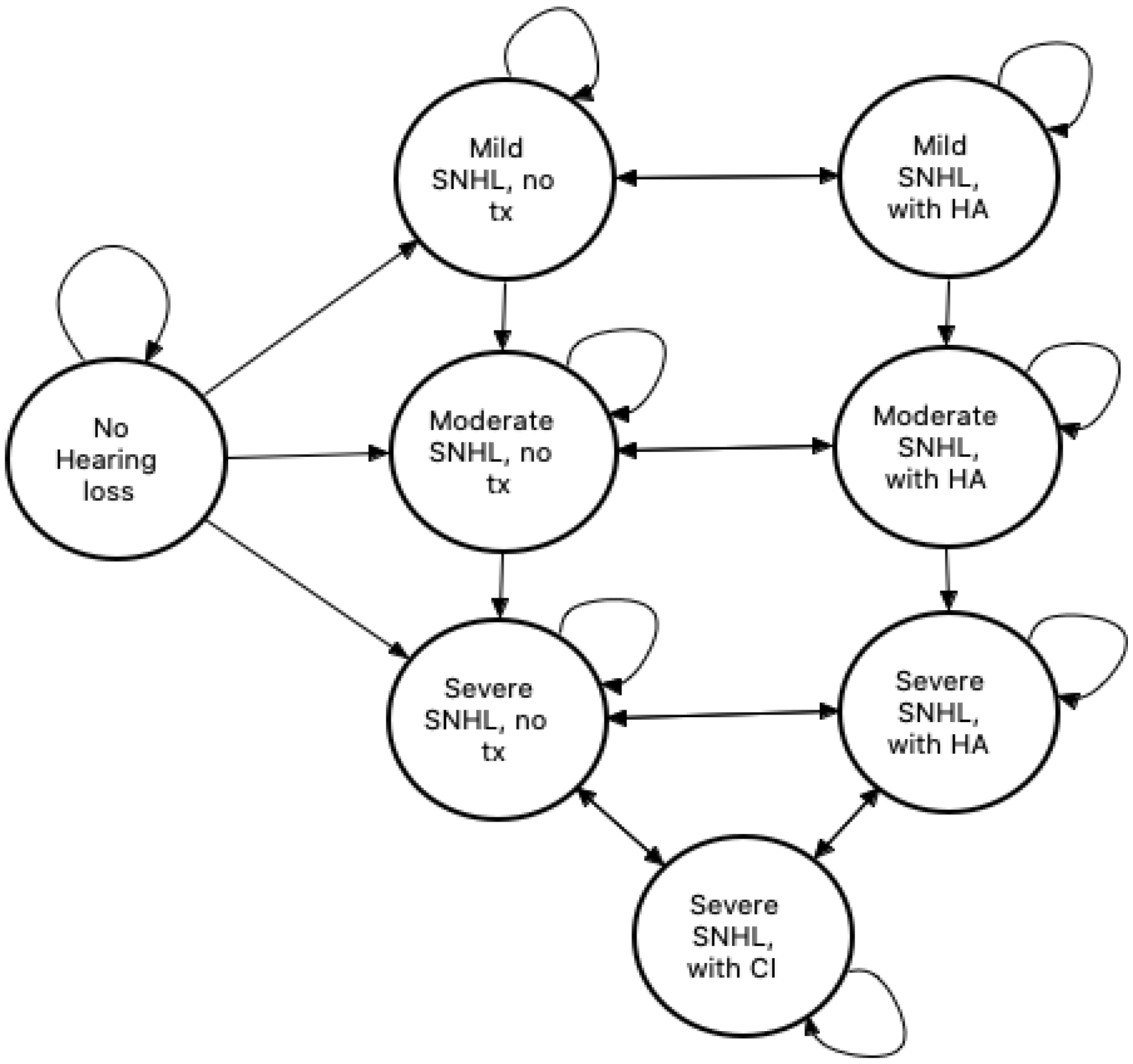
To develop and validate a decision modeling framework of hearing loss natural history, prevention, diagnosis, and treatment throughout the lifespan in the United States.

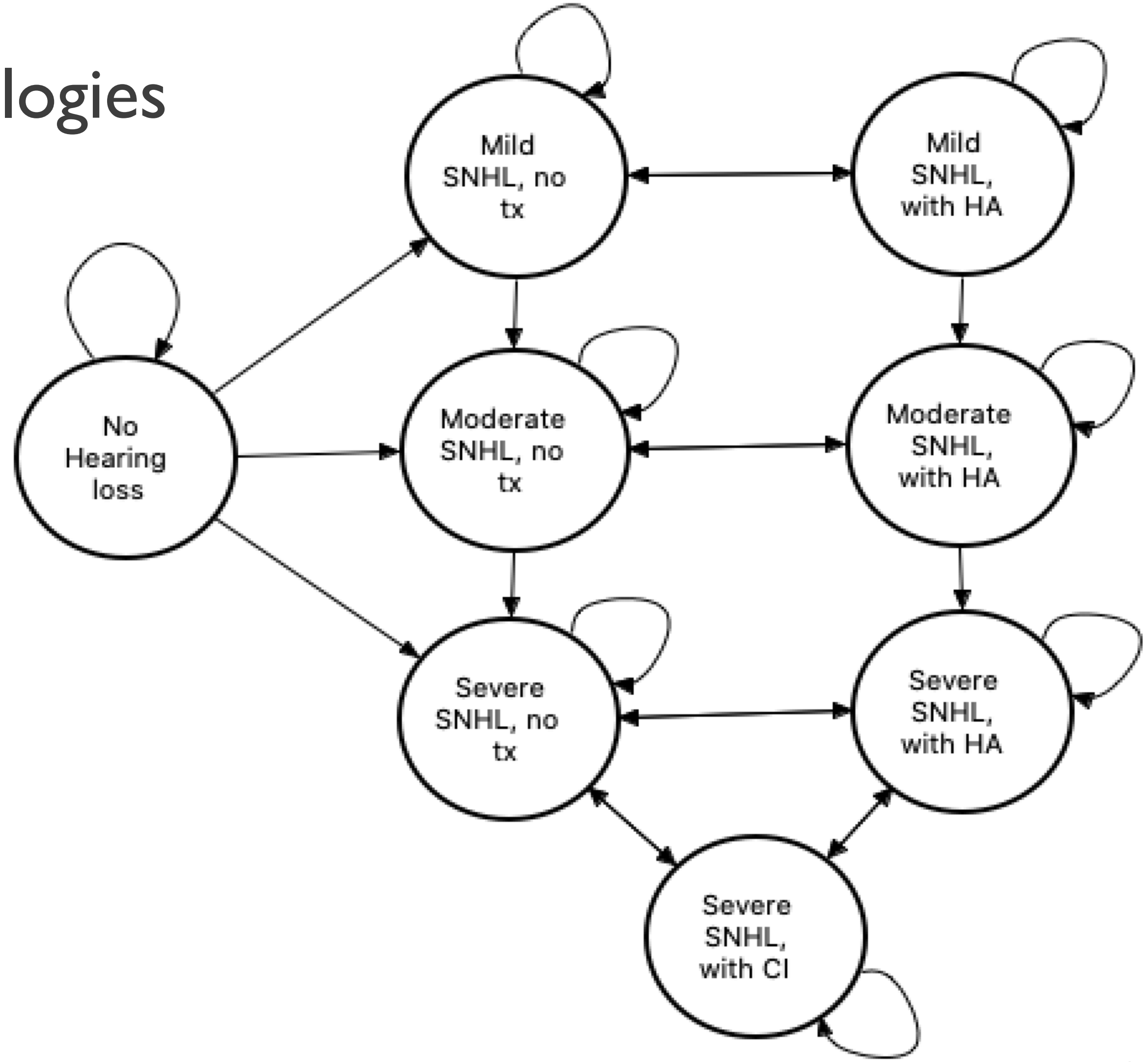
DECISION MODELING FRAMEWORK

- Lancet Commission informed and reviewed model structure
- Markov microsimulation model health states:
  - Presence of hearing loss
  - Type of hearing loss (SNHL vs. CHL)
  - Treatment modality (or none)
  - Pre/post-lingual loss
- Patient age and hearing level is tracked



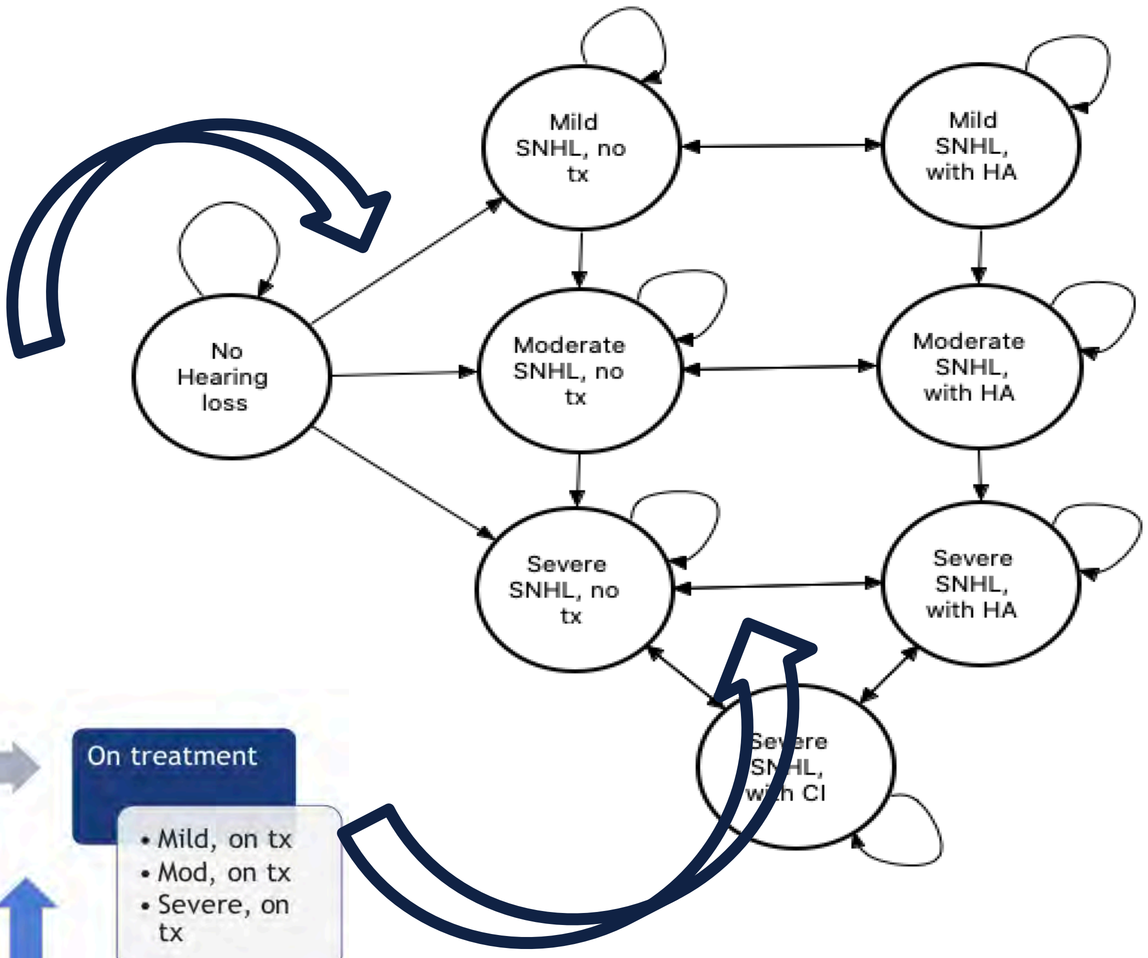
DECISION MODELING FRAMEWORK, SNHL

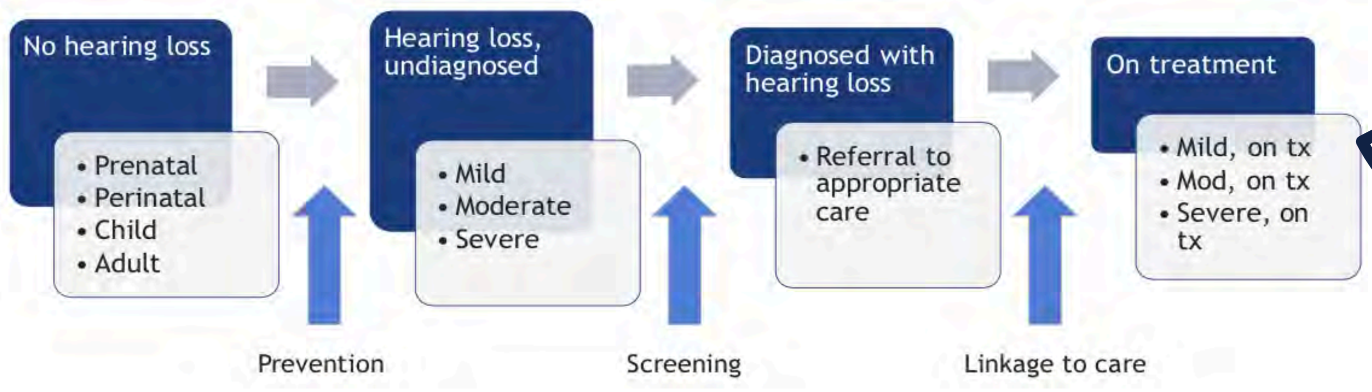
- Hearing loss is a symptom of many etiologies
  - Sensorineural hearing loss (SNHL)
  - Conductive hearing loss (CHL)
- SNHL: nerve-related hearing loss
- Simulated patients experience yearly probabilities of
  - Acquiring SNHL
  - Worsening of SNHL severity
  - Going on or off treatment (HA or CI)



DECIBHAL OVERVIEW

- Yearly transition probabilities are based on
  - age-specific incidence of hearing loss
  - hearing loss cascade of care





MODEL INPUTS, I

- Incidence of bilateral SNHL derived from published NHANES prevalence data[1]
  - Proportion CHL
  - M/F risk ratios
- After age 35, SNHL decline occurs at mean 1.05 dB/year (SD=0.4)[2]

Variable	Value	
Bilateral SNHL probability, yearly, %	Males	Females
Age 0y	0.100	0.100
Ages 1-15y	0.004	0.004
Ages 16-25y	0.024	0.023
Ages 26-35y	0.220	0.216
Ages 36-45y	0.762	0.057
Ages 46-55y	1.216	0.360
Ages 56-65y	2.334	1.251
Ages 66-75y	5.385	3.827
Ages 76+y	10.422	9.168

[1]Goman 2016, [2]Lee 2005

MODEL INPUTS, 2

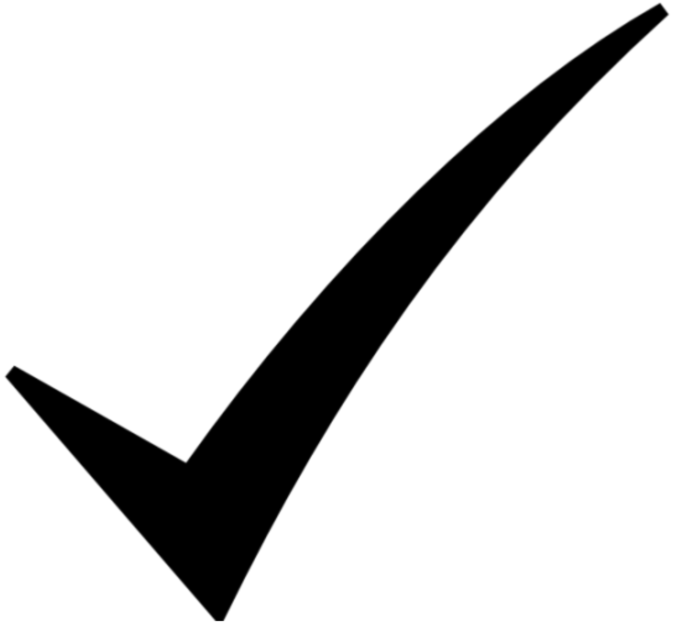
- Yearly probability of HA uptake derived from mean time to first HA (9 years)[1]
- Yearly probability of HA discontinuation 13-4% varying with time period of use[2,3]

Variable	Value	
Yearly probability of HA uptake, %*	PTA < 40dB	PTA ≥ 40 dB
Age 0y	75.95	75.95
Ages 1-5y	18.94	18.94
Ages 19-55y	0.54	2.35
Age 65y	0.51	4.60
Age 75y	0.60	8.14
Age 85y	0.71	7.20

[1]Simpson 2019, [2]Takahashi 2007, [3]Kochkin 2010

INTERNAL AND EXTERNAL VALIDATION

- Followed the AdVISHE framework[1]
- Internal validation
  - Model code review, extreme value testing, patient trace files
- External validation
  - Compared model-projected results to published estimates
  - Considered coefficient of variance of the root mean square error (CV-RMSE) ≤ 15% adequate model fit



[1]Vemer 2016

PREVALENCE OF SNHL

- We compared model projected estimates at each decile to adjusted NHANES estimates[1]
- CV-RMSE= 4.9% for males

	Bilateral SNHL Prevalence, Males	
Age	Model Outcome, %	NHANES, % (95% CI*)
15	0.13	0.16 (0.07-0.28)
25	0.38	0.39 (0.0-0.97)
35	2.4	2.5 (0.2-3.1)
45	9.9	9.7 (6.4-13.6)
55	20.0	20.3 (15.1-25.9)
65	36.7	37.2 (31.2-43.9)
75	64.4	66.5 (60.5-73.7)
85	89.7	86.4 (83.7-90.9)

[1]Goman 2016

PREVALENCE OF SNHL

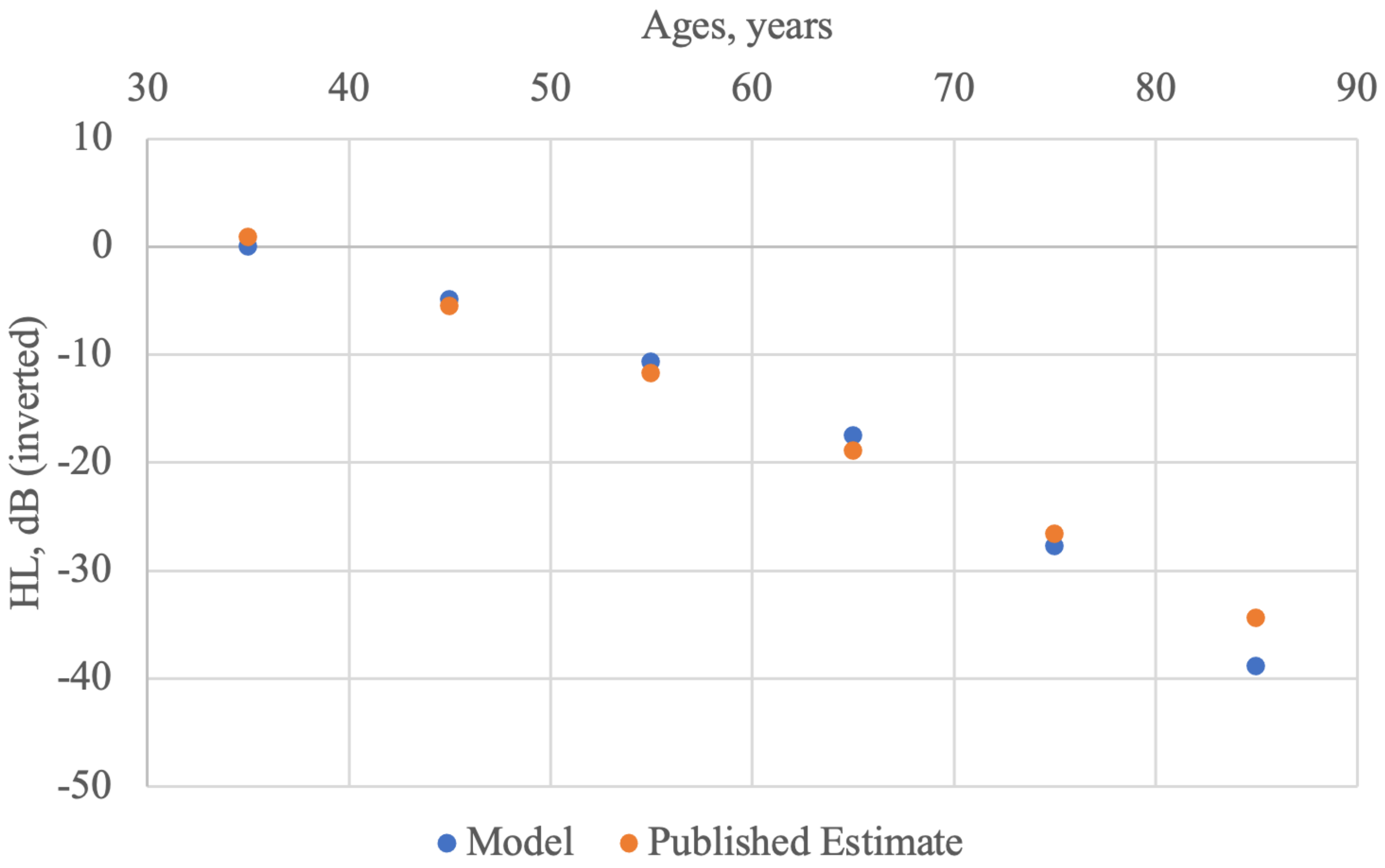
- We compared model projected estimates at each decile to adjusted NHANES estimates[1]
- CV-RMSE= 4.9% for males
- CV-RMSE = 5.7% for females

	Bilateral SNHL Prevalence, Males		Bilateral SNHL Prevalence, Females	
Age	Model Outcome, %	NHANES, % (95% CI*)	Model Outcome, %	NHANES, % (95% CI*)
15	0.13	0.16 (0.07-0.28)	0.08	0.16 (0.07-0.28)
25	0.38	0.39 (0.0-0.97)	0.31	0.39 (0.0-0.97)
35	2.4	2.5 (0.2-3.1)	2.4	2.5 (0.2-3.1)
45	9.9	9.7 (6.4-13.6)	3.0	3.0 (2.0-4.2)
55	20.0	20.3 (15.1-25.9)	6.6	6.3 (4.7-8.1)
65	36.7	37.2 (31.2-43.9)	17.5	16.9 (14.2-20.0)
75	64.4	66.5 (60.5-73.7)	45.6	43.7 (39.8-48.5)
85	89.7	86.4 (83.7-90.9)	79.4	77.0 (74.6-81.0)

[1] Goman 2016

PROGRESSION OF SNHL

- Model Projected (blue) and Baltimore Longitudinal Study on Aging (orange) population mean dB hearing level[1]

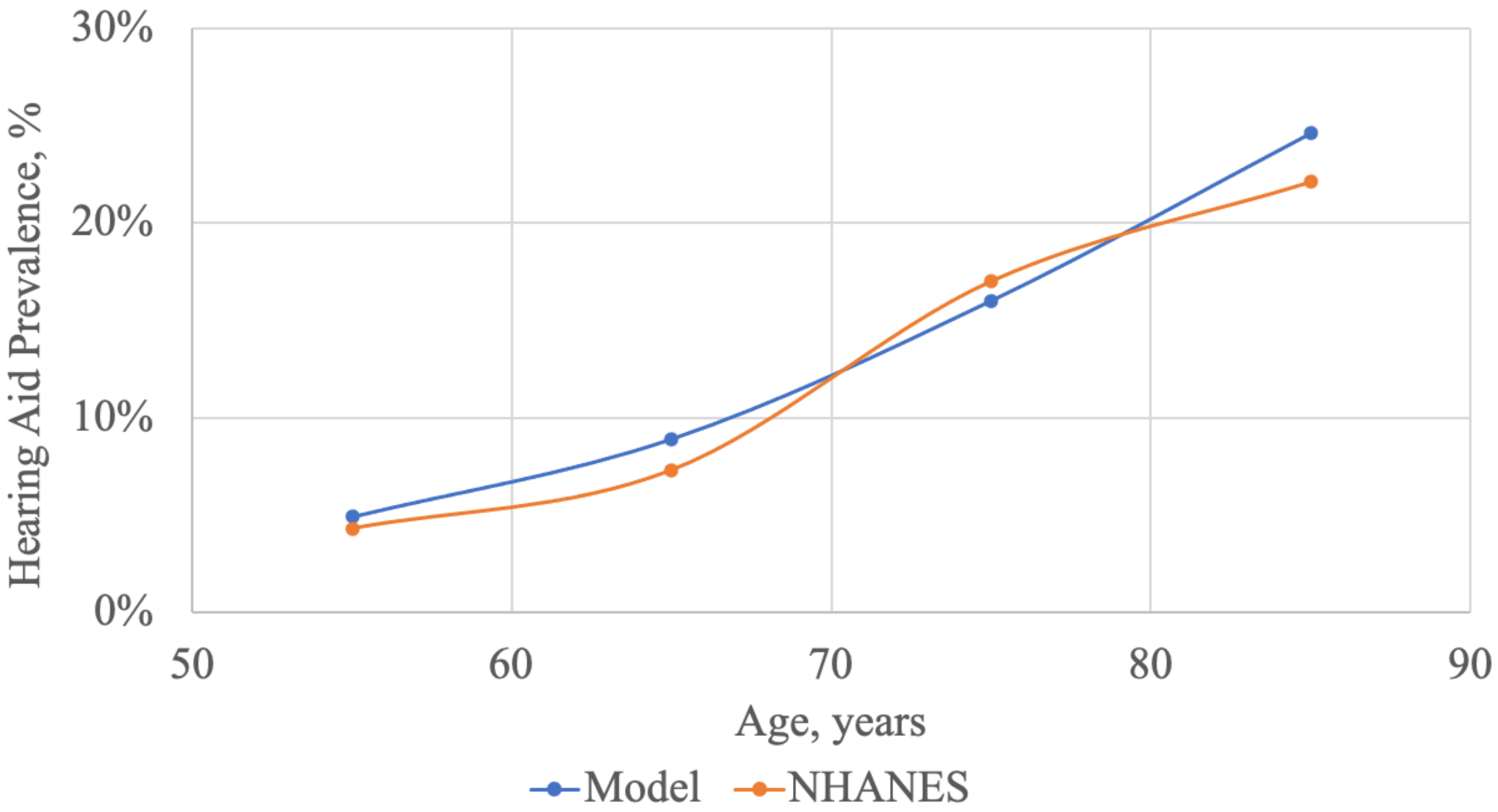


- CV-RMSE = 11.3%

[1]Morrell 1996

HL TREATMENT

- Model Projected (blue) and published NHANES (orange) hearing aid prevalence[1]
- Included a calibration factor
- CV-RMSE = 10.3%



- Yearly cochlear implants in adults matched to estimates (n=13,000)[2]

[1]Chien 2012, [2]Sorkin 2013

CONCLUSIONS

- Adequate fit to external data
- Lifespan approach to identify optimal points of intervention
- Included both SNHL and CHL
- Simulated cascade, with treatment uptake and discontinuation
- Limitations:
  - Simplifying assumptions, data limitations, excluded age-period-cohort effects

AGENDA:

1. CEA and Decision Analysis
2. Hearing loss in the United States
3. DeciBHAL development
4. Adult hearing screening CEA

OBJECTIVE

Model-Projected Cost-Effectiveness of Adult Hearing Screening in the USA

Ethan D. Borre, PhD[1,2], Judy R. Dubno, PhD[3], Evan R. Myers, MD, MPH[4], Susan D. Emmett, MD, MPH[5,6], Juliessa M. Pavon, MD[7], Howard W. Francis, MD, MBA[5], Osondu Ogbuoji, MBBS, MPH, ScD[5,8], and Gillian D. Sanders Schmidler, PhD[1,2,9]

To estimate the long-term clinical and economic effects of different adult hearing screening paradigms in the US.

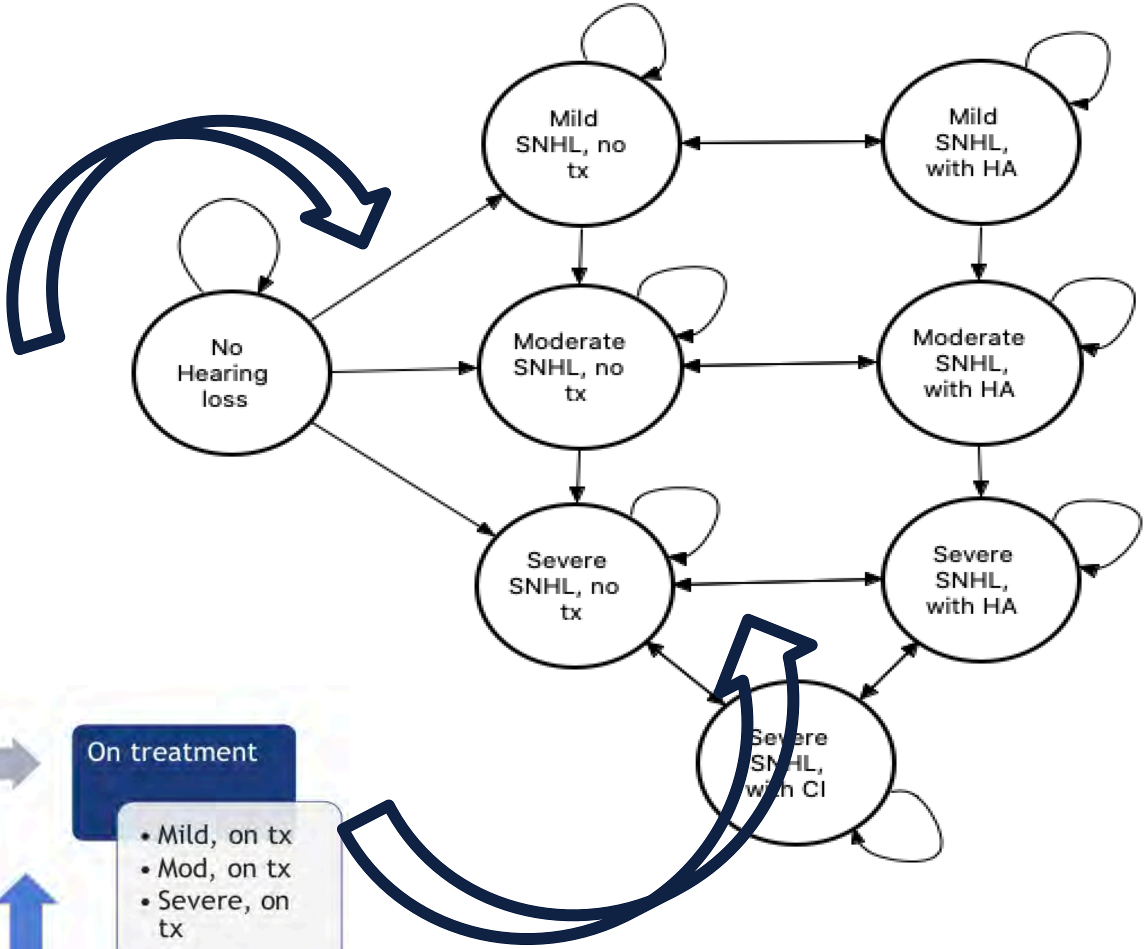
ANALYTIC OVERVIEW

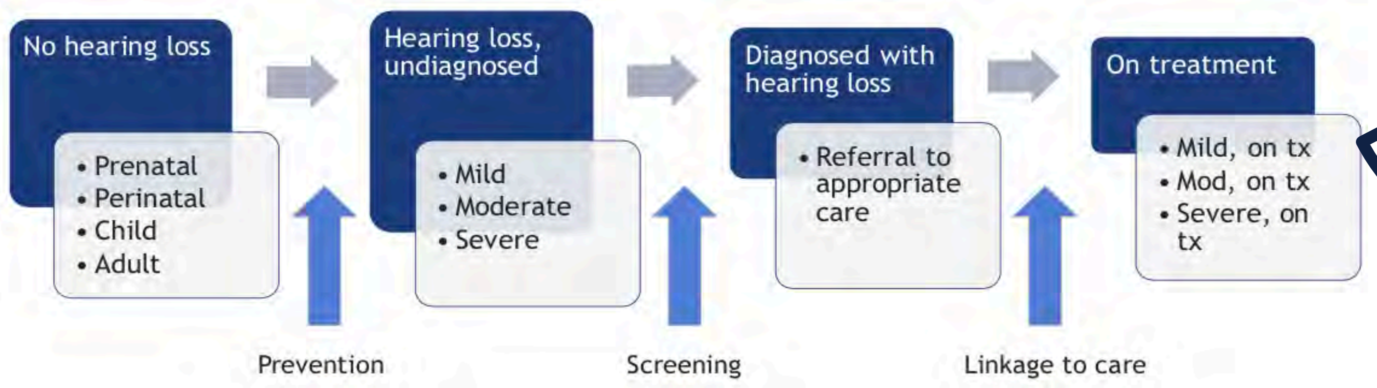
- Population: 40+yo adult primary care pts in the US
- Comparators:
  - "Current detection" current rate of symptomatic and asymptomatic presentation to hearing health care
  - Alternative screening strategies
- Perspective: Healthcare system
- Time Horizon: Lifetime
- WTP of $100,000/QALY

Screening strategies	
Screening characteristic	Strategy
Starting age	45, 55, 65, 75 years
Frequency	Every 1 or 5 years

DECIBHAL OVERVIEW, REMINDER

- We used DeciBHAL-US
- Yearly transition probabilities are based on
  - age-specific incidence of hearing loss
  - hearing loss cascade of care





INPUTS: HA UPTAKE

- Severity- and age-stratified HA uptake probabilities

Age, years	Mild HL, yearly uptake	Moderate+ HL, yearly uptake	
<65	0.5%	2.3%	
65-74	0.5%	4.6%	
75-84	0.6%	8.1%	
85+	0.7%	7.2%	

INPUTS: HA UPTAKE

- Severity- and age-stratified HA uptake probabilities
- Together with discontinuation rates (4-13%/year) calibrated to attain NHANES-estimated HA prevalence (Chien 2012)
-

Age, years	Mild HL, yearly uptake	Moderate+ HL, yearly uptake	HA prevalence (Current Detection)
<65	0.5%	2.3%	4.9%
65-74	0.5%	4.6%	8.9%
75-84	0.6%	8.1%	16.0%
85+	0.7%	7.2%	24.6%

INPUTS: HA UPTAKE

- Severity- and age-stratified HA uptake probabilities
- Together with discontinuation rates (4-13%/year) calibrated to attain NHANES-estimated HA prevalence (Chien 2012)
- Screening effectiveness incorporated as a multiplier on these probabilities

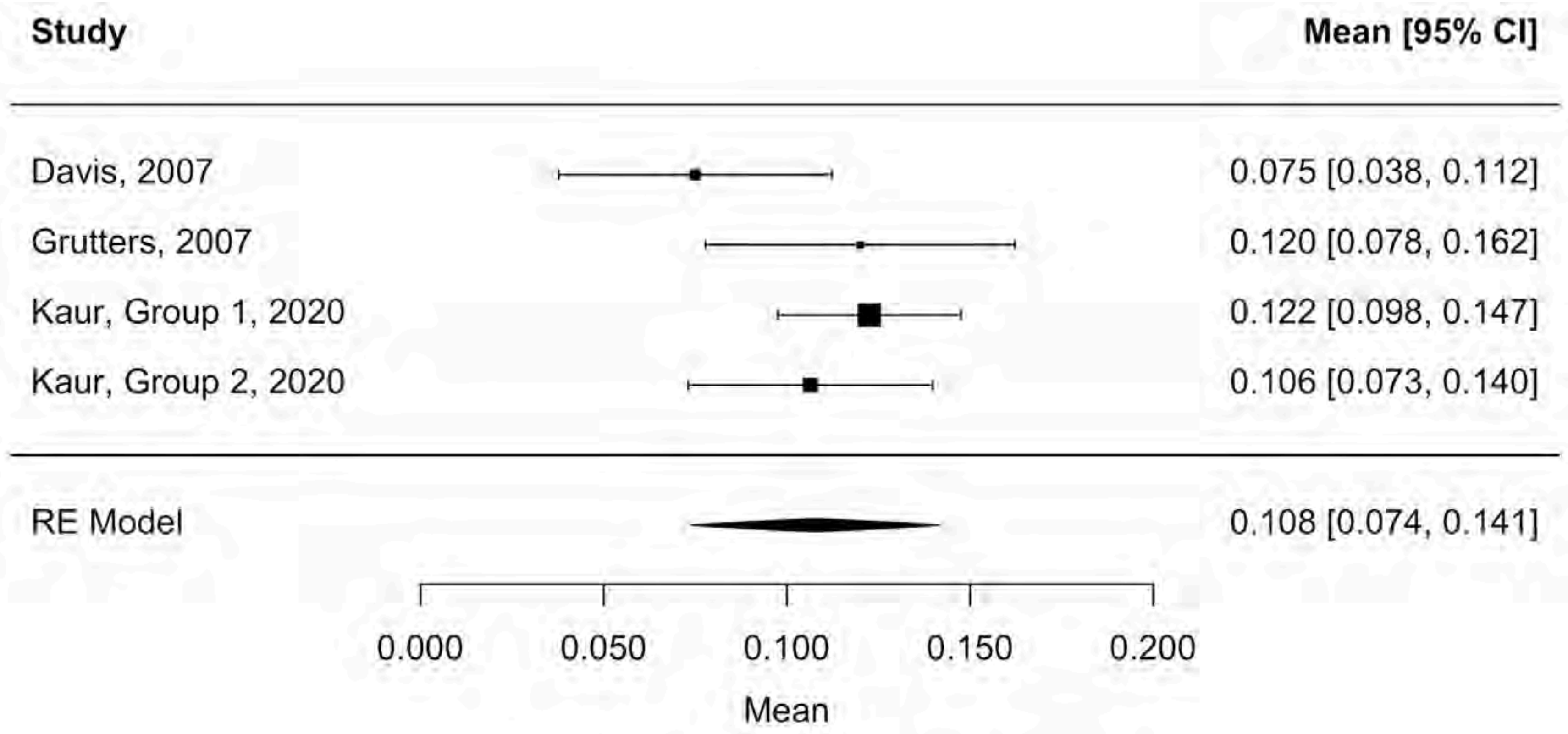
Age, years	Mild HL, yearly uptake	Moderate+ HL, yearly uptake	HA prevalence (Current Detection)
<65	0.5%	2.3%	4.9%
65-74	0.5%	4.6%	8.9%
75-84	0.6%	8.1%	16.0%
85+	0.7%	7.2%	24.6%

INPUTS: SCREENING EFFECTIVENESS

- Combined risk ratios from 2 studies (1 RCT, 1 obs)
  - RR=1.62 for HA uptake[1,2]
- Incorporated as a multiplier on base-line low rates of HA uptake
  - No impact on HA discontinuation (13-4%/year)[3,4]

[1]Yueh 2010, [2]Zazove 2020, [3]Takahashi 2007, [4]Kochkin 2010

INPUTS: HEARING AID EFFECTIVENESS

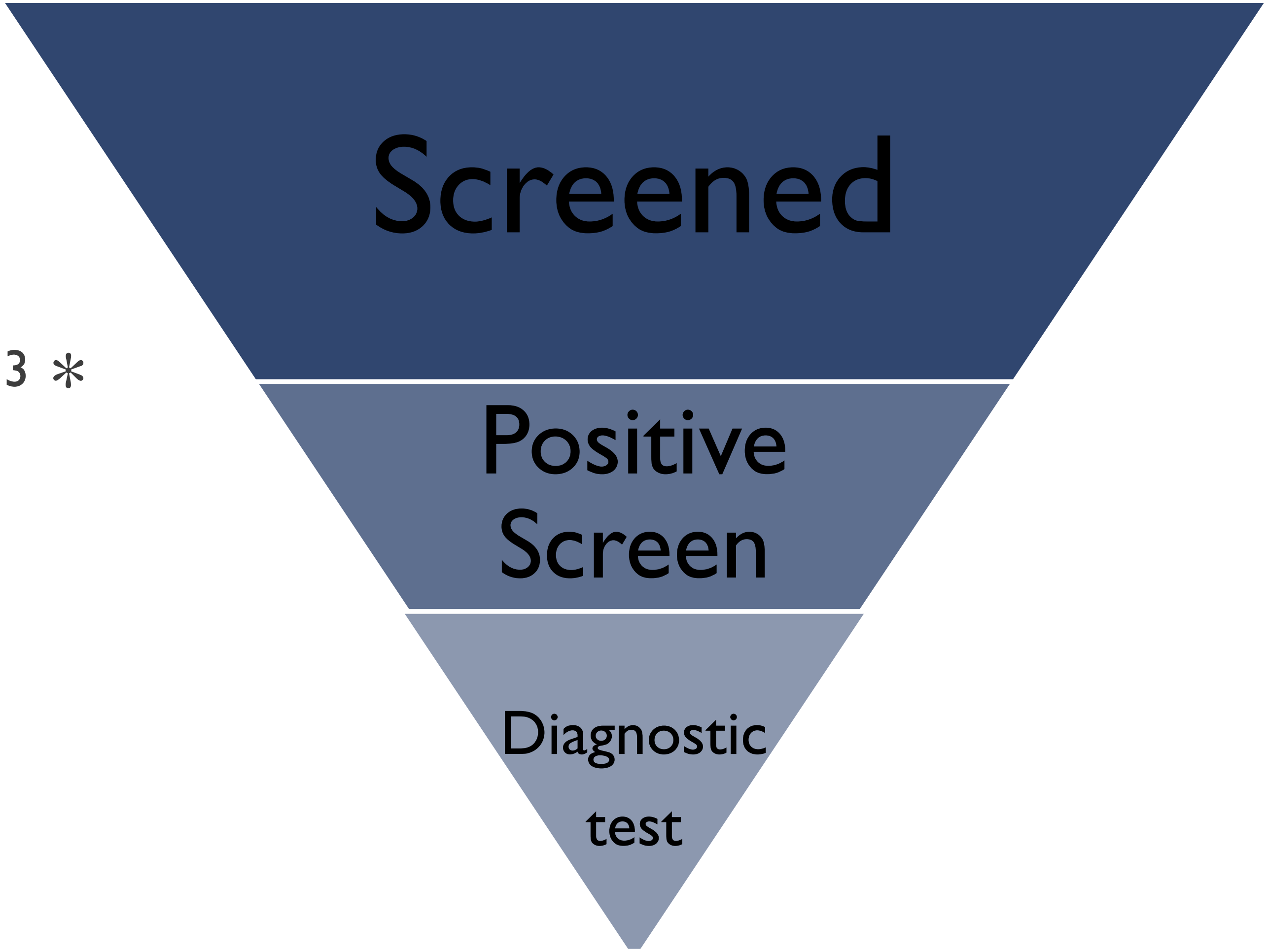


- Basecase efficacy of hearing aids used is 0.11, CIs is 0.17
- Sensitivity analysis using GBD/WHO assumptions

Borre et al., Under Review

INPUTS: COST OF SCREEN

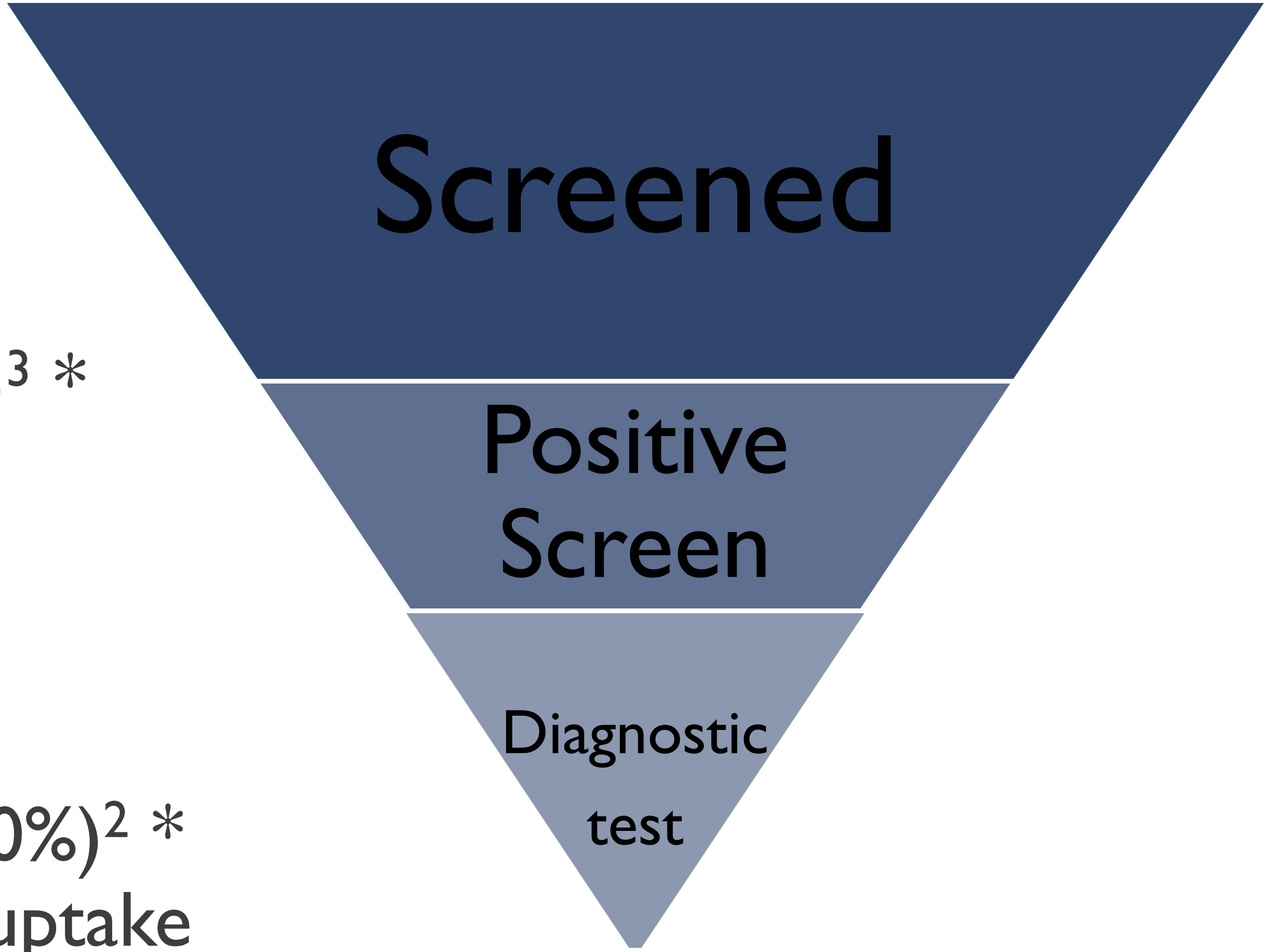
- People without HL: $33
  - Cost of screening test ($2.06)[1]
  - HHIE/Single Q FP rate (24%)[2] *
    Proportion that seek test (43.3%)[3] *
    Audiology test cost ($295)[4]



[1]Liu 2011, [2]USPSTF 2021, [3]Zazove 2020, [4]Hojjat 2017

INPUTS: COST OF SCREEN

- People without HL: $33
  - Cost of screening test ($2.06)[1]
  - HHIE/Single Q FP rate (24%)[2] * Proportion that seek test (43.3%)[3] * Audiology test cost ($295)[4]
- People with HL, but no HA: $120
  - Cost of screening test ($2.06)[1]
  - Best HHIE/Single Q Sensitivity (80%)[2] * Probability Screened and no HA uptake (51%)[3] * Audiology test cost ($295)[4]



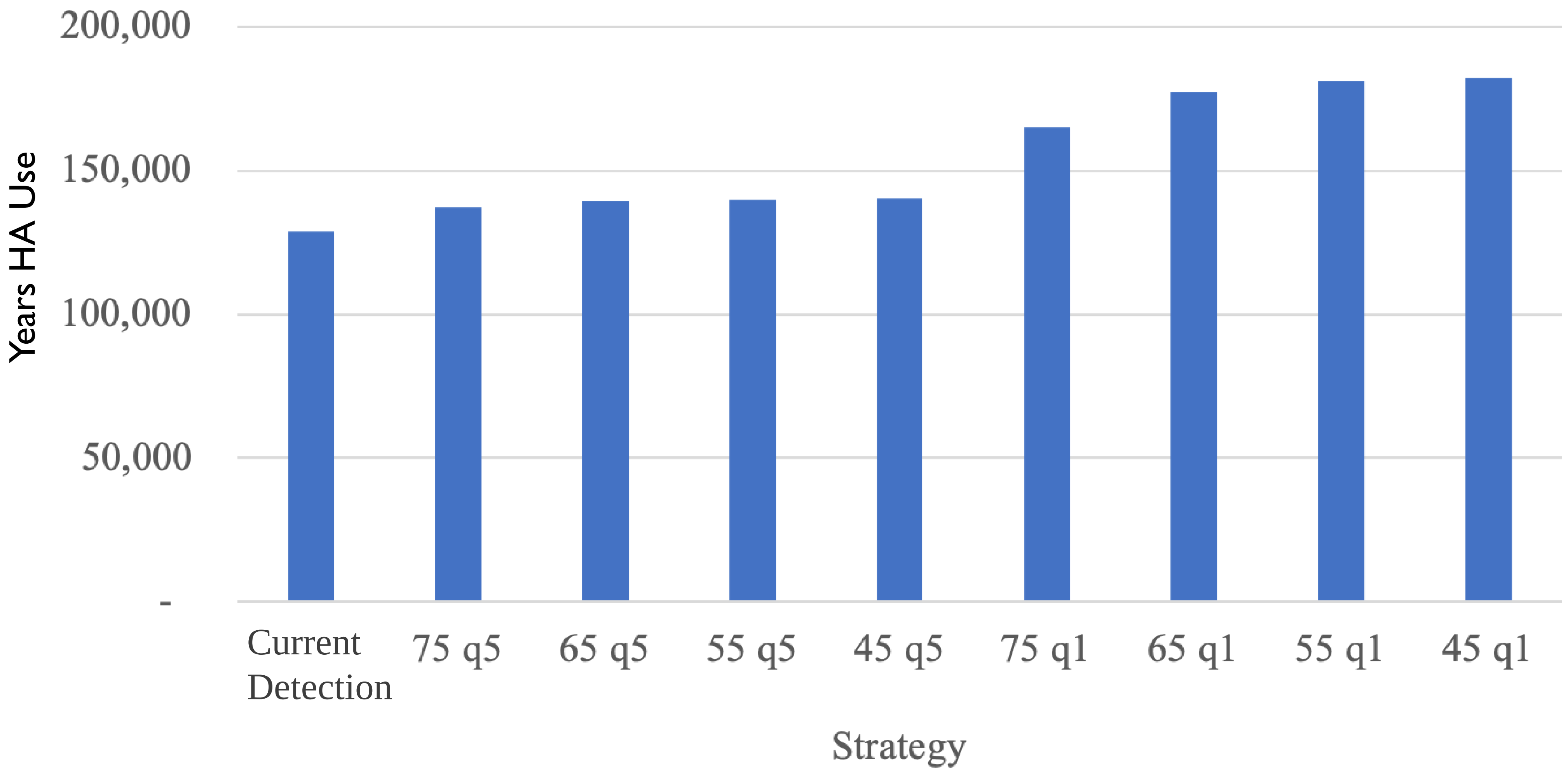
[1]Liu 2011, [2]USPSTF 2021, [3]Zazove 2020, [4]Hojjat 2017

INPUTS: COSTS OF HL TREATMENT

Component	Cost, 2020 USD	Reference
Hearing Aid		
One-time uptake[1]	$4,260	NAM, Hojjat 2017, Abrams 2002
Recurring[2]	$910	
Cochlear Implant[3]		
One-time implantation cost	$54,380	Hojjat 2017, Semenov 2013, Wyatt 1996
Recurring costs years 2-6	$1,400	
Recurring costs years 7+	$1,260	

[1]Assuming 84% bilateral, including lower VA pricing
[2]Assuming replacement every 4 years
[3]Unilateral CI

RESULTS: PERSON-TIME HA USE



RESULTS: EFFECTIVENESS AND COSTS

Per-person	Lifetime QALYs (undiscounted)		
Current Detection	32.107		
75 q5	32.117		
75 q1	32.149		
65 q1	32.168		
55 q1	32.175		
45 q1	32.177		

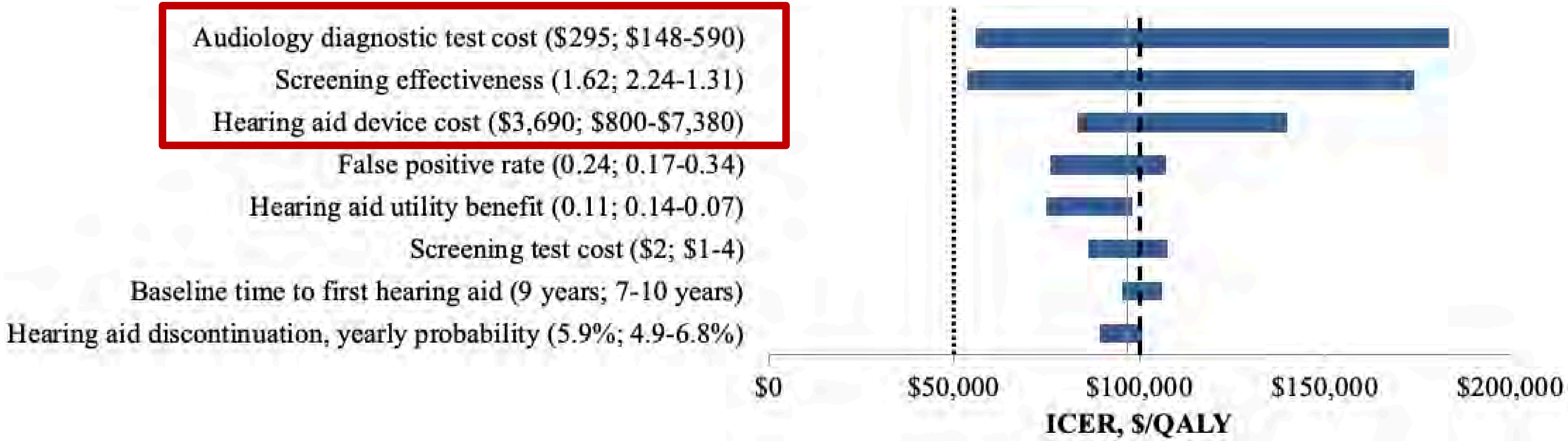
RESULTS: EFFECTIVENESS AND COSTS

Per-person	Lifetime QALYs (undiscounted)	Lifetime costs (undiscounted, 2020 USD)	
Current Detection	32.107	3,300	
75 q5	32.117	3,630	
75 q1	32.149	4,780	
65 q1	32.168	5,570	
55 q1	32.175	6,100	
45 q1	32.177	6,490	

RESULTS: EFFECTIVENESS AND COSTS

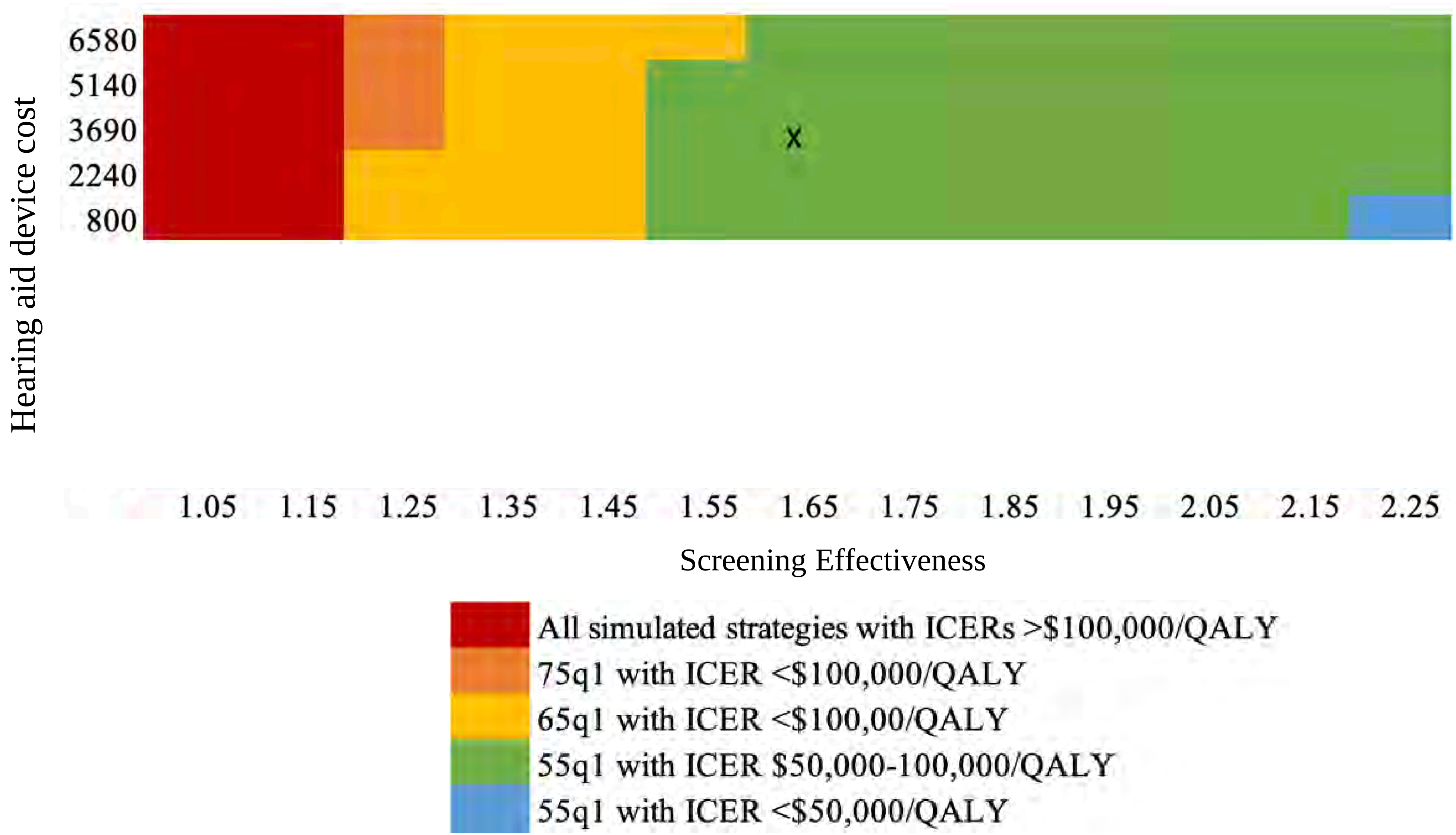
Per-person	Lifetime QALYs (undiscounted)	Lifetime costs (undiscounted, 2020 USD)	ICER (discounted, $/QALY)
Current Detection	32.107	3,300	-
75 q5	32.117	3,630	37,500
75 q1	32.149	4,780	39,100
65 q1	32.168	5,570	48,900
55 q1	32.175	6,100	96,900
45 q1	32.177	6,490	234,600

ONE-WAY SENSITIVITY ANALYSIS



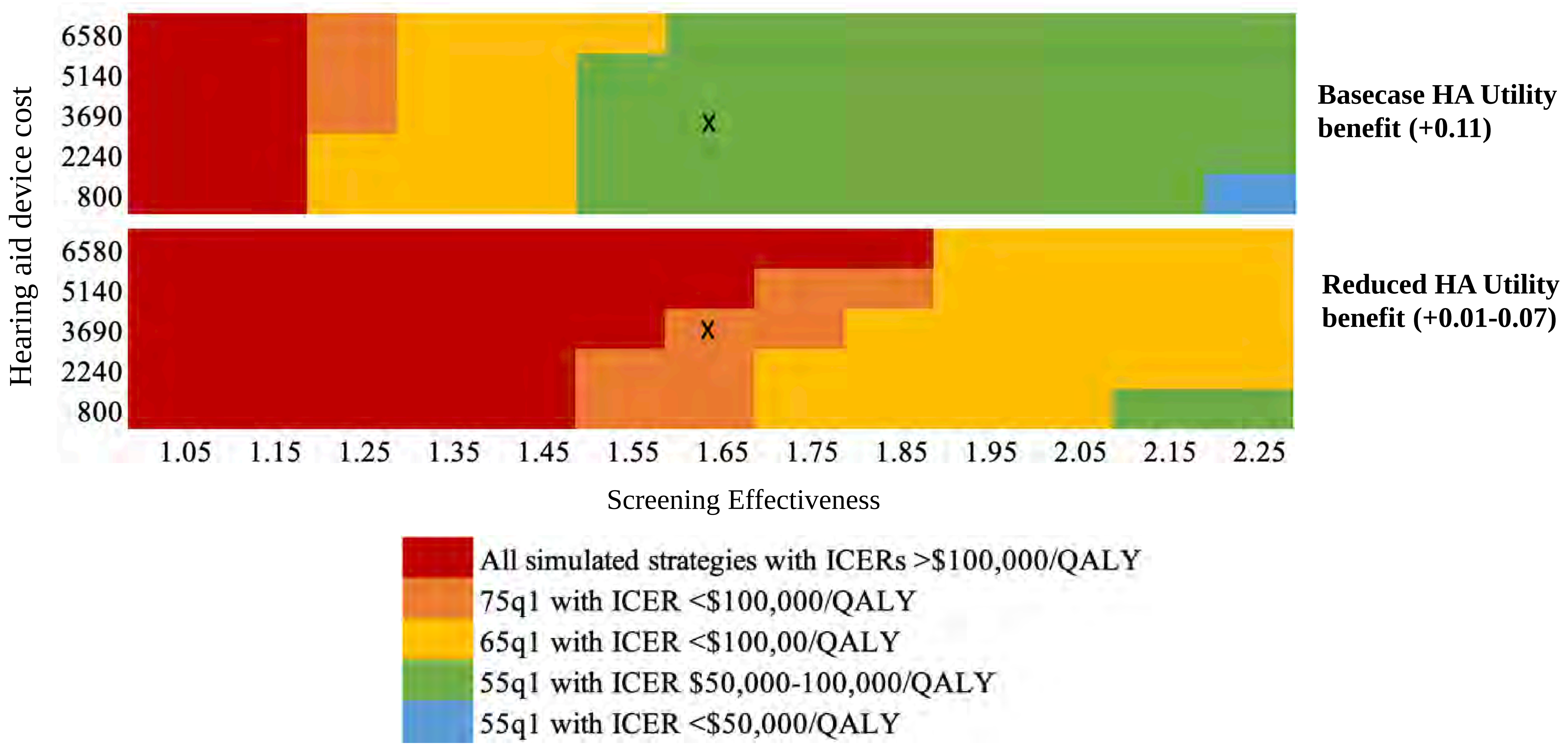
- Tornado showing ICER of yearly screening starting at age 55 years
- Audiology diagnostic test cost, screening effectiveness, and hearing aid device cost are the most influential parameters

THREE-WAY SENSITIVITY ANALYSIS



Basecase HA Utility benefit (+0.11)

THREE-WAY SENSITIVITY ANALYSIS



CONCLUSIONS

- Yearly screening beginning at age 55 years increases per-person undiscounted lifetime QALYs by 0.07
  - And is likely cost-effective at $96,900/QALY
- Variations in screening effectiveness and HA device cost (OTC HAs) influence optimal age at initiation (55-75 years)
- Limitations: model simplifications, effectiveness parameter uncertainty, effect of repeated HL screenings, no societal costs included

VALUE OF INFORMATION

JAMA Health Forum

Original Investigation

Estimated Monetary Value of Future Research Clarifying Uncertainties Around the Optimal Adult Hearing Screening Schedule

Ethan D. Borre, PhD; Evan R. Myers, MD, MPH; Judy R. Dubno, PhD; Susan D. Emmett, MD, MPH; Juliessa M. Pavon, MD; Howard W. Francis, MD, MBA; Osondu Ogbuoji, MBBS, MPH, ScD; Gillian D. Sanders Schmidler, PhD

- High level of decision uncertainty around age of screen initiation
- Monetary value of future research estimated at $9.6 billion
- Future research on screening effectiveness at $2.6 billion
  - Recent large trial (ACHIEVE: 850 patients over 3 years) cost $16.5 million
  - Entire NIDCD budget in 2020 was $446 million

POLICY IMPLICATIONS

- Yearly hearing screening beginning at age 55 is likely cost-effective
  - Current USPSTF guidelines leave this up to patient/clinician
- Optimal age of initiation is uncertain
- Research investments to clarify hearing screening effectiveness are likely warranted

FUTURE DIRECTIONS

- HL treatment as dementia prevention
- Extension of DeciBHAL to LMIC
- Online tool for decisionmakers
- Ongoing review to incorporate societal perspective
- Inclusion of spillover health benefits (falls, healthcare spending)
- Consideration of HHC disparities

ACKNOWLEDGEMENTS

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- Bass Connections Team
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- Austin Ayer, Gloria Zhang
- Evan Myers, Shelby Reed, Deb Tucci, Judy Dubno, Corinna Sorensen, Blake Wilson, Juliessa Pavon

PRESENTATION OBJECTIVES

1. Decision modeling is a quantitative method that can inform health policy
2. Hearing loss is prevalent, undertreated, and significantly impacts quality of life, physical, and mental health
3. Yearly hearing screening of persons 55+ is likely a cost-effective intervention in the US

COST-EFFECTIVENESS OF ADULT HEARING SCREENING IN THE US

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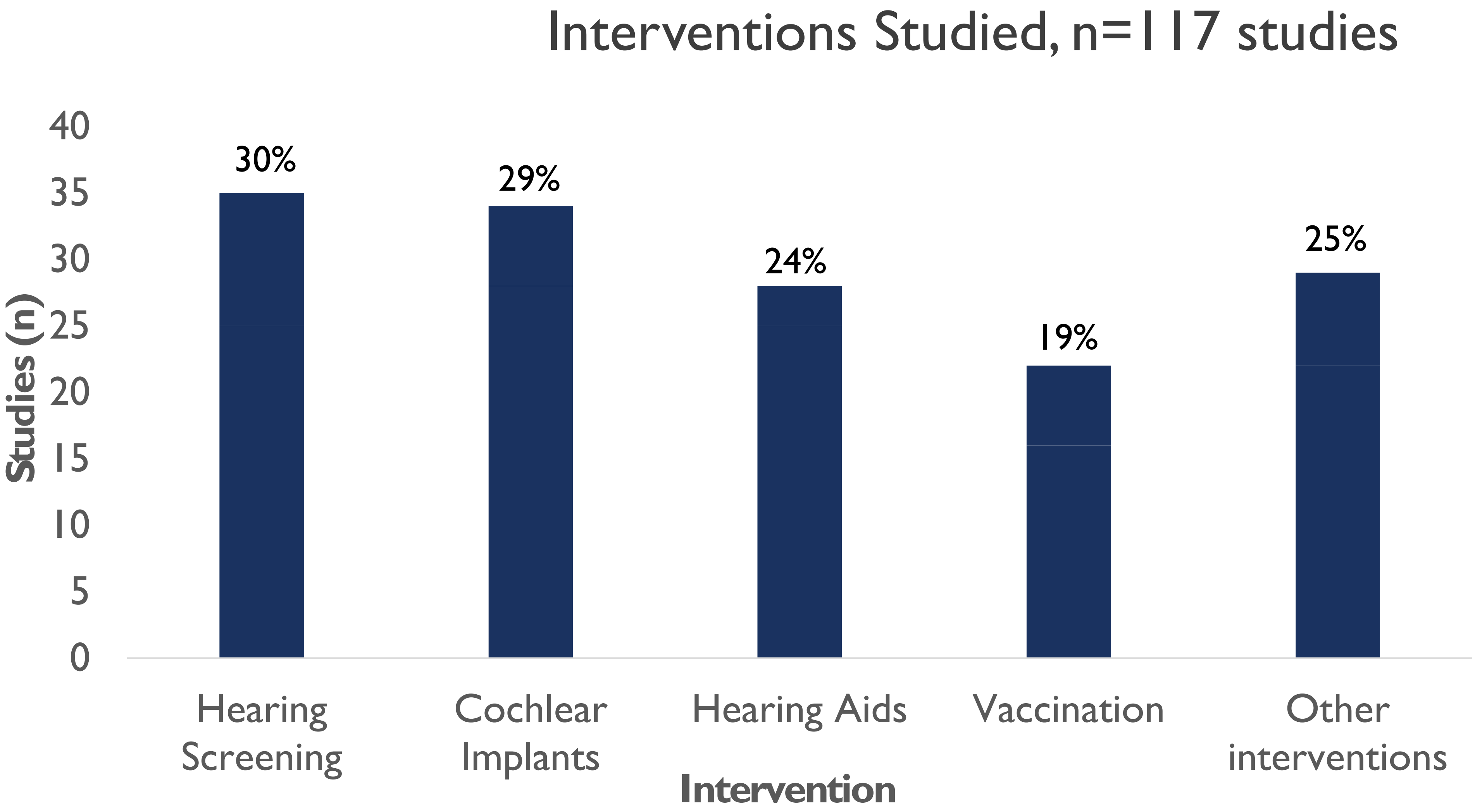
UC Davis Research Seminar
10.11.23

MGH 1811

Duke | MARGOLIS CENTER for Health Policy

STUDY CHARACTERISTICS



Multiple interventions explored in each study, will not sum to 100%

MODELING CHARACTERISTICS

- 62% used tree diagrams*
- 35% used Markov models*
- 7% other

Sensitivity Analyses included

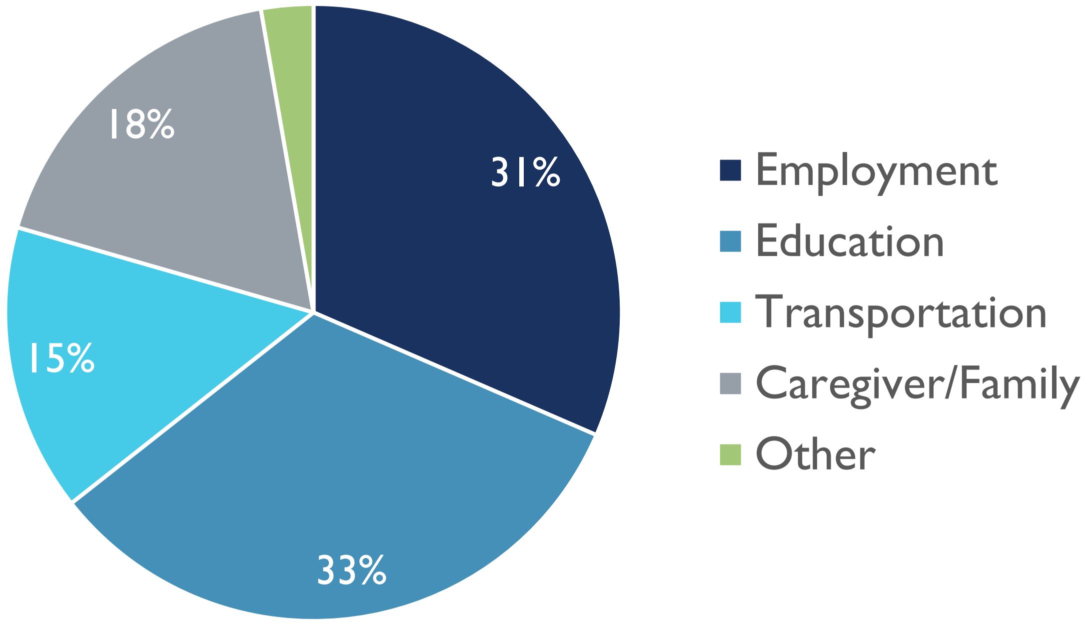
One-way Deterministic	83%
Probabilistic	42%
Multi-way Deterministic	26%
None	7%

*Some models used a combination tree and Markov model

UTILITY AND INDIRECT ECONOMIC EFFECTS

- Utility values used for hearing health states varied widely between studies
  - 28% derived study-specific utility values
- 35% of studies included indirect economic effects

Types of Indirect Economic Effects Included



AGENDA:

1. Introduction
2. Previous decision models of hearing loss

Detour: Utility impact of hearing loss and its treatment

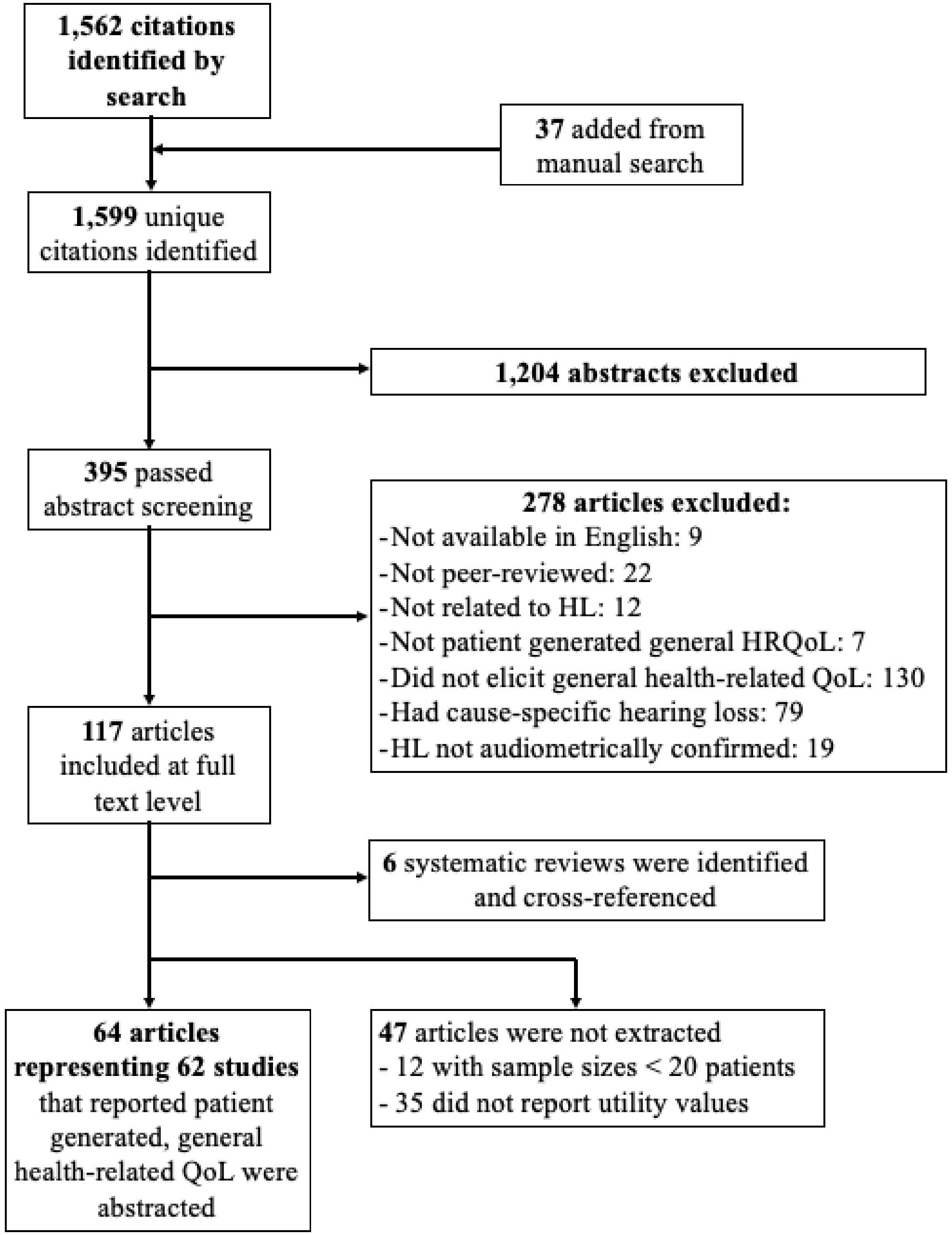
5. Value of future research

OBJECTIVE

To identify and synthesize current estimates of HRQoL utility values for untreated and treated HL and thereby to inform economic analyses and hearing healthcare clinical and policy decision-making.

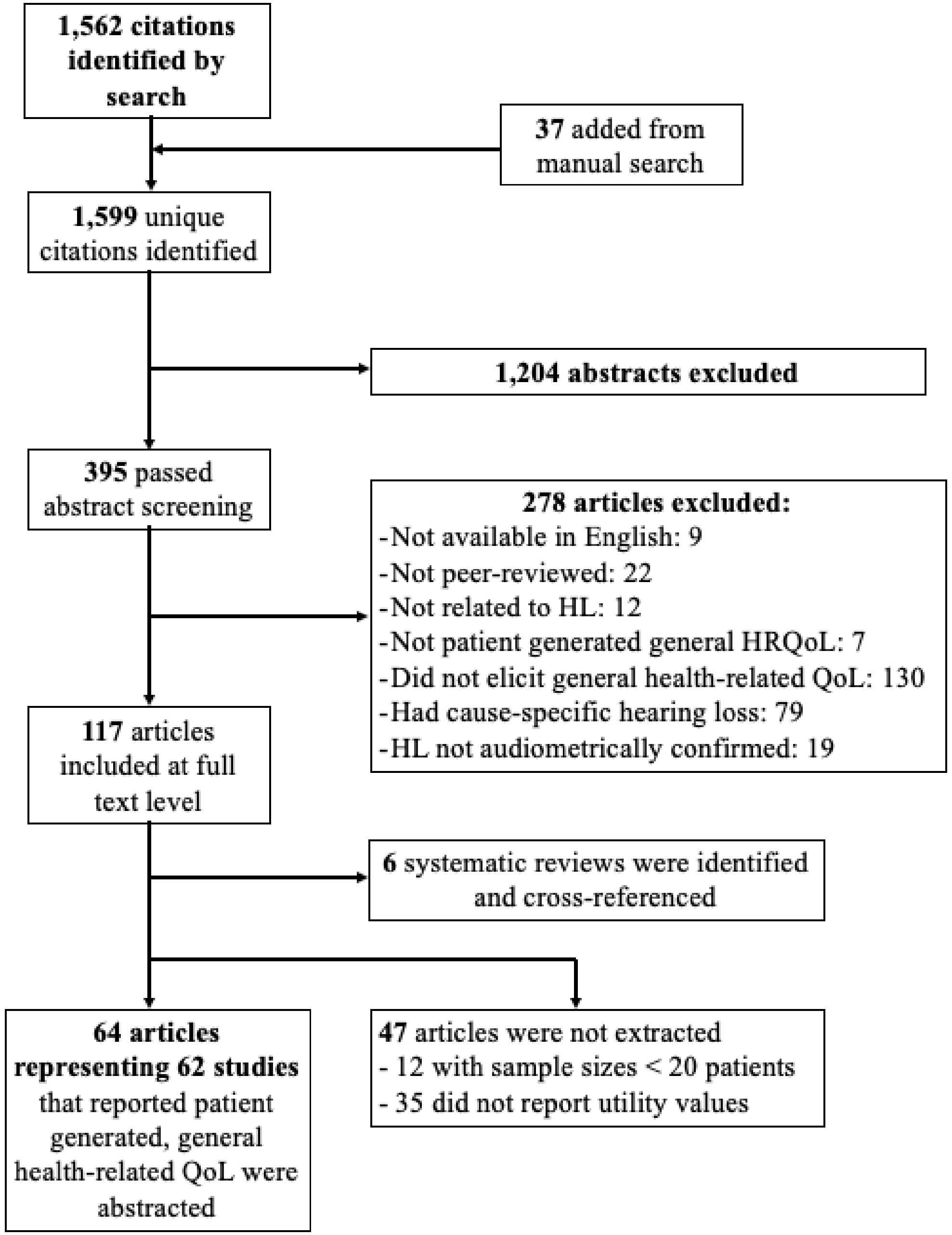
METHODS

- Searched MEDLINE, EMBASE, Scopus, CINAHL EBSCO, and Global Health EBSCO on 1 February 2021
- Inclusion criteria:
  - Treated or untreated hearing loss
  - Patient-reported health-state utility values
- Meta-analysis of utility values if ≥3 estimates with identical utility elicitation measures and health states



RESULTS

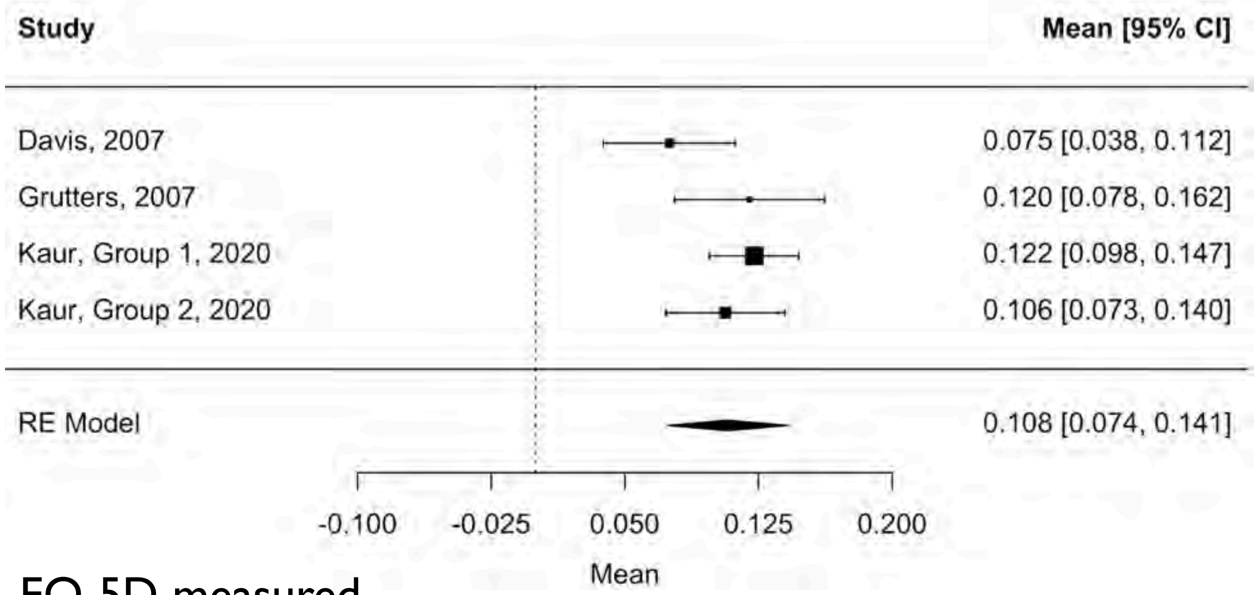
- 61% of studies used pre/post design
- 65% evaluated unilateral cochlear implantation
- 71% administered the HUI3
- 84% conducted in Europe/North America
- Most studies found a benefit of hearing loss treatment, except if EQ-5D was used



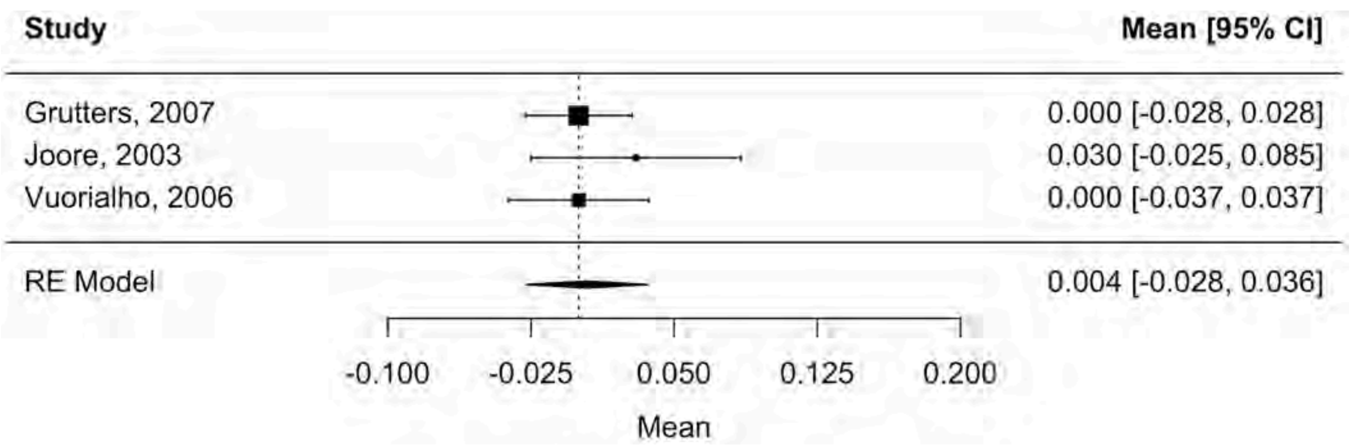
META-ANALYSIS RESULTS, I

- Hearing aids improved adult HUI3-estimated utility by 0.11 [95% CI: 0.07-0.14]
- No significant effect on utility was seen when the EQ-5D was used

HUI3 measured

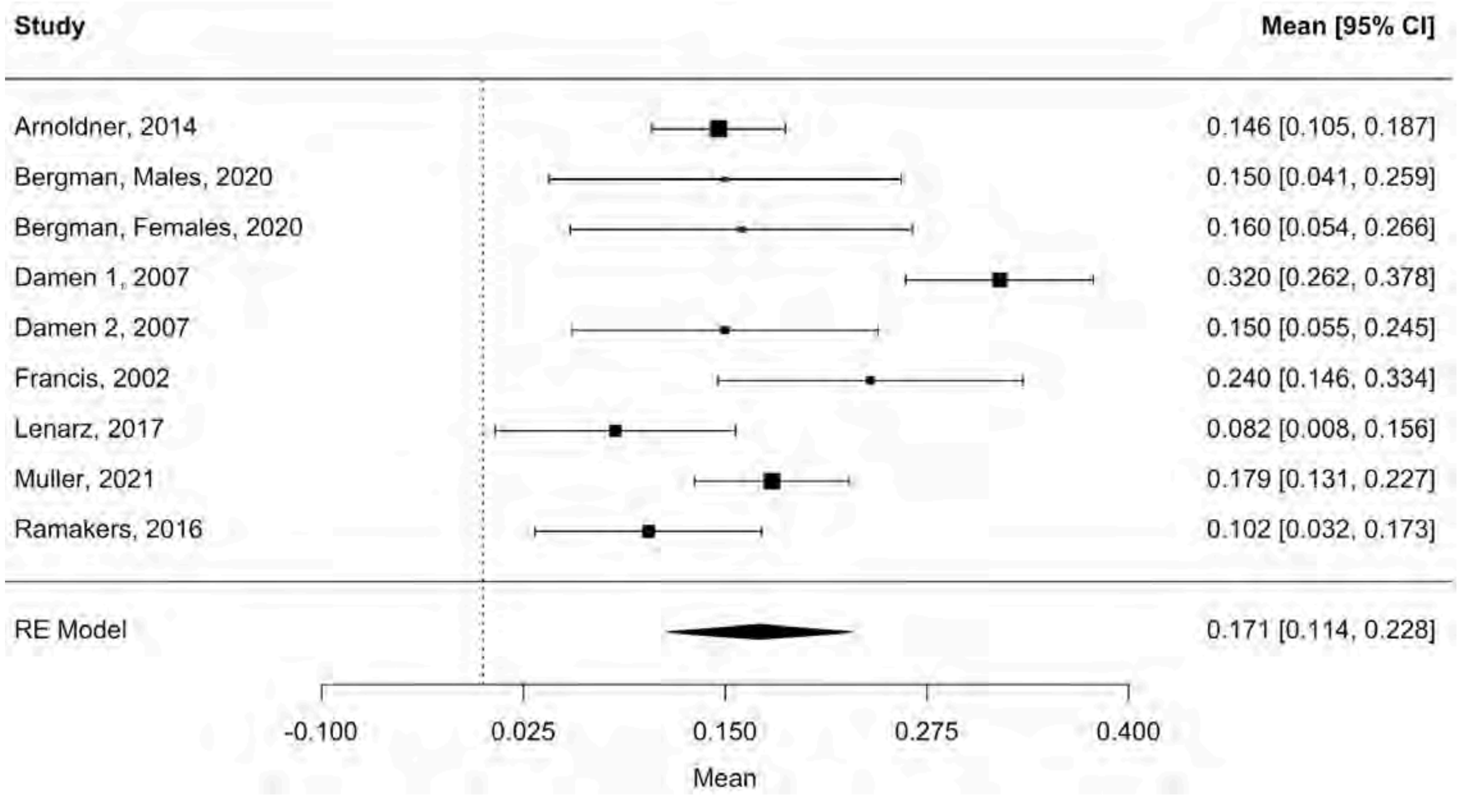


EQ-5D measured



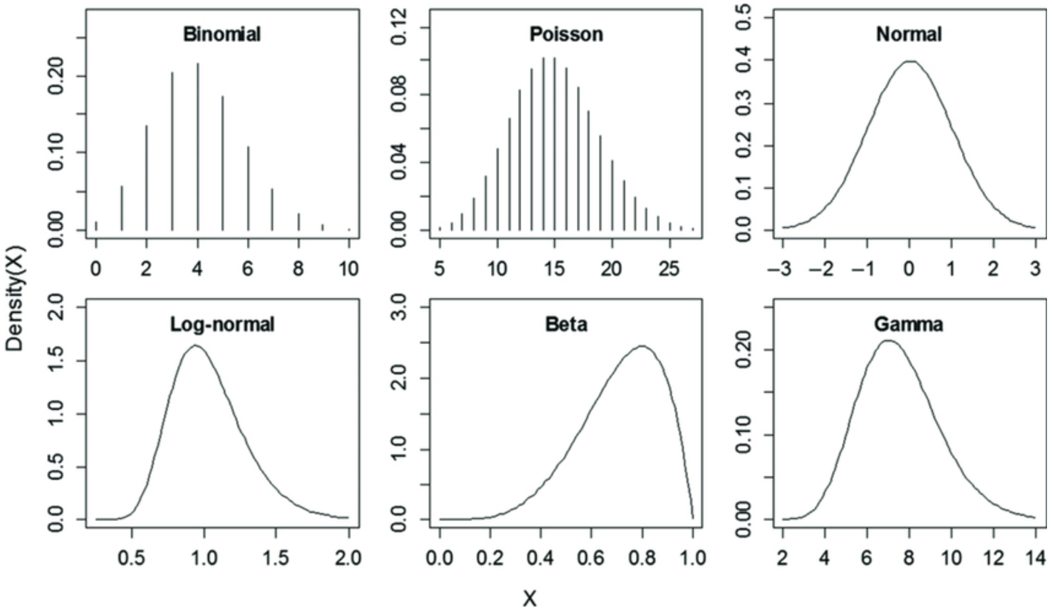
META-ANALYSIS RESULTS, 2

- Cochlear implants improved adult utility by 0.17 [95% CI: 0.11-0.23] at ≥1 year
- Pediatric VAS-estimated utility, mean=0.12, had CI that included no effect [-0.02-0.25]
- Unable to synthesize estimates of untreated HL, pediatric hearing aids



CONCLUSIONS

- Few analyses in LMIC
- EQ-5D and SF-6D elicitation measures are insensitive to changes in hearing
  - HUI3, HUI2, VAS, and TTO methods can detect hearing improvements
- Current assumptions about treatment benefits, like that of WHO and GBD, 0.01-0.07, may underestimate true utility benefits



- Assigned distributions to 5 uncertain parameters
  - Utility benefit of hearing aids
  - Screening effectiveness
  - Screening test false positive rate
  - Audiology diagnostic test cost
  - Hearing aid device cost
- Ran 1,000 iterations of the simulation, drawing from each distribution
- Created cost-effectiveness acceptability curve (CEAC)

VOI METHODS, EVPI

- EVPI: value of reducing all uncertainty of **every input**
  - Calculated net marginal benefit of each strategy for every PUA iteration
  - NMB= (QALYxWTP) – Costs
  - Optimal strategy= one with highest positive NMB
- EVPI = summed differences between maximum NMB of each PUA iteration and the expected average NMB across all simulations

$$EVPI = \mathrm{E}_{\boldsymbol{\theta}}[\max_t \mathrm{NB}_t(\boldsymbol{\theta})] - \max_t \mathrm{E}_{\boldsymbol{\theta}}[\mathrm{NB}_t(\boldsymbol{\theta})]$$

Sample	CD	Screen age 65	Screen age 55	Opportunity Loss
1	400	1,000	950	50
2	-100	600	500	100
3	2,300	2,400	2,500	0
4	3,600	3,900	3,800	100
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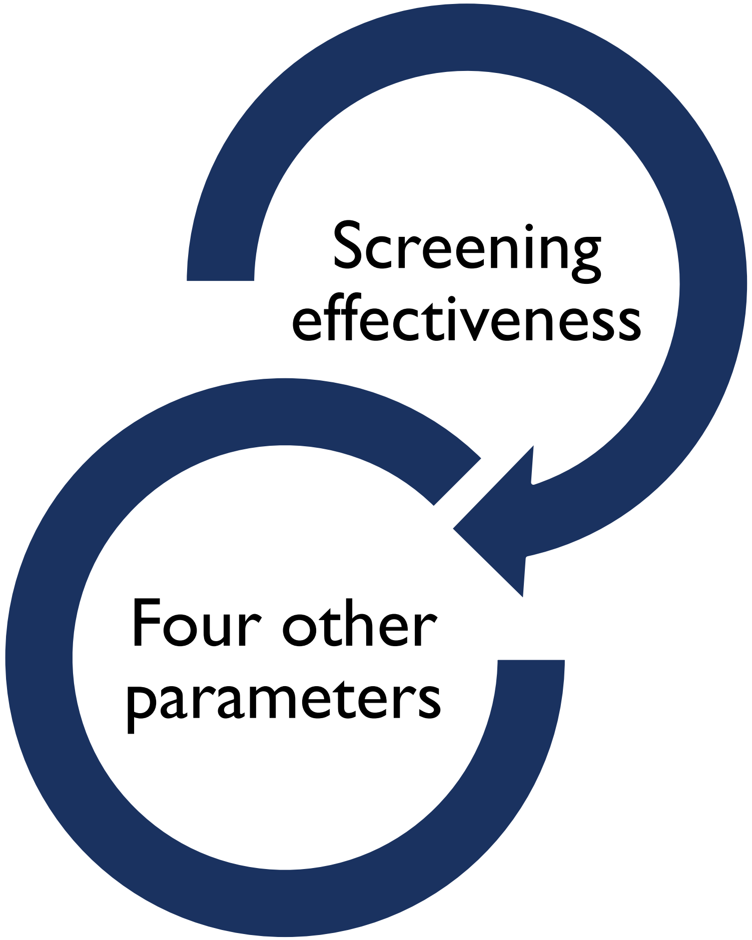
	1,625	**1,900**	**1,940**	**300**

EVPI

Example adapted from CONVOI

VOI METHODS, EVPPI

- EVPPI: value of reducing all uncertainty of **one input**
- Performed EVPPI for screening effectiveness parameter
  - Determine upper bound of a new trial's value
- Outer loop: DeciBHAL drew from screening effectiveness distribution
- Inner loop: DeciBHAL drew from the four other distributions simultaneously



POPULATION EVPI AND EVPPI

- Calculated population EVPI and EVPPI using the per-person estimates
- Multiply per-person values by population affected
  - Prevalent: 40+ years in US who who currently have hearing loss
  - Incident: persons expected to acquire HL over the next 5 years
  - Discount the incident population

RESULTS: EXPECTED VALUE OF PERFECT INFORMATION

Willingness to Pay ($/QALY)	Expected value of perfect information	Population expected value of perfect information (2020 USD, billions)
$50,000	$234	$12.641
$100,000	$176	$9.555
$150,000	$152	$8.244
$200,000	$167	$9.020

- This is the expected monetary value of reducing all uncertainty across the 5 parameters

RESULTS: EXPECTED VALUE OF PARTIAL PERFECT INFORMATION

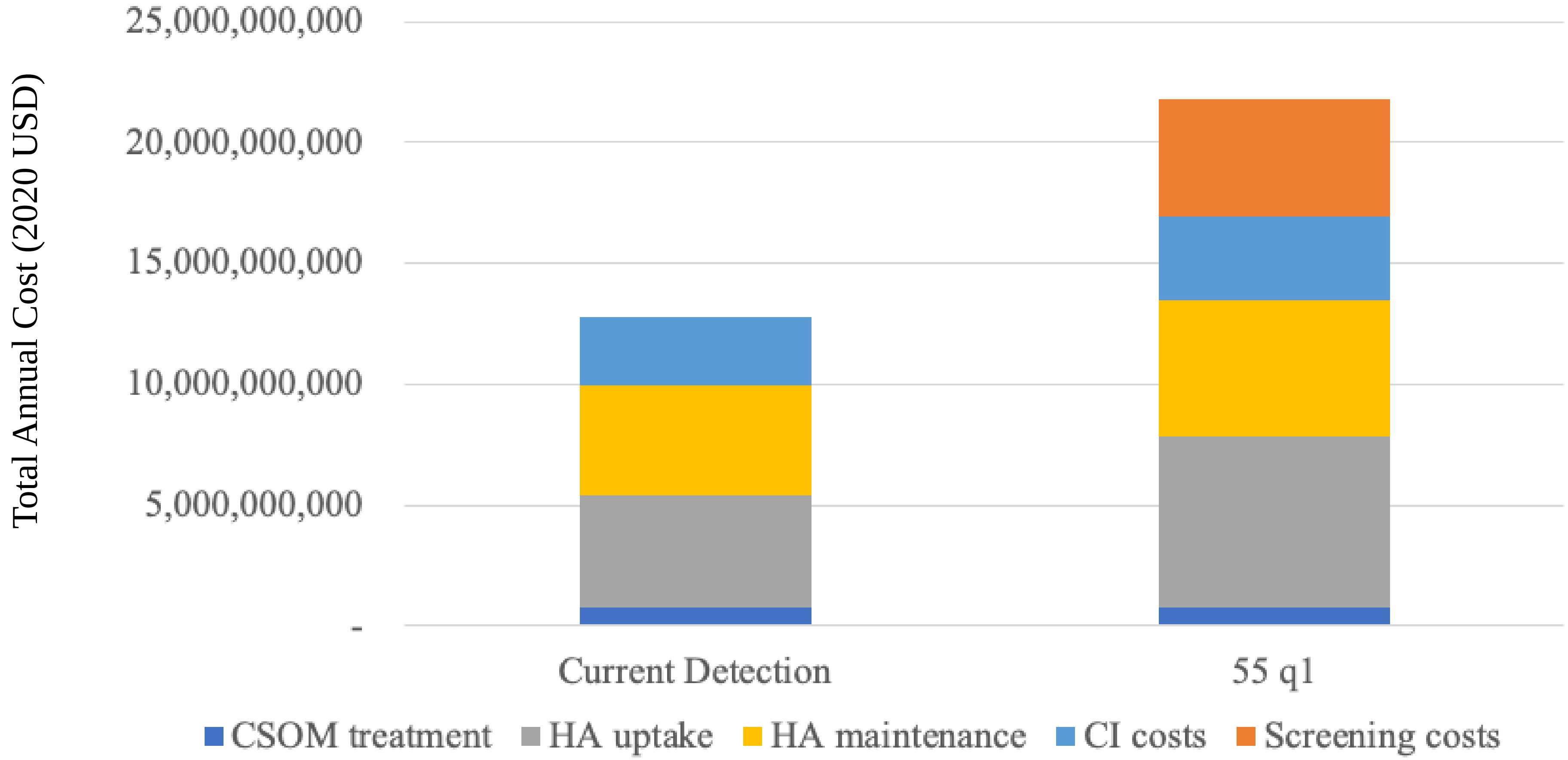
Willingness to Pay ($/QALY)	Expected value of partial perfect information for screening effectiveness	Population expected value of partial perfect information for screening effectiveness (2020 USD, billions)
$50,000	$23	$1.270
$100,000	$45	$2.434
$150,000	$38	$2.038
$200,000	$58	$3.148

- This is the expected monetary value of reducing all uncertainty for the effectiveness of screening

RESULTS: AGE AT FIRST HA

	40-49 years	50-59 years	60-69 years	70-79 years	80-89 years	90-99 years
No Screen	0.55%	2.63%	12.23%	34.21%	38.87%	11.50%
70 q10	0.54%	2.56%	11.92%	33.68%	39.05%	12.15%
60 q10	0.54%	2.56%	12.09%	33.71%	38.97%	12.13%
70 q5	0.53%	2.50%	11.61%	35.09%	39.03%	11.26%
50 q10	0.54%	2.74%	12.08%	33.59%	38.93%	12.12%
40 q10	0.54%	2.74%	12.08%	33.59%	38.93%	12.12%
60 q5	0.52%	2.49%	12.10%	34.85%	38.82%	11.22%
50 q5	0.52%	2.79%	11.95%	34.73%	38.79%	11.21%
40 q5	0.61%	2.75%	11.91%	34.73%	38.79%	11.21%

BUDGET IMPACT ANALYSIS

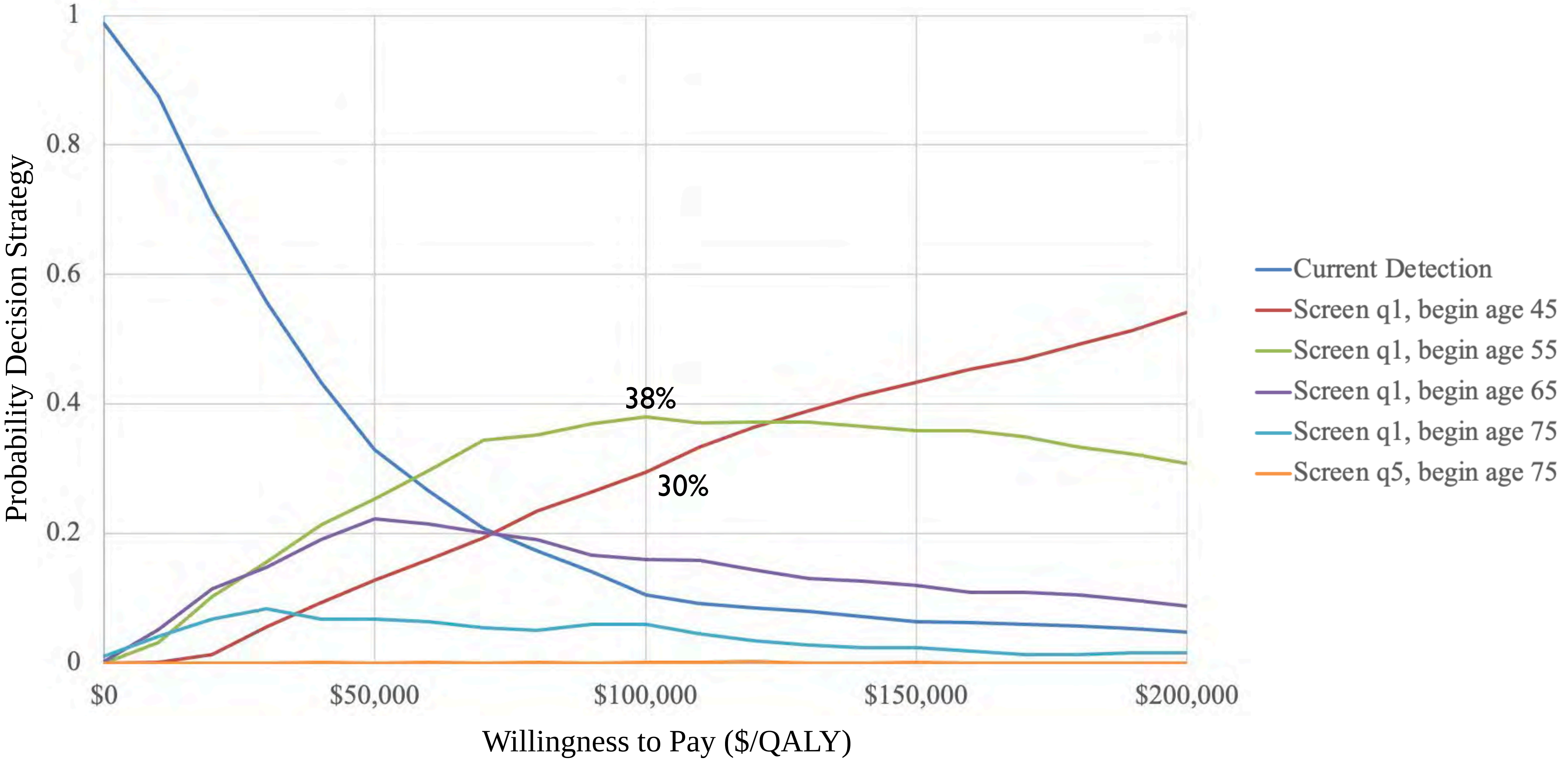


- Yearly average undiscounted costs for prevalent US population over 5 years
- Total yearly budget impact at $9B, majority (~$5B) is screening costs

DISTRIBUTIONS FOR PUA

Variable	Value	Distribution
Utility benefit of hearing aids	+0.11	Beta; alpha=33.61, beta=285.93
Utility benefit of cochlear implants	+0.16	-
Screen Effectiveness, multiplier on HA uptake	1.62	Normal; mean=1.6, SD=0.4
Screening test false positive rate	14%	Beta, alpha=93.54, beta=29.70
Economic input parameters	**Value (2020 USD)**	**Distribution**
Screening test cost	2	-
Audiology diagnostic test cost	295	Beta; alpha=1, beta=295
Hearing aid device(s) cost	3,890	Gamma; shape=1, scale=3890
Yearly Hearing aid recurring cost	910	Varied along with device cost
Cochlear implantation cost	54,380	-
Yearly recurring costs, cochlear implantation	1,260-1,400	-

RESULTS: PROBABILISTIC UNCERTAINTY ANALYSIS



RESULTS: EVPI AND EVPPI

- Population (p)EVPI: $8.2-12.6 billion
  - This is the expected monetary value of reducing all uncertainty across the 5 parameters
- Population (p)EVPPI: $1.3-2.4 billion
  - This is the expected monetary value of reducing all uncertainty for the effectiveness of hearing screening

ANALYTIC OVERVIEW

- Extended the hearing screening CEA
- Assigned distributions to key uncertain inputs to perform probabilistic uncertainty analysis (PUA)
- Calculated expected value of perfect information (EVPI) and expected value of partial perfect information (EVPPI)

JAMA Health Forum

Original Investigation

Estimated Monetary Value of Future Research Clarifying Uncertainties Around the Optimal Adult Hearing Screening Schedule

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