Current Challenges in Health Economics

Prof. Dr. Weerachai Kosuwon BSc., MSc.,MD.,FIMS

Director of Special Orthopedic skills training Center Khon Kaen University,

Director of Research Center for Orthopedic Biomechanics Khon Kaen University.

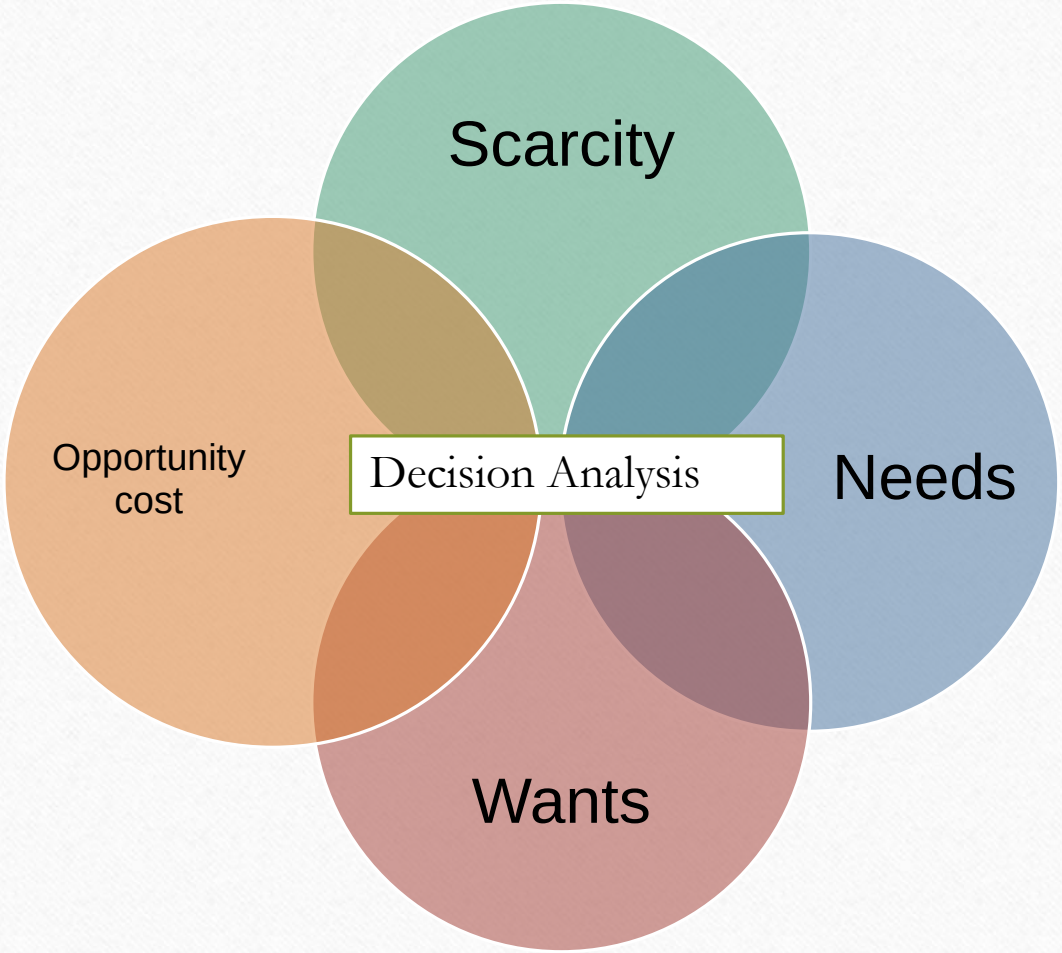
Topics of my talk

- What is Health and Clinical Economics and its principles.
- Types of Health Economics
- Costs and types and Discounting
- Decision analysis
- Types of economic evaluation
- Sensitivity analysis

What is Health?

- According to WHO constitution health is a state of complete physical, mental and social well being and not merely the absence of disease or infirmity
- "Health in health economic evaluation is health status according to some measures of resources available input for health and health-status outcomes.
- Economics deals with use of scarce resources to satisfy human wants and needs how best to use the resources available.

Principal of Economic evaluations



Health and Economics

- Health
  - Human behavior
  - Science
  - Hospital, clinic, nursing-home, Home health care
  - Patients- Relatives and Health Providers
- Economics
  - Human behavior
  - Science
  - Market
  - Buyer and Seller

Health care market

- กลุ่มผู้ให้บริการมีไม่มากกลุ่ม
- บริการทดแทนกันไม่ได้
- ผู้ให้บริการเป็นผู้กำหนดบริการและราคา
- ผู้ซื้อไม่ทราบคุณภาพและชนิดของบริการ
- แทรกแซงโดยรัฐ (Extensive government interventions)
- Intractable uncertainty in several dimension of both input and output data

Supplier induces demand

Types of Economics

- Microeconomics : unit cost, program evaluation
- Macroeconomics: Demand and Supply
- Trial-Based (RCT)Economic evaluation
- Modeling-Based Economic evaluation

Costs

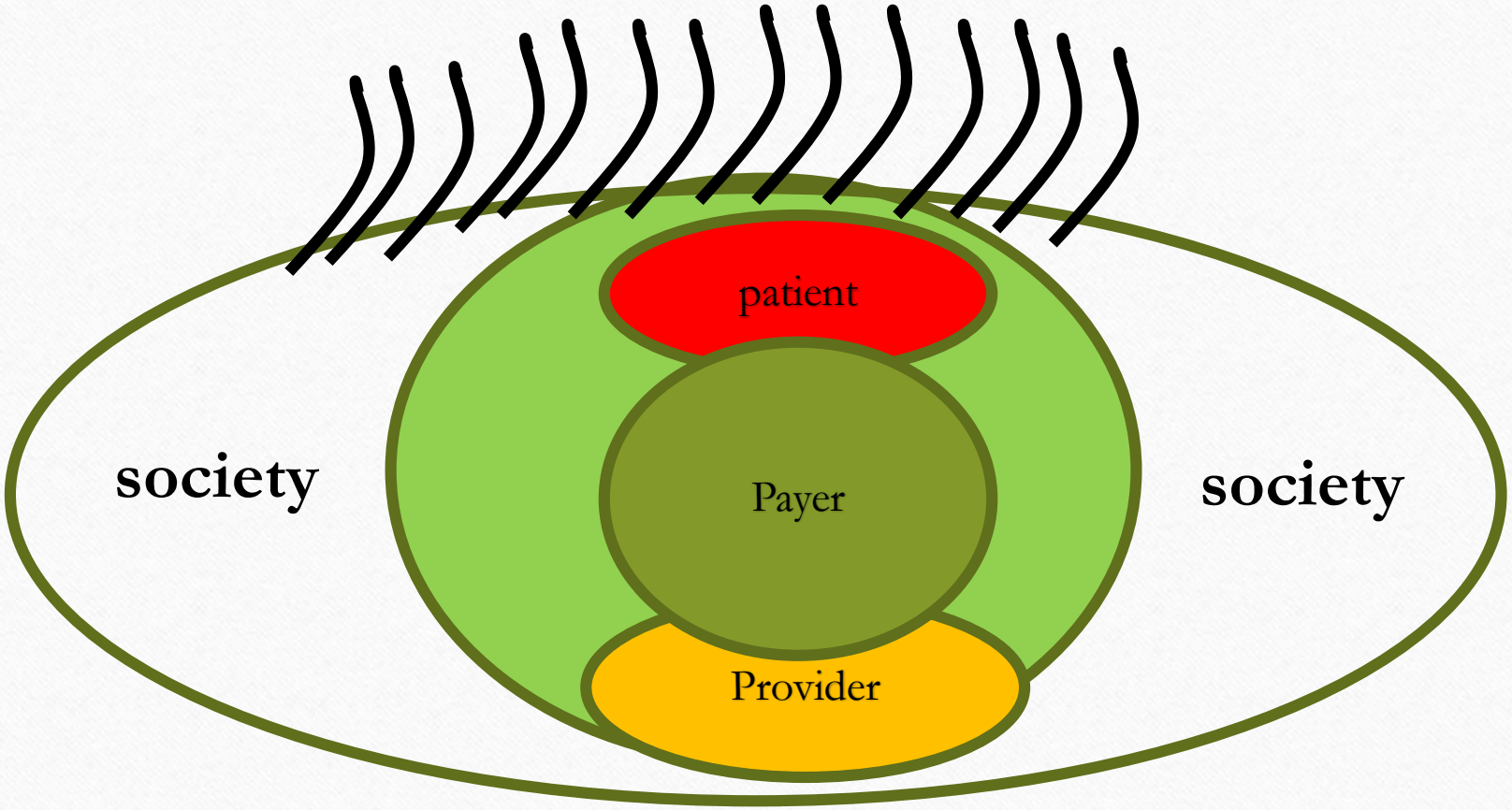
- Medical care cost
- Non-medical care cost
- Cost of productivity loss
- Cost of concerning (intangible cost)

Types of cost

1. Direct cost
   - Medical
     - •Hospital stay
     - •Drug
     - •X-ray
     - •Surgery
     - •Lab.
   - Non-Medical
     - •Traveling
     - •Food
     - •Baby sister
     - •Hotel
2. Indirect cost (Productivity loss)
3. Intangible cost

Point of Views

- Patient
- Provider
- Payer
- Society



How to do cost analysis

1. Identify
2. Measure
3. Value

Unit cost analysis in a university hospital: an example from Srinagarind Hospital, Khon Kaen.

Vatanasapt V, et al. J Med Assoc Thai. 1993.

Authors

Vatanasapt V[1], Kosuwon W, Pengsaa P.

Author information

[1] Department of Surgery, Khon Kaen University, Thailand.

Citation

J Med Assoc Thai. 1993 Dec;76(12):647-53.

Abstract

This is the first analytic study to identify the unit cost in the University Hospital using the standard method of analysis in health economics. The unit costs in the report can be used to calculate the cost of each service for any disease. The costs of the hospital administration cost center and the supportive cost center were both allocated to the patient care service center by the simultaneous allocation method. The cost of teaching personnel was excluded from the analysis because it is quite difficult to estimate and differentiate the ratio of teaching costs to

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THE TRUE COST OF RECYCLE SYRINGE COMPARED WITH DISPOSABLE SYRINGE AT SRINAGARIND HOSPITAL

การเปรียบเทียบต้นทุนที่แท้จริงของกระบอกฉีดยาชนิดแก้วกับชนิดพลาสติก

Weerachai Kosuwon (วีระชัย โควสุวรรณ) 1, Pensri Kosuwon (เพ็ญศรี โควสุวรรณ) 2

ได้ศึกษาเปรียบเทียบต้นทุนที่แท้จริงของกระบอกฉีดยาชนิดแก้ว และชนิดพลาสติกที่ใช้ในโรงพยาบาลศรีนครินทร์ตลอดปี 2530 ต้นทุนที่แท้จริงประกอบด้วยค่าแรง, มูลค่าปัจจุบันของเครื่องมือ เครื่องใช้ในการทำความสะอาดล้างและฆ่าเชื้อโรคของกระบอกฉีดยาชนิดแก้ว ตลอดจนค่าโสหุ้ยที่เกี่ยวข้องในหน่วยจ่ายกลางของโรงพยาบาล, ผลการศึกษาพบว่าอัตราการใช้กระบอกฉีดยาชนิดแก้วทุกขนาดมีจำนวนเท่ากับ 698,484 ครั้ง/ปี ต้นทุนที่แท้จริงของกระบอกฉีดยาชนิดแก้วมีค่าเท่ากับ 566,632 บาทต่อปี ในขณะที่ต้นทุนของกระบอกฉีดยาชนิดพลาสติกมีมูลค่า 1,808,850 บาทต่อปี ตัวแปรที่สำคัญที่จะทำให้ต้นทุนของกระบอกฉีดยาชนิดแก้วสูงขึ้น คือ จำนวนการแตกชำรุดของกระบอกฉีดยาชนิดแก้ว และอัตราค่าแรงงานของเจ้าหน้าที่หน่วยจ่ายกลาง, อย่างไรก็ตามจากการวิเคราะห์ความไวพบว่าถ้าอัตราการแตกชำรุดของกระบอกฉีดยาชนิดแก้วเกินร้อยละ 600 หรือค่าแรงงานของเจ้าหน้าที่เพิ่มขึ้นเป็น 6 เท่าของอัตราในปัจจุบันกระบอกฉีดยาชนิดพลาสติกจึงจะมีต้นทุนถูกกว่ากระบอกฉีดยาชนิดแก้ว โดยสรุป ควรใช้กระบอกฉีดยาชนิดแก้วต่อไป เพราะต้นทุนถูกกว่ากระบอกฉีดยาชนิดพลาสติกอย่างมาก

Abstract.

A comparative study of the true cost of recycled syringe and disposable syringe at Srinagarind hospital in 1987. The labour cost, present value of the capital cost and overhead cost of the central supply service department were taken into account. The result presented that the usage rates of all recycled syringes were 698, 484 per year. The total cost of recycled syringe was 566,632 bahts per year whereas that of disposable syringe was 1,808,850 bahts per year. There are two factors which might change the total cost of the recycled syringe such as the rates of broken-defective syringe and the labour cost. However the sensitivity analysis shows that the result is not sensitive to change by those factors. At the present time the use of recycled syringe is more economically than that of disposable syringe.

. . . Full text.

Cost analysis

- Cost is not a charge :

Item	cost	charge
CBC	102	68
Private ward (19)	1358	980
Appendectomy	5890	1500

Nursing care cost

Identify	Measure	value
Nursing care	•Working time (min) •Workload (NDNQI and ANA I. ICU II. Operating III. AE	Salary Baht/minute

NDNQI : National Database of Nursing Quality Indicator
ANA: American Nurses Association

The costs of intensive care

J Seidel PhD (D) FRCA
PC Whiting FRCA
DL Edbrooke FRCA

Table 1 Cost components used in the studies reviewed by Gyldmark[1]

• Overheads	• Medical time	• Nursing time
• Other staff	• Disposables	• Theatre
• Medicine	• Nuclear medicine	• Blood bank
• Radiology	• Ultrasound	• Biochemistry
• Microbiology	• Kitchen equipment	• Non-hospital costs

Discounting in Economic Evaluations

Health care interventions incur costs and outcomes over a number of years. Discounting seeks to take into account the impact of time on how those costs and outcomes are valued.

"In general, individuals prefer to experience a good health status or consume a product now relative to doing so in the future."

Discounting in Economic Evaluations in Health Care: A Brief Review

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The present value of future costs or outcomes is estimated by adjusting them using the discount rate, where *X* is the cost or outcome of interest, *r* is the discount rate, and *t* is the number of years into the future *X* occurs:

$$Present\ Value = \frac{X}{(1+r)^t}$$

The discounted present value of a cost or outcome of a given amount is lower the further into the future we discount.

Table 1: Hypothetical Cancer Screening Promotion

Year	Costs ($)	Benefits ($) undiscounted	Benefits ($) in 2014 values (r=5%)	Benefits ($) in 2014 values (r=10%)
2014	450	100	100	100
2015		100	$95 = 100/(1+0.05)^1$	$91 = 100/(1+0.10)^1$
2016		100	$91 = 100/(1+0.05)^2$	$83 = 100/(1+0.10)^2$
2017		100	$86 = 100/(1+0.05)^3$	$75 = 100/(1+0.10)^3$
2018		100	$82 = 100/(1+0.05)^4$	$68 = 100/(1+0.10)^4$
Total		**500**	**455**	**417**
Net Benefit		**50**	**5**	**-33**

Notes: r is the discount rate.
Superscripts represent *t*, being the number of years from the current year – 2014 – to which the numerator is raised to the power of.

Discounting in Economic Evaluations in Health Care: A Brief Review

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Table 2: Guidelines on Discounting in Selected Countries

Country	Discount rate		
	Costs	Health Outcomes	Sensitivity analysis
Australia (PBAC) [10]	5%	5%	0%
UK (NICE)** [11]	3.5%	3.5%	1.5%
France[9]	4% < 30 years, 2% ≥ 30 years	4% < 30 years, 2% ≥ 30 years	0% to 6%
Netherlands (CVZ)[8]	4%	1.5%	0%
Germany (IQWiG) [12]	3%	3%	0, 5, 7 and 10%
Finland[13]	3%	3%	0%
Portugal[14]	5%	5%	0% for health outcomes
Canada (CADTH)[15]	5%	5%	0% and 3%
New Zealand (PHARMAC) [16]	3.5%	3.5%	0, 5 and 10%

Abbreviations: CADTH denotes Canadian Agency for Drugs and Technologies in Health, CVZ College Voor Zorgverzekeringen, IQWiG Instituts für Qualität und Wirtschaftlichkeit im Gesundheitswesen, NICE National Institute for Health and Care Excellence, PBAC Pharmaceutical Benefits Advisory Committee, PHARMAC Pharmaceutical Management Agency.

- Standard practice (Evan& Hurley 1995 discount rate **5%/yr**.
- US Public Health (Gold et al. 1996) discount rate **3%/QALY gain**
- World Bank (Jamison et al. 1993 discount rate **3%**

Principal of Economic evaluations

- Cost, Consequences, and their times.
- Two or more alternatives
- Decision and Sensitivity analyses
- Point of views

Evaluation of Health Care

Are two or more options compared?	Are both costs & consequences examined?	
	No	**Yes**
No	Partial evaluation	Partial evaluation
Yes	Partial evaluation	**Full economic evaluation**

Economic evaluation

Input 1

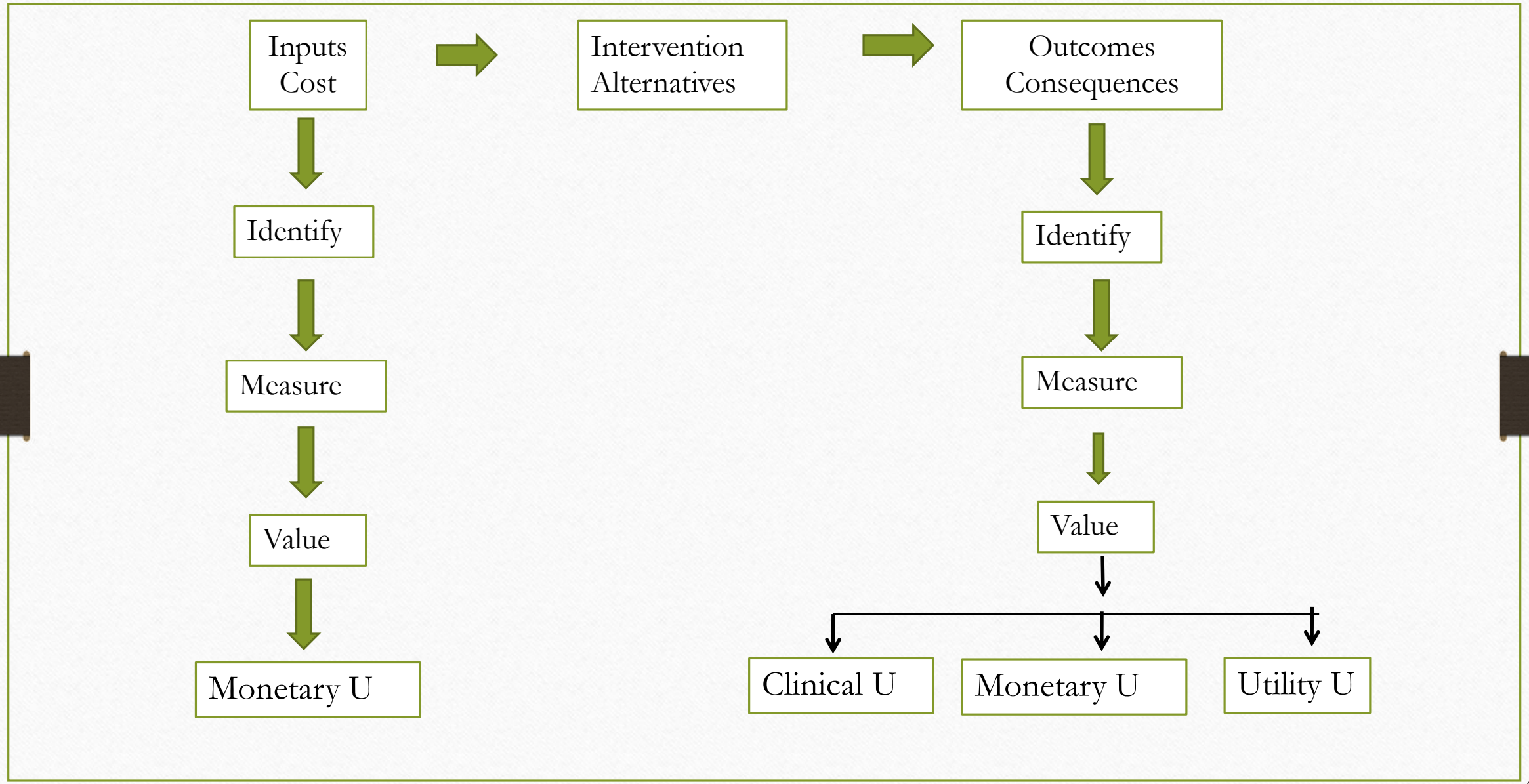
Input 2

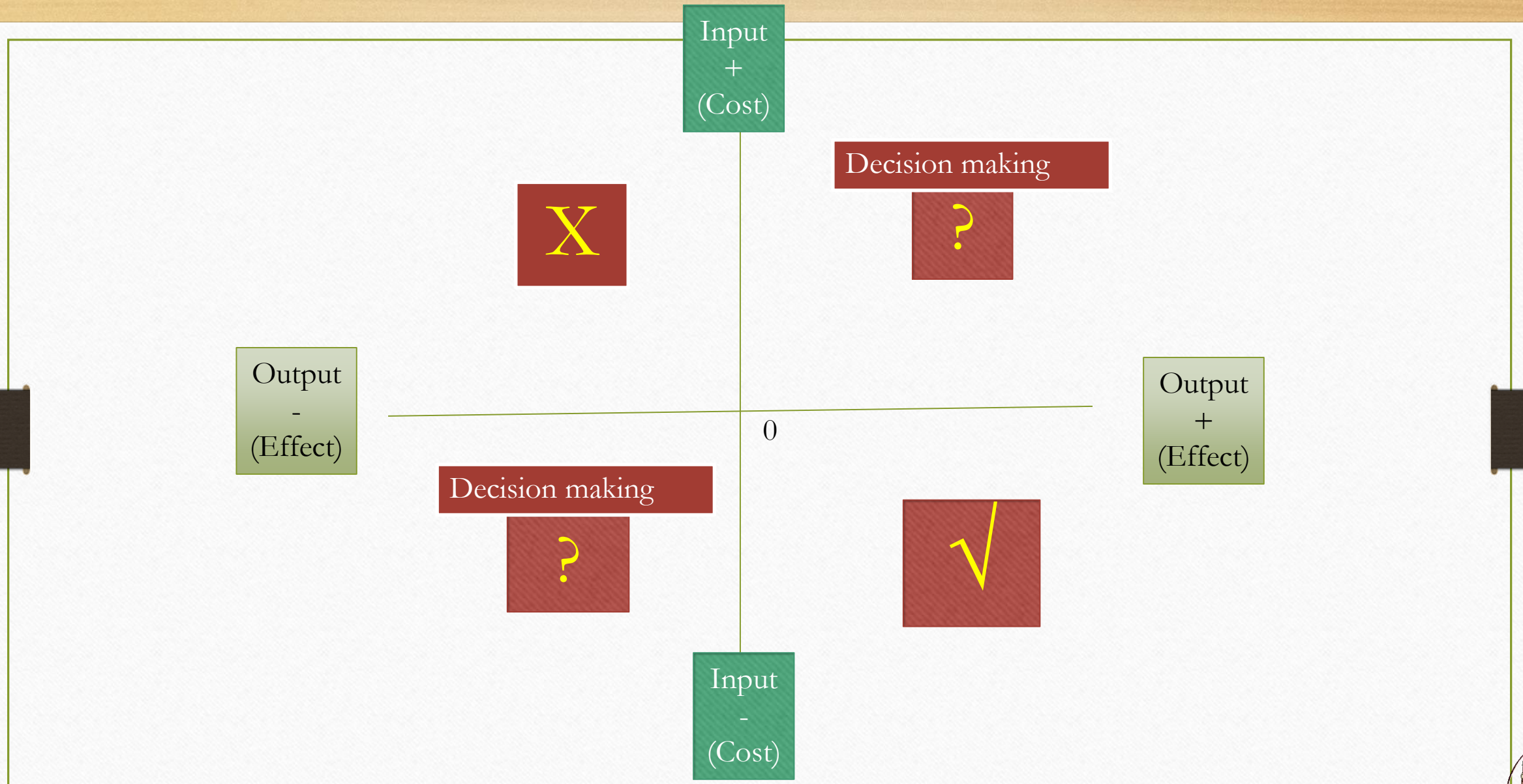
Output 1

Output 2

Economic efficiency = Output > input

Economic Evaluations





Decision analysis

- A systematic quantitative approach for assessing the relative value of one or more different decision options.

ขั้นตอนการเขียน decision tree

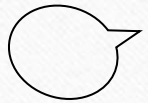
- กำหนดชนิดของการรักษา หรือ ทดสอบ
- เขียนเส้นกิ่งก้านของ ผลลัพธ์ที่น่าจะเกิดขึ้นในแต่ละการรักษาหรือทดสอบโดยเขียนเรียงลำดับการเกิดก่อนหลัง
- กำหนด ผลลัพธ์สุดท้ายไว้ส่วนสุดท้ายของแต่ละกิ่ง
- กำหนดและเขียนค่าความน่าจะเป็นของผลลัพธ์แต่ละอัน ค่าโอกาสของแต่ละกิ่งต้องรวมกันได้ 100 หรือ 1 เสมอ
- คำนวณค่าเฉลี่ยของความน่าจะเป็นของแต่ละกิ่งทางเลือกการรักษาหรือทดสอบ

สัญญาลักษณ์ต่างๆที่ใช้เขียน decision tree

- choice node

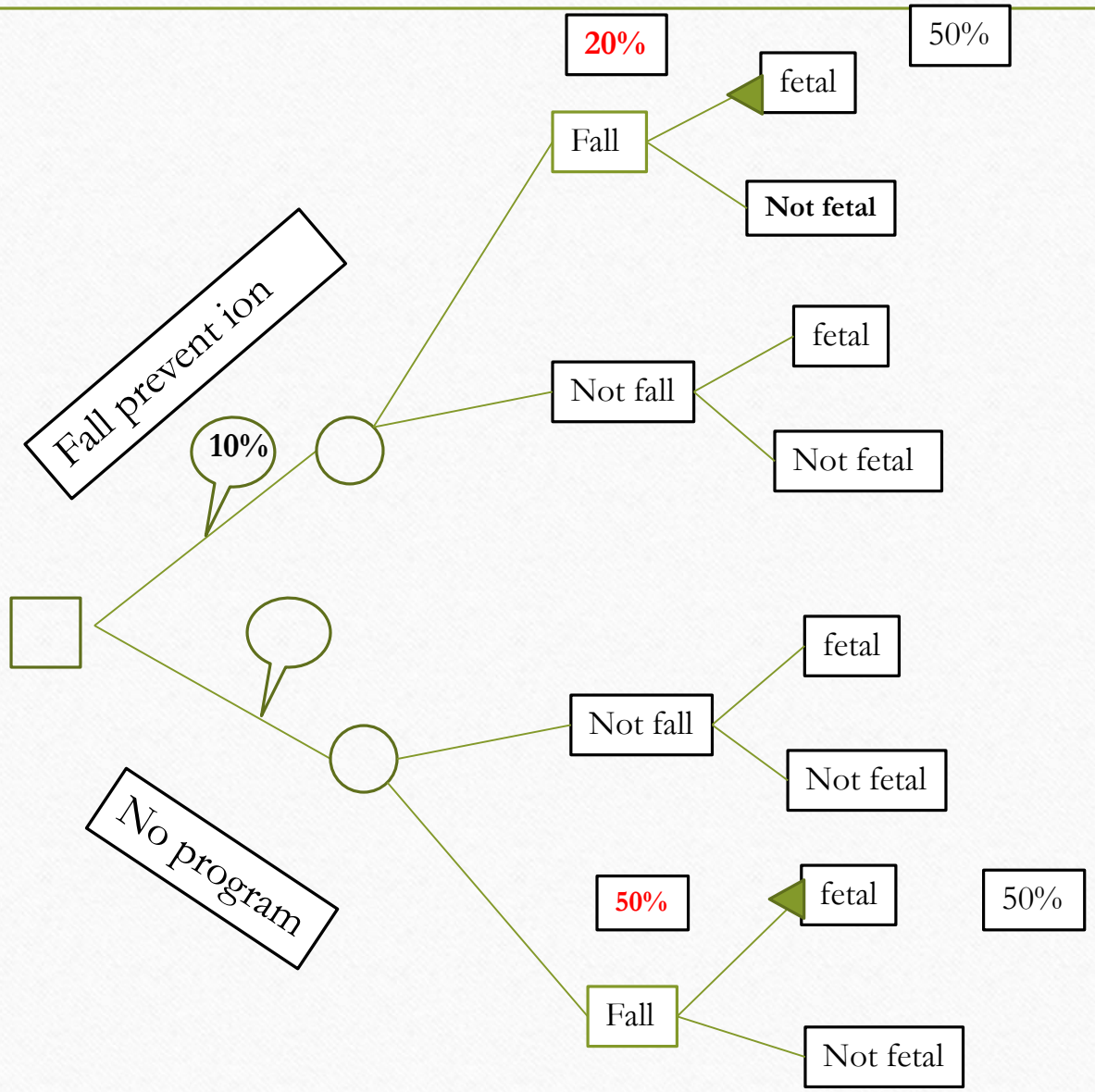
- chance node

- balloon



- final outcome

Decision Tree



1.Cost of preventive program
2.Cost of treatments due to fall

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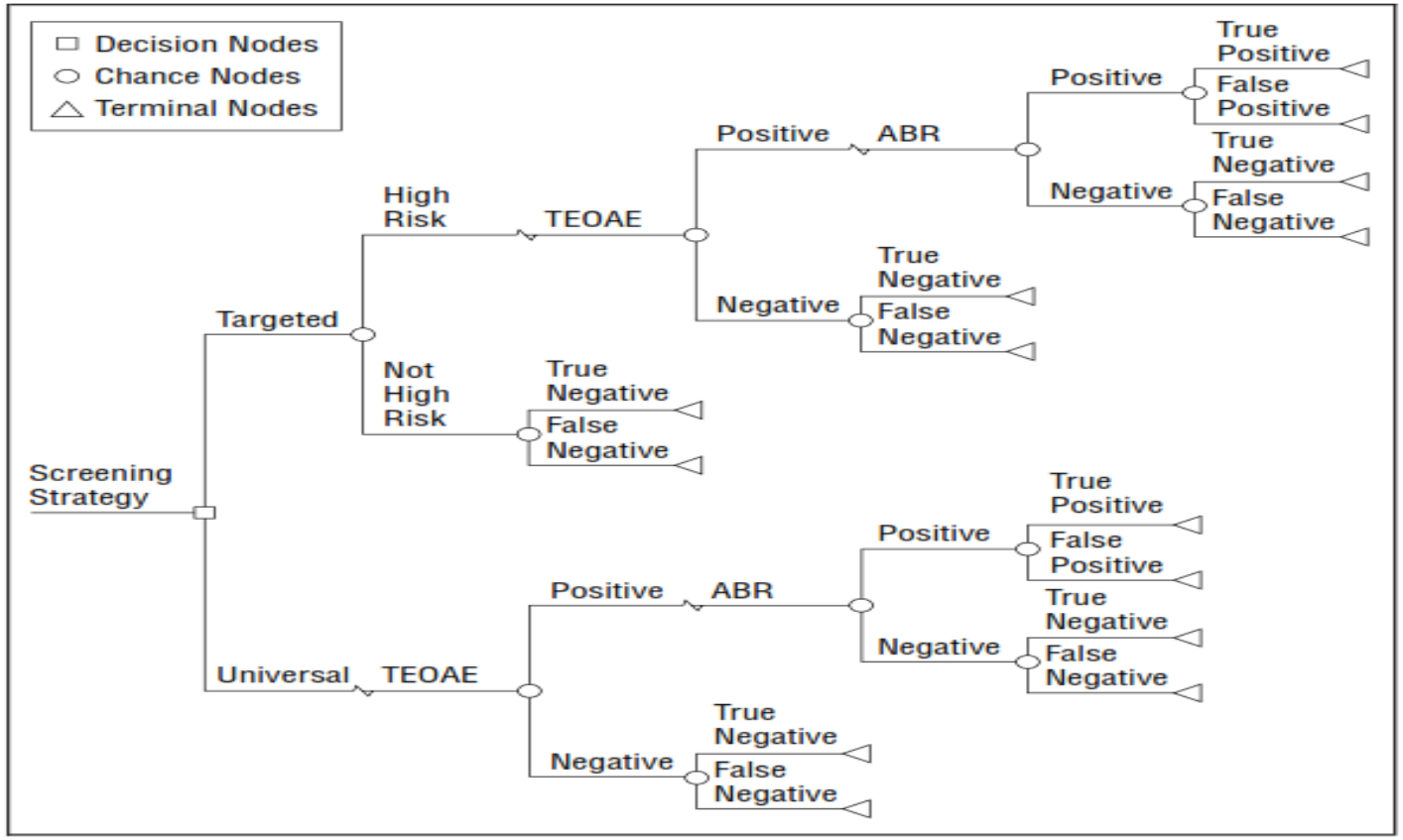
Alex R. Kem



Decision tree for 2-stage newborn hearing screening. With universal screening, all newborns received screening by transient evoked otoacoustic emission (TEOAE). Those with positive results were screened by automated auditory brainstem response (ABR). With targeted screening, newborns were first screened by risk assessment.

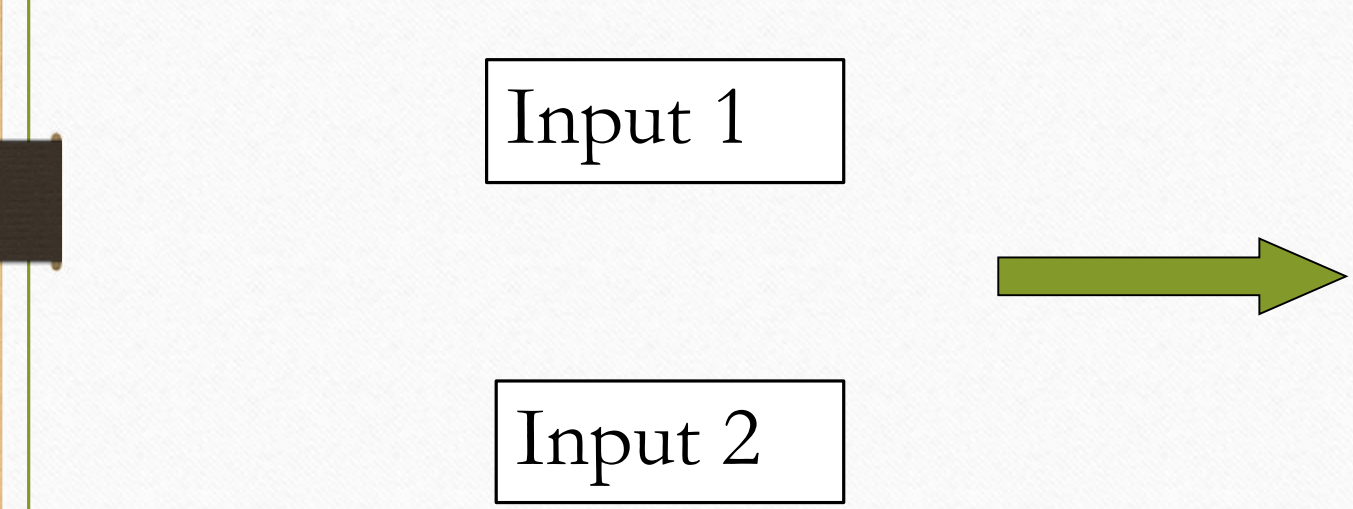
Arch Pediatr Adolesc Med. 2000;154:484-488

Economics Evaluations

- Cost-minimization analysis
- Cost-Effectiveness analysis
- Cost-Benefit analysis
- Cost-Utility analysis

Cost Minimization analysis

Cost-minimization analysis



Output 1 = Output 2

Equivalent studies
Non-inferiority trial
Systematic review

A cost-minimization analysis of diuretic-based antihypertensive therapy reducing cardiovascular events in older adults with isolated systolic hypertension

G John Chen*[1], Luigi Ferrucci[2], William P Moran[3] and Marco Pahor[3]

Drug Class	Commonly Prescribed	5-year Cost Per Patient	5-Year NNT	Total Cost
SHEP-based drug therapy		$456	15	$6,843
Beta-Blocker	Atenolol			
	25 mg daily	$1,255	15	$18,825
	50 mg daily	$1,245	15	$18,675
	100 mg daily	$1,792	15	$26,880
ACE inhibitor	Enalapril			
	5 mg daily	$2,031	15	$30,465
	10 mg daily	$2,132	15	$31,980
	20 mg daily	$3,034	15	$45,510
Alpha-Blocker	Terazosin			
	2 mg daily	$2,984	15	$44,760
	5 mg daily	$2,984	15	$44,760
	10 mg daily	$2,984	15	$44,760
Calcium channel blocker	Nifedipine			
	30 mg daily	$881	15	$13,215
	60 mg daily	$1,762	15	$26,430
	90 mg daily	$2,644	15	$39,660

Published: 25 January 2005

Cost Effectiveness and Resource Allocation 2005, **3**:2 doi:10.1186/1478-7547-3-2

Cost-M…in Treatm…

Shuyan Gu, Hengjin Do…, MPA[1],

Scenario	Price*	Annual treatment cost (¥)		Cost difference (¥)†	Saving in annual cost (%)‡
		Acarbose	Metformin		
Base case	Lowest	2260.08	1358.90	901.18	39.87
	Highest	2708.30	1598.70	1109.6	40.97
Patients with T2DM with weight ≤ 60 kg					
Scenario 1	Lowest	753.36	452.97	300.39	39.87
	Highest	902.77	532.90	369.87	40.97
Scenario 2	Lowest	2260.08	1811.86	448.22	19.83
	Highest	2708.30	2131.60	576.7	21.29
Scenario 3	Lowest	2216.74	1332.83	883.91	39.87
	Highest	2656.36	1568.04	1088.32	40.97
Scenario 4	Lowest	2216.74	1759.74	457	20.62
	Highest	2656.36	2070.28	586.08	22.06
Patients with T2DM with weight > 60 kg					
Scenario 1	Lowest	753.36	452.97	300.39	39.87
	Highest	902.77	532.90	369.87	40.97
Scenario 5	Lowest	4520.16	1358.90	3161.26	69.94
	Highest	5416.60	1598.70	3817.9	70.49
Scenario 6	Lowest	4520.16	1811.86	2708.3	59.92
	Highest	5416.60	2131.60	3285	60.65
Scenario 7	Lowest	4346.78	1332.83	3013.95	69.34
	Highest	5208.84	1568.04	3640.8	69.90
Scenario 8	Lowest	4346.78	1759.74	2587.04	59.52
	Highest	5208.84	2070.28	3138.56	60.25

T2DM, type 2 diabetes mellitus.

* Lowest, the lowest set by market; highest, the highest price set by government.

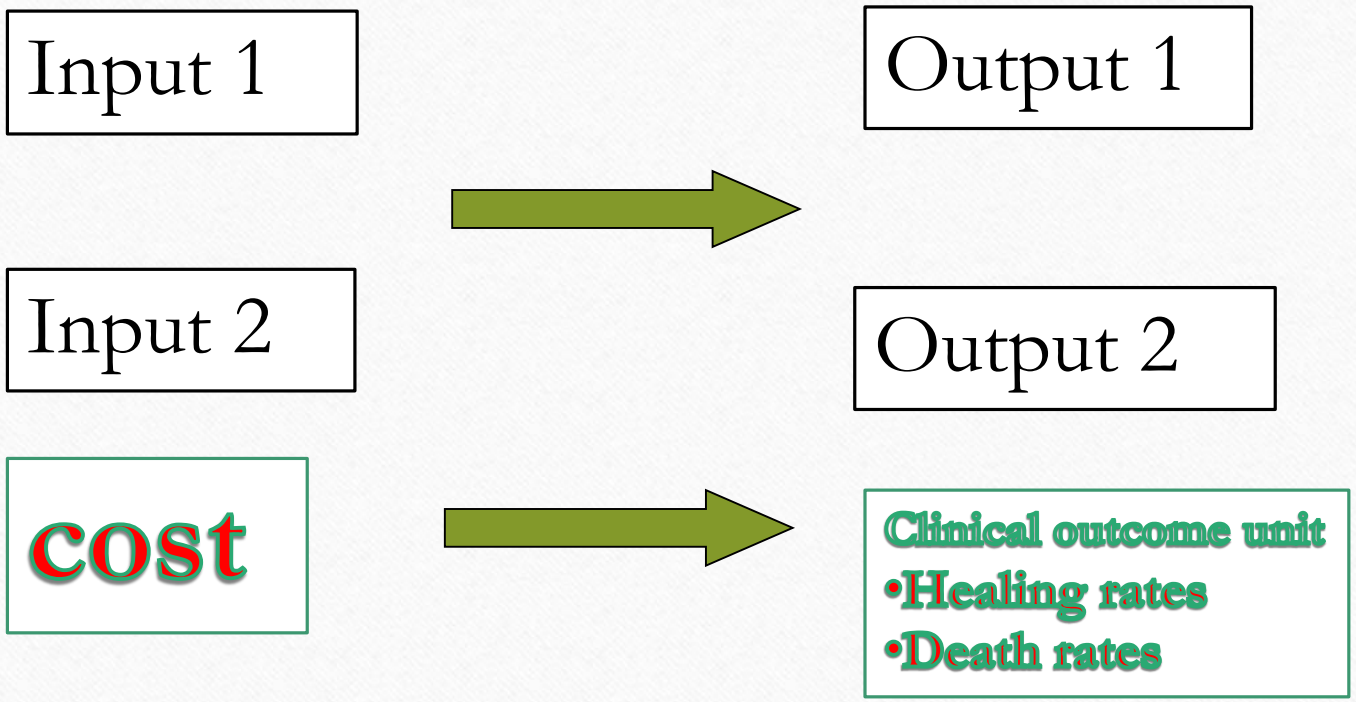
† Cost difference = annual cost of acarbose − annual cost of metformin.

‡ Saving in annual cost = (annual cost of acarbose − annual cost of metformin) × 100/annual cost of acarbose.

Cost-effectiveness analysis

Incremental Cost-Effectiveness analysi

Cost-effectiveness analysis



Cost-effectiveness ratio

Input A
(24,000 baht of Duloxatine treatment Program in 100 cases)

Output A
(Number of patient painless = 85 cases

$$\text{Cost-effectiveness ratio in A} = \frac{\text{Cost A}}{\text{Output A}}$$

$$= \frac{\text{12,000 baht}}{\text{45 cases}}$$

= 266 baht/case

Cost-effectiveness ratio in Dulox $= \frac{\text{cost Dulox}}{\text{Output Dulox}}$

$= \frac{\text{24,000 baht}}{\text{85}}$

= 282 baht/case

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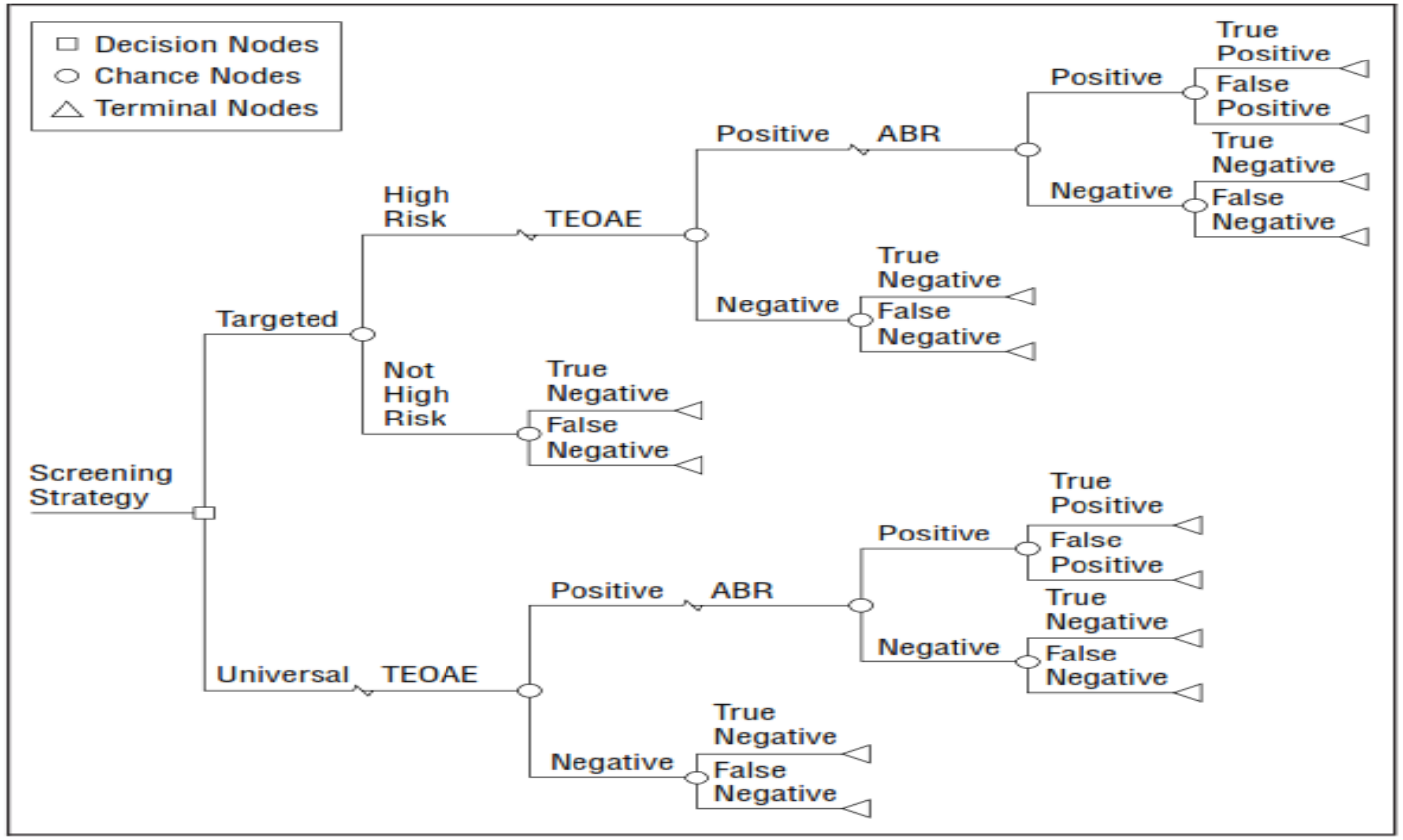

Decision tree for 2-stage newborn hearing screening. With universal screening, all newborns received screening by transient evoked otoacoustic emission (TEOAE). Those with positive results were screened by automated auditory brainstem response (ABR). With targeted screening, newborns were first screened by risk assessment.

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Table 1. Probability Estimates*

Parameter	Baseline Estimate (Range), %	References
Prevalence of hearing loss	0.11 (0.10-0.59)	1, 2, 9, 20
Risk screening		
Sensitivity	59 (50-64)	5, 6, 9, 17, 18
Specificity	95 (91-99)	5, 6, 9, 17, 18
Automated TEOAE		
Sensitivity	80 (66-100)	20, 21
Specificity	92 (91-93)	21
Automated ABR		
Sensitivity	98 (80-100)	1, 19
Specificity	96 (86-98)	1, 19

**TEOAE indicates transient evoked otoacoustic emission; ABR, auditory brainstem response.*

Table 2. Cost Estimates*

Parameter	Baseline Estimate (Range), $	References
Risk screening	1.00 (0.50-15.00)	5, 18, AE
Automated TEOAE	7.42 (5.00-15.00)	22, AE
Automated ABR	25.00 (15.00-40.00)	23, 24
Diagnostic ABR	150.00 (100.00-200.00)	20, AE

Table 3. Baseline Results for 100 000 Newborns Screened*

Strategy	No. of Cases Detected	No. of False Positives	Total Cost, $	Cost per Case Detected, $
Targeted screening	51	16	158 860	3120
Universal screening	86	320	1 004 860	11 650

Incremental cost-effectiveness ratio (ICER)

An important principle in the calculation of ICER dictated by the economic theory underlying health economics research, is that each relevant strategy should be compared with the next best alternative, based on the economic concept of "opportunity costs"

"ถ้าจะเลือกการรักษาที่ให้ผลดีกว่าเดิม 1 หน่วยต้องลงทุนเพิ่ม(ลด)ขึ้น(ลง) เท่าใด"

$$\text{ICER} = \frac{\text{Cost new} - \text{Cost reference}}{\text{Effect of new} - \text{Effect of reference}}$$

J Am Coll Cardiol. 2008 December 16; 52(25): 2119–2126. doi:10.1016/j.jacc.2008.09.018.

$$ICER = \frac{\text{cost New pain killer} - \text{cost Reference pain killer}}{\text{Number of painless patients in New} - \text{Number of painless in Reference}}$$

$$= \frac{24{,}000 - 12{,}000}{85 - 45}$$

CR of New= 24,000/85= 282/case
CR of Reference= 12000/45= 266/case

$= (12{,}000/40)$

$= (300/1)$

= **ลงทุนเพิ่มขึ้น 300 บาท เพื่อเพิ่มจำนวน ผป ที่ไม่ปวด 1 คน**

Cost-Benefit analysis

Cost-Benefit analysis

- เป็นการวิเคราะห์เปรียบเทียบต้นทุนและผลได้(consequence) โดยผลได้จะวัดออกมาเป็นรูปตัวเงิน

Cost (input) → Cost (output)

- **สามารถ**เปรียบเทียบโครงการหรือการรักษาที่วัดผลได้ทางคลินิกที่แตกต่างกันได้

โครงการป้องกันการเกิดข้อเข่าเสื่อม vs. โครงการป้องกันการเกิดความดันโลหิตสูง

ข้อเสีย การตีค่าเป็นเงินของ output

Net Benefit= $(\text{Benefit}_T - \text{Cost}_T) - (\text{Benefit}_C - \text{Cost}_C)$

$(2000 - 1000) - (700 - 500)$

$= (\text{Benefit}_T - \text{Benefit}_C) - (\text{Cost}_T - \text{Cost}_C)$

$(2000 - 700) - (1000 - 500)$

$= +800$

Positive net benefit means the treatment group is more benefit than the control group 800 unit.

Cost-Benefit Analysis from the Hospital Perspective of Universal Active Screening Followed by Contact Precautions for Methicillin-resistant *Staphylococcus aureus* Carriers

James A. McKinnell, MD[1,2], **Sarah M. Bartsch, MPH**[3,4], **Bruce Y. Lee, MD, MBA**[3], **Susan S. Huang, MD, MPH**[5], and **Loren G. Miller, MD, MPH**[1]

Cost-Benefit Analysis

The economic impact of adopting a universal surveillance and contact precautions program was based on the difference between the benefits (i.e., cost-savings from averting MRSA infections) and intervention costs. For each simulation, the economic impact to the hospital for each screening strategy was calculated as:

(Number Infections Averted × MRSA Attributable Length of Stay × Cost of Lost Bed Day) – (Cost of Contact Precautions + Cost of Screening)

The optimal strategy was defined as the strategy with the best cost-benefit to the hospital; i.e. cost-neutral (costs = benefit) or cost-saving (cost<benefit).

Infect Control Hosp Epidemiol. 2015 January ; 36(1): 2–13. doi:10.1017/ice.2014.1.

Costs and Benefit [mean (95% credibility interval)] per 10,000 admissions with baseline MRSA prevalence on admission, a 6-day attributable MRSA length of stay, and an extreme contact precaution efficacy estimate (0.03 infections averted per MRSA colonized patient isolated)

	Chromogenic Agar Screening			PCR Screening		
Total number of MRSA colonized patients	953 (780 - 1,140)			946 (770 - 1,140)		
Body Site(s) Tested	**Nares**	**Nares/Oropharynx**	**Multi Site Swab**	**Nares**	**Nares/Oropharynx**	**Multi Site Swab**
Patients Correctly Identified as Colonized	542 (410 - 680)	680 (530 - 820)	786 (630 - 950)	575 (430 - 730)	720 (560 - 890)	824 (660 - 1,000)
Patients Placed in Contact Precautions	622 (470 - 760)	758 (590 - 920)	863 (690 - 1,040)	915 (740 - 1,110)	1,054 (870 - 1,250)	1,155 (960 - 1,370)
Intervention Cost	$251,555 (205,554 - 299,868)	$304,142 (250,214 - 353,933)	$346,774 (292,645 - 402,702)	$571,564 (515,439 - 632,775)	$625,012 (566,246 - 690,416)	$666,295 (601,959 - 733,215)
Swabs	$10,000	$20,000	$30,000	$10,000	$20,000	$30,000
Testing *	$46,876 (46,740 - 47,006)	$46,876 (46,740 - 47,006)	$46,876 (46,740 - 47,006)	$275,455 (275,165 - 275,715)	$275,455 (275,165 - 275,715)	$275,455 (275,165 - 275,715)
Gloves	$11,583 (8,841 - 14,452)	$14,119 (10,941 - 17,159)	$16,061 (12,867 - 19,366)	$17,025 (13,750 - 20,763)	$19,610 (16,127 - 23,420)	$21,475 (17,658 - 25,422)
Gowns	$117,659 (90,020 - 146,384)	$143,386 (110,867 - 173,361)	$163,125 (130,381 - 196,500)	$172,913 (139,405 - 209,892)	$199,178 (164,097 - 238,282)	$218,074 (179,641 - 258,298)
Nursing Time	$65,437 (49,952 - 82,027)	$79,762 (61,666 - 96,407)	$90,713 (72,656 - 109,830)	$96,171 (77,118 - 116,404)	$110,768 (90,856 - 133,000)	$121,293 (99,495 - 143,780)
MRSA Infections Avoided	16 (12 - 20)	20 (16 - 25)	24 (19 - 29)	18 (13 - 22)	22 (17 - 27)	25 (20 - 30)
Cost Averted	$147,777 (110,142 - 186,002)	$143,386 (110,867 - 173,361)	$163,125 (130,381 - 196,830)	$158,993 (121,130 - 199,233)	$196,630 (152,043 - 243,162)	$223,685 (176,000 - 272,216)
Cost-Benefit ^	−$103,778 (−$83,491 - −$126,252)	−$119,474 (−$97,905 - −$143,518)	−$133,349 (−$110,865 - −$157,160)	−$412,571 (−$376,833 - −$452,963)	−$428,381 (−$392,508 - −$469,522)	−$442,609 (−$405,763 - −$481,495)
Gain vs. Loss	**Loss**	**Loss**	**Loss**	**Loss**	**Loss**	**Loss**

* Includes test materials and technician labor to process sample; Multiple samples were tested by splitting Chromogenic Agar plates and combining samples for PCR runs

^ Negative values indicate a economic loss to hospital given a $0 break-even threshold

Costs and Benefit [mean (95% credibility interval)] per 10,000 admissions under baseline conditions (contact precautions avert 0.005 MRSA infections per carrier isolated and a 6 day attributable length of stay for MRSA infection)

	Chromogenic Agar Screening			PCR Screening		
Total Number of MRSA Colonized Patients	954 (770 - 1,106)			955 (780 - 1,150)		
Body Site(s) Tested	**Nares**	**Nares/Oropharynx**	**Multi Site Swab**	**Nares**	**Nares/Oropharynx**	**Multi Site Swab**
Patients Correctly Identified as Colonized	545 (420-684)	683 (540-863)	786 (630-943)	577 (440 - 720)	723 (560 - 890)	832 (670 - 1,010)
Patients Placed in Contact Precautions	625 (490-766)	761 (600-950)	864 (700-1,020)	921 (740 - 1,110)	1,060 (870 - 1,260)	1,164 (980 - 1,370)
Intervention Cost	$252,234 (209,295 - 299,142)	$304,977 (254,186 - 359,529)	$347,253 (293,332- 397,025)	$573,179 (514,179 - 641,748)	$626,601 (565,180 - 701,205)	$669,420 (608,348 - 732,835)
Swabs	$10,000	$20,000	$30,000	$10,000	$20,000	$30,000
Testing *	$46,879 (46,747-47,062)	$46,879 (64,747-64,062)	$46,879 (46,747-47,062)	$275,451 (275,201 - 285,451)	$275,451 (275,201 - 285,451)	$275,451 (275,201 - 285,451)
Gloves	$11,618 (9,074-14,308)	$14,163 (11,185-17,533)	$16,087 (12,915-19,224)	$17,117 (13,680 - 20,625)	$19,716 (16,035 - 23,655)	$21,657 (18,014 - 25,502)
Gowns	$118,046 (92,456-145,878)	$143,880 (113,479-176,394)	$163,414 (131,081-192,441)	$173,878 (138,931 - 209,645)	$209,645 (162,818 - 239,539)	$219,971 (183,116 - 257,964)
Nursing Time	$65,691 (51,017-81,893)	$80,054 (62,774-98,540)	$90,873 (72,574-108,297)	$96,733 (76,587 - 116,027)	$111,416 (90,620 - 132,810)	$122,341 (102,017 - 143,661)
MRSA Infections Avoided	2.7 (2.1-3.4)	3.4 (2.7-4.3)	3.9 (3.2-4.7)	2.9 (2.2 - 3.8)	3.6 (2.8 - 4.6)	4.2 (3.4 - 5.1)
Cost Averted	$24,740 (18,930-30,963)	$30,904 (24,162-38,740)	$35,552 (28,137-42,757)	$26,596 (20,184 - 33,422)	$32,914 (25,779 - 40,879)	$37,630 (30,311 - 45,562)
Cost-Benefit ^	**−$227,494** (189,867 - 273,610)	**−$274,072** (233,858 - 322,300)	**−$311,701** (279,386 - 360,541)	**−$546,583** (493,450 - −599,579)	**−$593,937** (−536,988 - −651,979)	**−$631,790** (−577,609 - −689,002)
Gain vs. Loss	**Loss**	**Loss**	**Loss**	**Loss**	**Loss**	**Loss**

Cost-Utility analysis

Utility

- Utility is the value or worth of a level of health as measured by preferences of an individual or society.
- Cost Utility analysis is one form of cost-effectiveness analysis which allowa the comparison of different health outcomes by measuring them all in term of a single unit (Quality adjusted life years, QALYs and Disability adjusted life years, DALY)

Cost-Utility analysis

- เปลี่ยนการตีค่า output หรือ consequence เป็น Utility unit หรือ quality of life score
- วิธีวัด utility score

    1. Visual analog scale
    2. Time-trade off
    3. Standard gamble
    4. Other methods (AQoL, EuroQol, Health Utility Index)

Utility score

Health state	Utility score
Migraine relief with no recurrence	1
Migraine relief, recurrence within 24 hr.	0.9
No relief, and patient endures migraine episode	0.3
No relief, patient attends emergency room, finds relief	0.1
No relief, patient attends emergency room, find no relief and hospitalized	-0.3

Utility Measurement
EuroQo (EQ-5D)

1. Mobility
2. Self-care
3. Usual activity
4. Pain/discomfort
5. Anxiety/depression

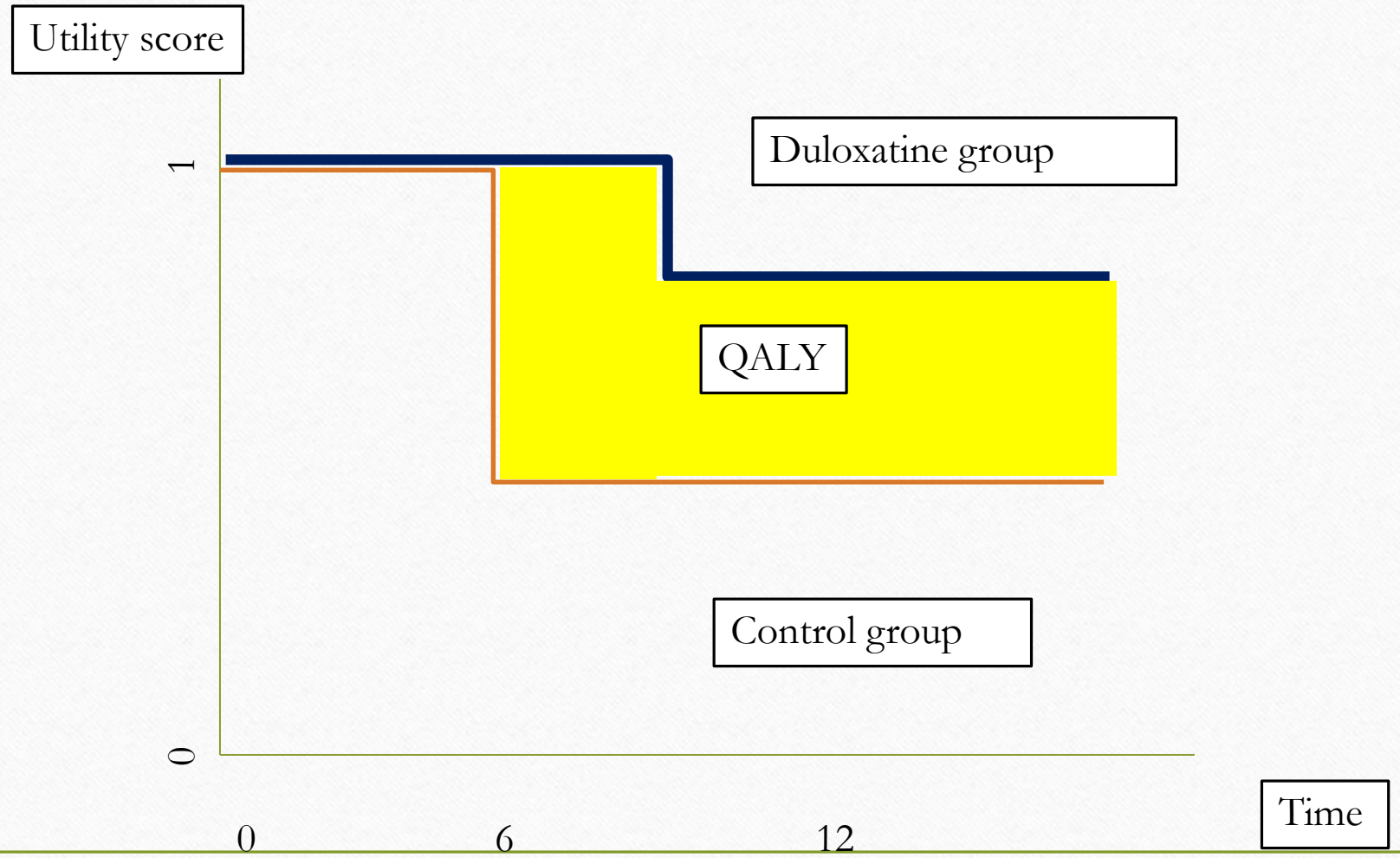
Each attribute has three levels:

1. No problem
2. Some problem
3. Major problem

Recent revised (added two health status: unconscious and dead)

Dolan et al. 1996

Quality-adjusted life-year (QALY)

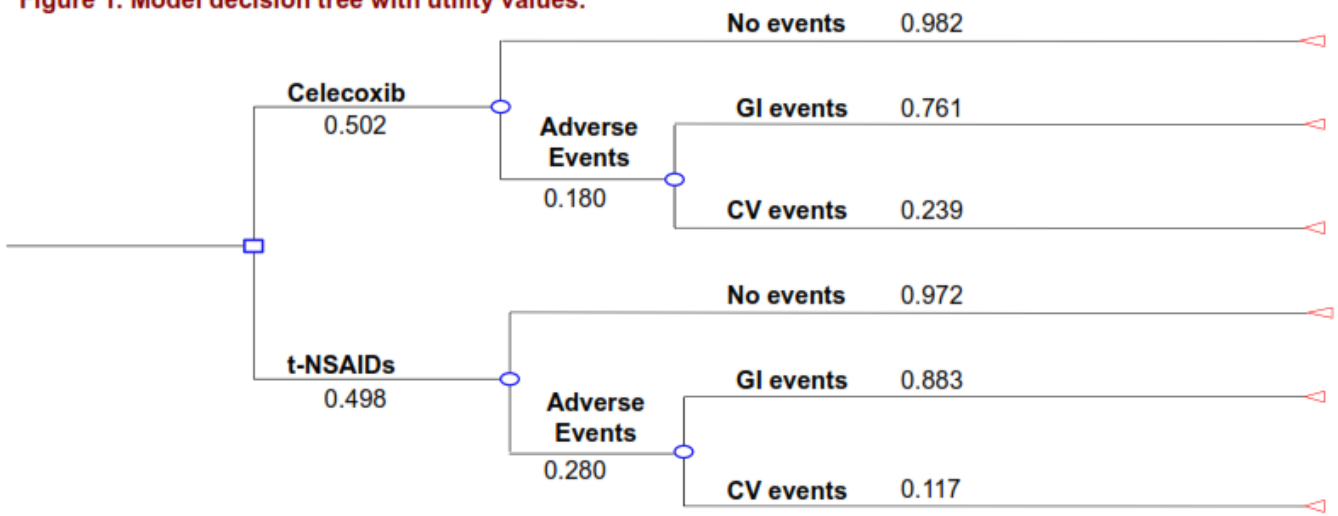


COST-EFFECTIVENESS OF CELECOXIB AND NON STEROIDAL ANTI-INFLAMMATORY DRUGs THERAPY FOR THE TREATMENT OF OSTEOARTHRITIS IN SPAIN: A DECISION-TREE MODEL

Alfonso de Lossada Juste[1,2], Ángel Oteo Álvaro[3], Javier Rejas Gutiérrez[2]

[1]Master program in Health Technology Appraisal and Market Access, Universidad Carlos III, Getafe (Madrid), Spain; [2]Health Economics and Outcomes Research Department, Pfizer, S.L.U., Alcobendas (Madrid), Spain; [3]Department of Orthopedic Surgery and Traumatology, Hospital General Universitario Gregorio Marañón, Madrid, Spain

Figure 1. Model decision tree with utility values.



- Compared with t-NSAIDs, celecoxib treatment had higher drug costs than traditional NSAIDs (€119 vs. €34), and the overall treatment cost was estimated at €201 and €157, respectively.
- Celecoxib was associated with slightly increase in QALY gain and significant lower incidence of gastrointestinal events ($p<0.001$) with mean ICERs of €13,286 per QALY gained and €4,471 per event averted (Table 3).
- Probabilistic and univariate sensitivity analyses were robust and confirmed results of the base case scenario.

Table 3. Cost-effectiveness analysis in the base case scenario

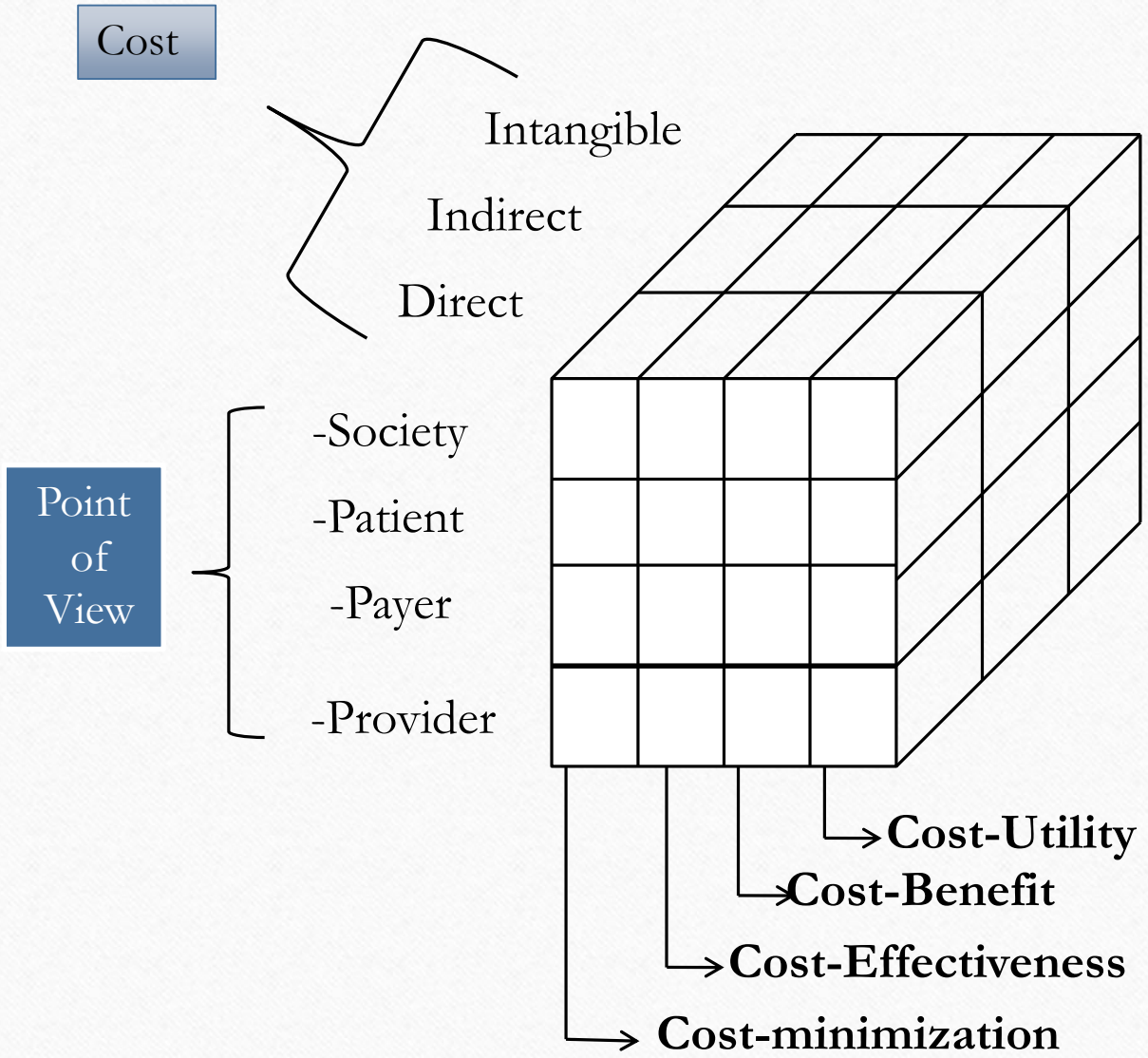
	Celecoxib	t-NSAID	Difference	ICER
Treatment cost (Drugs) / Patient	119 €	34 €	86 €	
GI Events cost / Patient	57 €	104 €	-47 €	
CV events cost / Patient	24 €	19 €	5 €	
Treatment cost (Total) / Patient	201 €	157 €	44 €	
Total events	71	111	-40	
Utility (QALY/patient)	0.9938	0.9905	0.0033	
ICER (€/QALY)				13,286
Cost event averted (€)				4,471

t-NSAID: non-selective non steroidal anti-inflammatory drug, ICER: Incremental Cost Effectiveness Ratio, QALY: Quality-adjusted life year. GI: GastroIntestinal, CV: Cardiovascular.

Economic analyses

Types of analysis	Input	Output
Cost-minimization	Cost	Clinical outcome
Cost-effectiveness	Cost	Clinical outcome
Cost-benefit	Cost	Cost
Cost-utility	Cost	Utility score/QALY

Three-dimension of Economic Analysis



Ceiling Ratio

$$ICEA = \frac{\text{Cost T- Cost C}}{\text{Effect T – Effect C}} = \frac{\blacktriangle \text{ Cost}}{\blacktriangle \text{ Effect}} < \textbf{Ceiling Ratio}$$

Ceiling Ratio = 50,000 C$/ QALYs <100,000 C$*

=40,000 A$/QALYs <70,000 A$**

*Laupacis A, Feeny D 1992; CMAJ 146(4).473-81

**George, Harris , Mitchell 2000 Pharmaceutical Benefits Schedule

Ceiling ratio

US$ 50,000 per QALY

Owens DK. Interpretation of cost-effectiveness analysis. *J Gen Intern Med* 1998
Paltiel AD, et al. Resource allocation and the funding of HIV prevention.
In Handbook of Economic Evaluation of HIV Prevention Programs. 1998

AU$ 42,000-76,000 per QALY

George B, et al. *Pharmacoeconomics* 2001

Ceiling ratio

- 2-3 times of per capita GDP per QALY

World Bank. The 1993 World Development Report,
Investing in Health.
Oxford University Press, Washington DC

- 3 times of per capita income* per QALY

Commission on Macroeconomics and Health.
Investing in Health for Economic Development.
WHO, 2001.

- In 2015, GDP per capita for Thailand = 5,720 US)

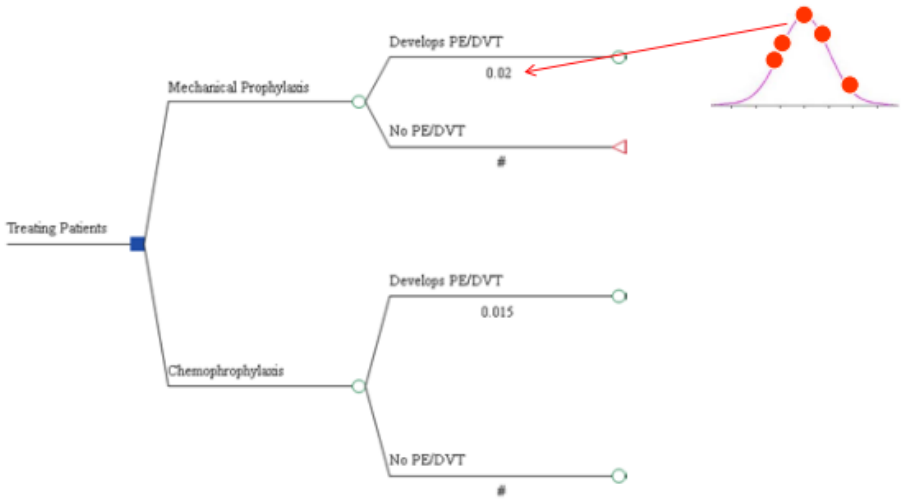
The World Bank

1103-1109.

Sensitivity analysis

- Method to evaluate the stability of the conclusions of an analysis to assumptions made and uncertainty variables in model ***inputs*** affects the model ***outputs***

Varying point estimates
(TreeAge model)



Types of inputs

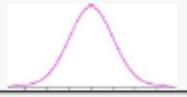
- Cost
- Health Effect
  - Life Years Saved
  - Utilities
  - Cases of Disease Avoided
  - Infections Cured
- Probabilities
- Discount Rate

Types of sensitivity analysis

- Deterministic sensitivity analysis
- Probabilistic sensitivity analysis

DSA versus PSA

Example: Cost input, cost of outpatient visit

	DSA	PSA
Base case	$100	$100
Input	$80, $90, $110, $120	
Results	ICER A (when cost is $80) ICER B (when cost is $90) ICER C (when cost is $110) ICER D (when cost is $120)	The mean ICER when we vary the base-case using a normal distribution with a mean of $100 and standard deviation of $10 is X, using 1000 iterations

Types of sensitivity analysis

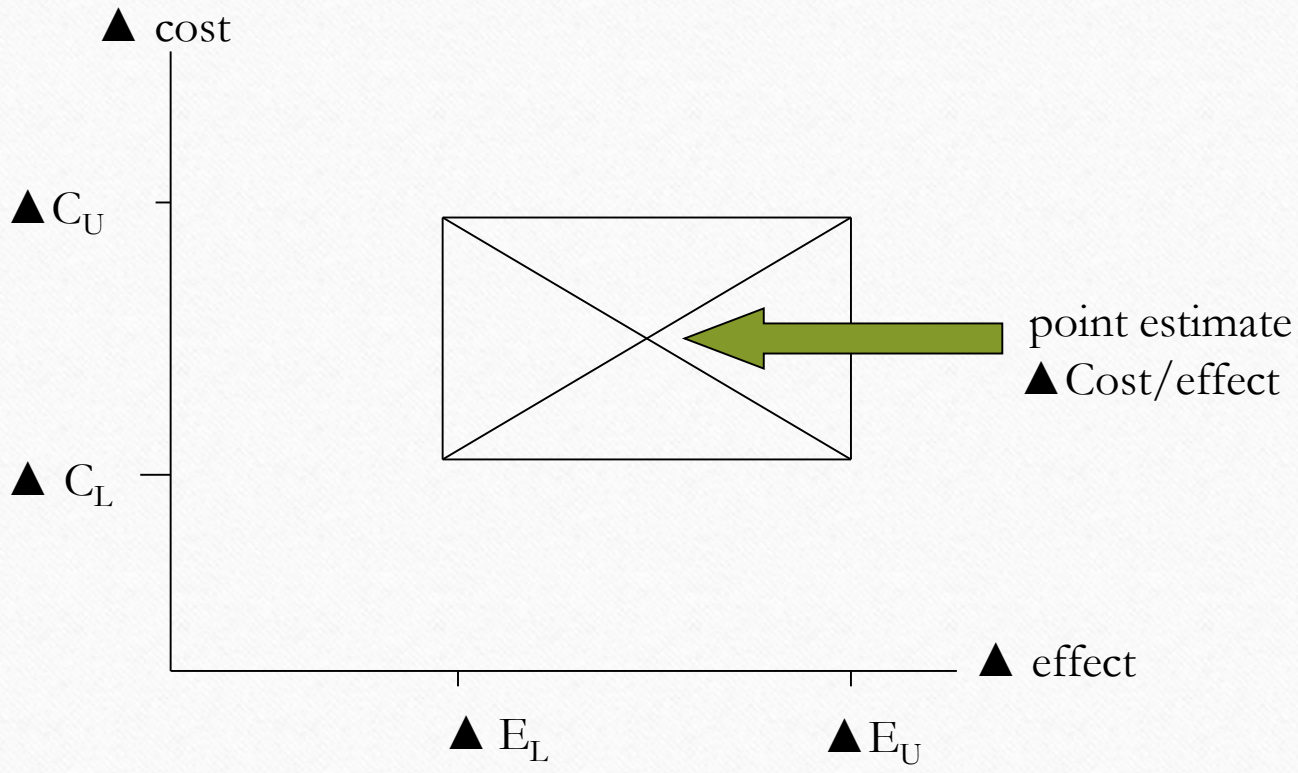
- One way sensitivity analysis
- Two ways sensitivity analysis
- Tornado Diagrams
- N-ways or multi-ways sensitivity analysis

Methods for calculation

1.Simple method

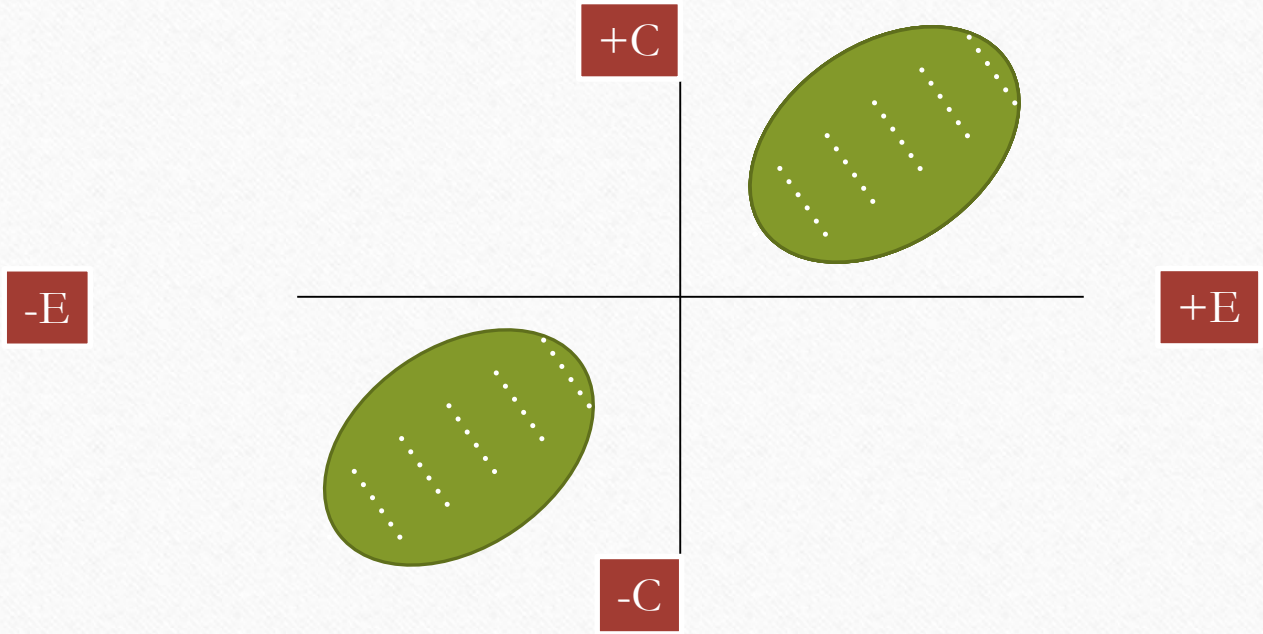
2. Probability method (Monte Carlo)

95% confidence interval of▲ CE ratio (Deterministic Sensitivity analysis)



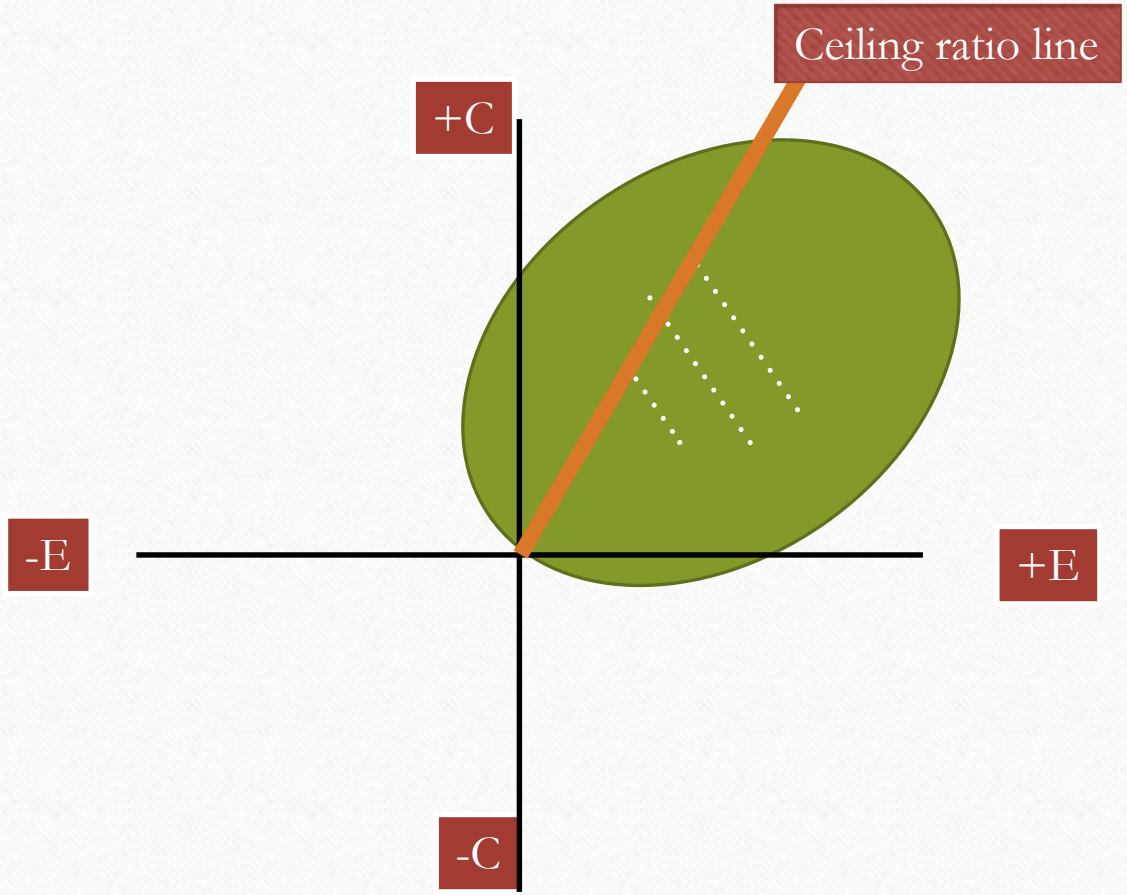
Probabilistic Sensitivity analysis

- Confidence interval of estimation of cost-effectiveness ratio or cost-utility ratio



Probabilistic Sensitivity analysis

- Confidence interval of estimation of cost-effectiveness ratio or cost-utility ratio



COST-EFFECTIVENESS OF CELECOXIB AND NON STEROIDAL ANTI-INFLAMMATORY DRUGs THERAPY FOR THE TREATMENT OF OSTEOARTHRITIS IN SPAIN: A DECISION-TREE MODEL

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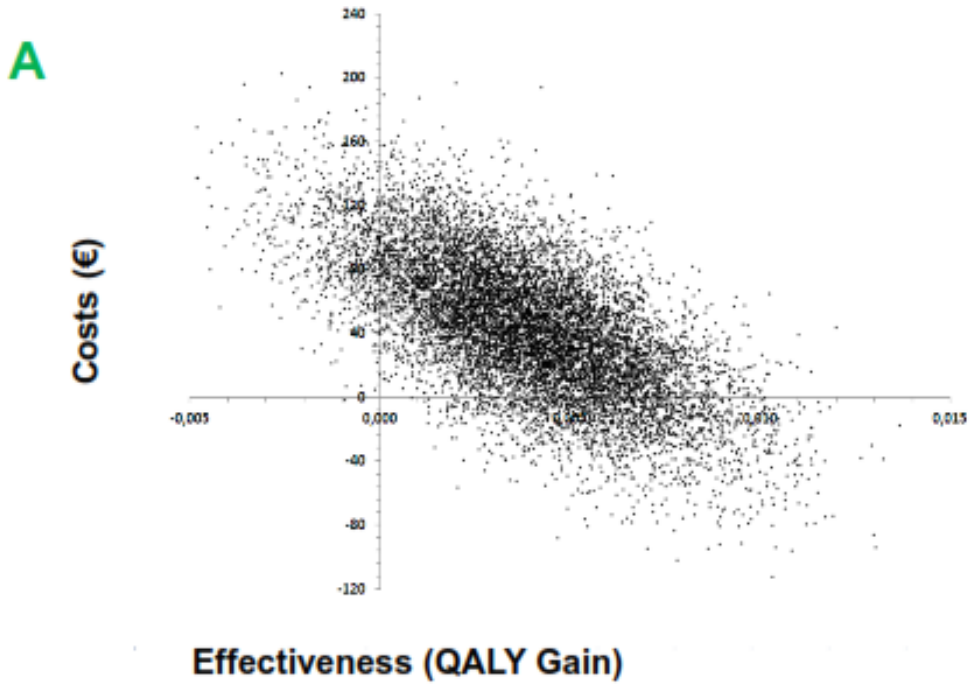
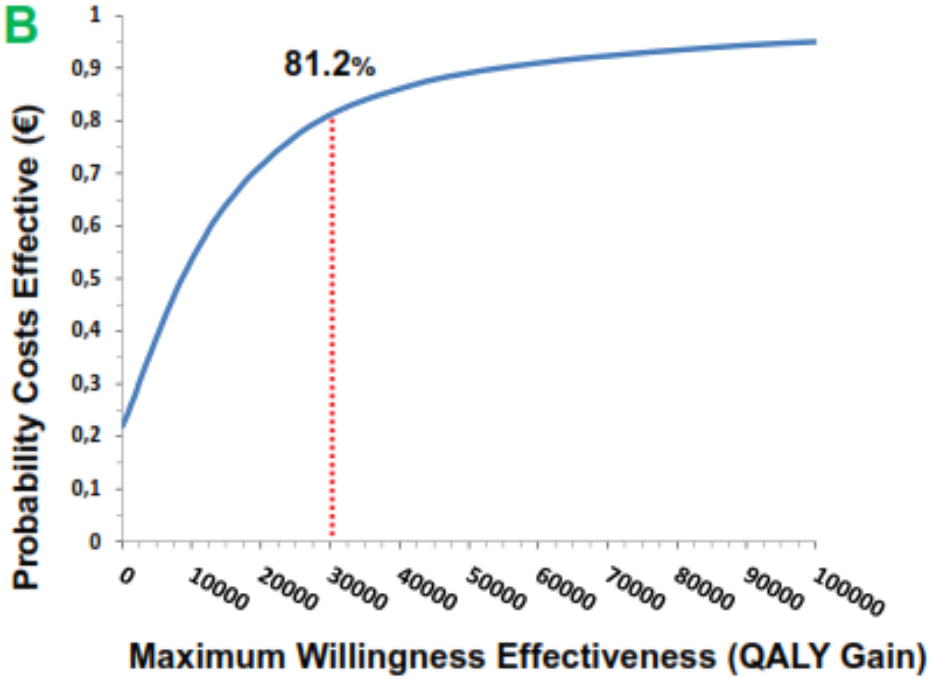
Cost-Utility analysis plane (A) and Cost-Utility analysis acceptability curve (B)





Cost Effectiveness of Duloxetine for Osteoarthritis: A Quebec Societal Perspective

RONALD C. WIELAGE,[1] ANKUR J. PATEL,[1] MEGHA BANSAL,[1] SHANNON LEE,[2] ROBERT W. KLEIN,[1] AND MICHAEL HAPPICH[3]

Table 1. Treatments*

Therapy	Drug class	Dose
Duloxetine	SSNRI	60 mg every day
Celecoxib	COX-2 inhibitor NSAID	200 mg
Diclofenac	Nonselective NSAID	100–150 mg
Naproxen	Nonselective NSAID	750 mg
Hydromorphone	Strong opioid	3–9 mg twice a day
Oxycodone	Strong opioid	10–30 mg twice a day

* SSNRI = selective serotonin and norepinephrine reuptake inhibitor; COX-2 = cyclooxygenase 2; NSAID = nonsteroidal antiinflammatory drug.

Arthritis Care & Research
Vol. 66, No. 5, May 2014, pp 702–708
DOI 10.1002/acr.22224

Table 2. Treatment costs

Treatment	First 3-month drug cost	First 3-month physician cost	Subsequent 3-month cost	Discontinuation drug cost	Discontinuation physician cost
Duloxetine 60 mg	$335.26*	$65.32†	$340.31‡	$0.00§	$44.63†
Celecoxib 200 mg	$126.04‡	$0.00	$126.04‡	$0.00	$0.00
Diclofenac 100–150 mg	$47.78‡	$0.00	$47.78‡	$0.00	$0.00
Hydromorphone 3–9 mg twice a day	$83.43‡	$83.63†	$94.26‡	$27.73§	$63.46†
Naproxen 750 mg	$36.14‡	$0.00	$36.14‡	$0.00	$0.00
Oxycodone 10–30 mg twice a day	$224.87‡	$83.63†	$257.22‡	$99.19§	$63.46†

* Provided by Lilly Canada.
† Calculated from the Ministry of Health and Long-Term Care (2010) (34), guided by expert opinion solicited by questionnaire.
‡ Calculated from IMS-Brogan (2010) (33).
§ Calculated from IMS-Brogan (2010) (33), using tapering calculated by the Washington State Department of Social and Health Services, 2010 (32).

Table 3. Results of the base-case incremental cost-effectiveness analysis*

Treatment	Cost over naproxen†	QALYs over naproxen†	ICER vs. baseline‡	Incremental cost§	Incremental QALYs‡	ICER
Oxycodone	$1,722	0.0173	$99,456			Dominated
Hydromorphone	$1,394	0.0165	$84,636			Dominated
Duloxetine	$937	0.0284	$32,960	$806 vs. celecoxib	0.0222 vs. celecoxib	$36,291 vs. celecoxib
Celecoxib	$131	0.0062	$21,056	$68 vs. diclofenac	0.0024 vs. diclofenac	$28,258 vs. diclofenac
Diclofenac	$63	0.0038	$16,491	$63 vs. naproxen	0.0038 vs. naproxen	$16,491 vs. naproxen
Naproxen (baseline)	–	–	–	–	–	–

* QALYs = quality-adjusted life years; ICER = incremental cost-effective ratio.
† Costs and QALYs discounted at 5.0%. "Baseline" is the least expensive treatment.
‡ "Baseline" is the least expensive treatment.
ed at 5.0%.

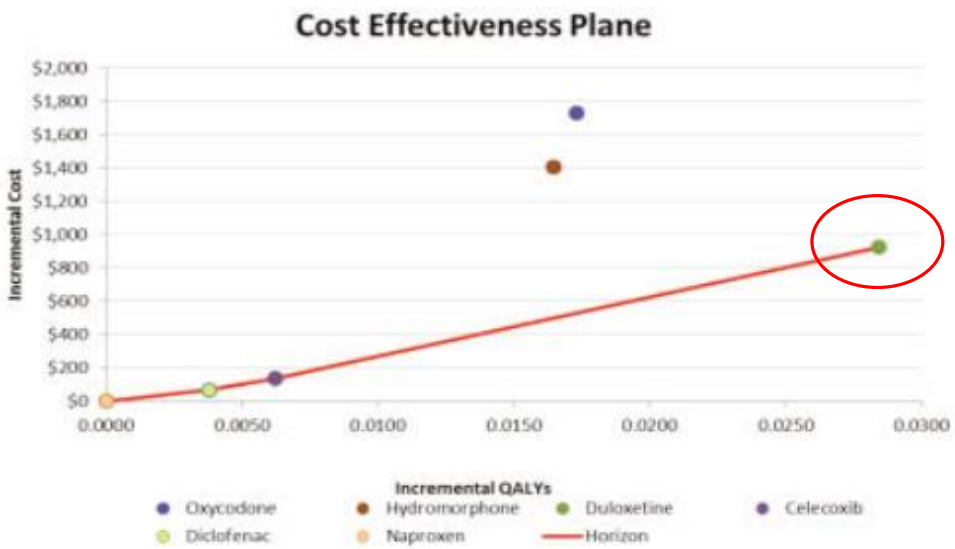


Figure 1. Cost-effectiveness plane of the base-case analysis based on the Quebec societal perspective. QALYs = quality-adjusted life years.

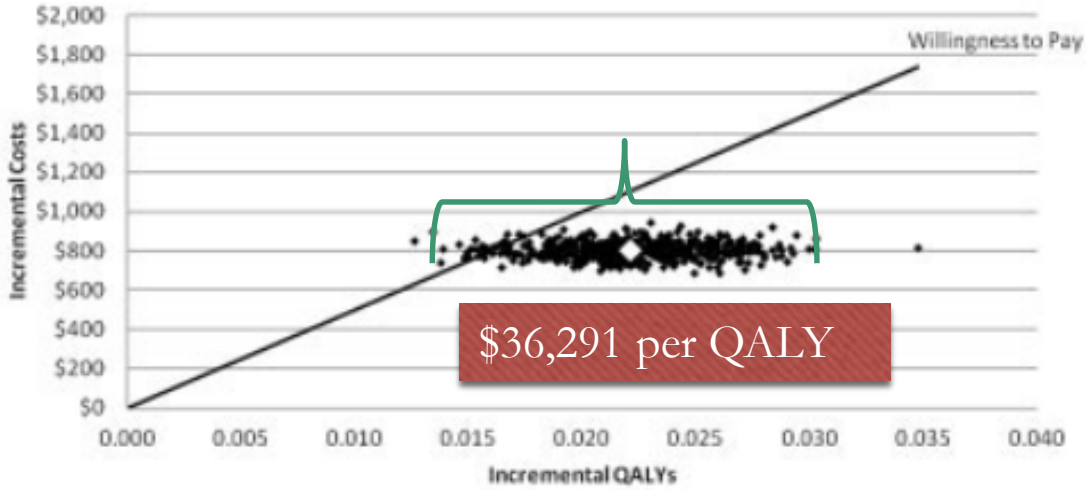


Figure 2. Probabilistic sensitivity analysis of duloxetine versus celecoxib, with the white diamond showing the base-case scenario. QALYs = quality-adjusted life years.

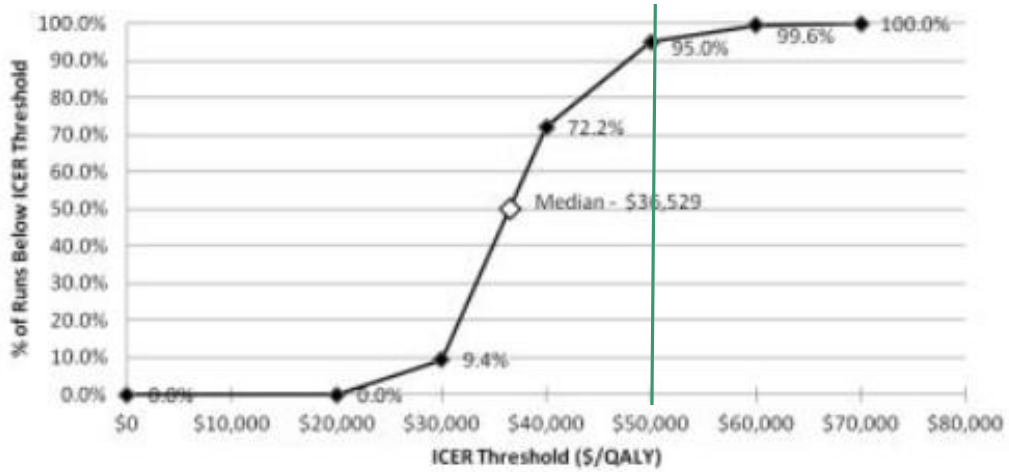


Figure 3. Cost-effectiveness acceptability curve for the base-case analysis showing willingness to pay for duloxetine versus celecoxib. ICER = incremental cost-effective ratio; QALY = quality-adjusted life year.

Celebrex vs Doloxetine

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The Cost-Effectiveness of Duloxetine in Chronic Low Back Pain: A US Private Payer Perspective

Ronald C. Wielage, MPH[1,], Megha Bansal, MA[1], J. Scott Andrews, PharmD[2], Madelaine M. Wohlreich, MD[2], Robert W. Klein, MS[1], Michael Happich, PhD[3]*

[1]*Medical Decision Modeling Inc., Indianapolis, IN, USA;* [2]*Eli Lilly and Company, Indianapolis, IN, USA;* [3]*Lilly Deutschland GmbH, Bad Homburg, Germany*

VALUE IN HEALTH 16 (2013) 334–344

Table 1 – Treatment characteristics.

Comparator	Duloxetine	Celecoxib	Naproxen	Pregabalin	Oxycodone/APAP	Oxycodone ER	Tapentadol ER	Tramadol IR
Clinical								
Dosing	60–120 mg	200 mg QD	500 mg BID	300 mg BID	7.5/325– 15/650 Q6h	10–30 mg BID	300–600 mg QD	200–300 mg QD
Utility	0.7541*	0.7688*	0.7688*	0.7282† [21]	0.7628+	0.7628*	0.7603*	0.7587*
Discon—initial 3 mo (%)	27.6*	23.8§	30.0§	35.0 [22,23]	58.9+	58.9§	44.0 [24]	48.5§
Discon—subsequent 3 mo (%)‖	1.9	4.7	5.7	4.5	13.3	13.3	8.3	25.4
PPI usage (%)	5.1 [25]	15.5 [26]	43.7 [27]	5.1 [25]	21.0 [25]	21.0 [25]	21.0 [25]	21.0 [25]
Share of PDT (%) [28]	5.0	9.2	17.1	8.6	19.2	6.0	1.0	33.9
Treatment costs ($)								
Initial 3-mo drug cost [29,30]	576.41	371.09	162.41	439.83	154.55	589.04	1,229.27	262.63
Initial 3-mo physician cost‖ [31,32]	167.50	0.00	0.00	192.84	184.06	287.65	169.95	153.82
Cost—subsequent 3 mo [29]	590.23	371.09	162.41	474.28	188.20	667.51	1,340.30	309.89
Discon drug cost [29,30]	0.00	0.00	0.00	94.62	27.57	190.34	632.28	44.01
Discon provider cost‖ [31,32]	94.80	0.00	0.00	106.03	222.28	183.89	92.62	117.47
3-mo persistent AE probabilities (%)								
Symptomatic ulcer [33]	0.04¶	0.09	0.28	0.04¶	0.04¶	0.04¶	0.04¶	0.04¶
Complicated GI bleed [33]	0.02¶	0.05	0.07	0.02¶	0.02¶	0.02¶	0.02¶	0.02¶
Myocardial infarction [33]	0.06¶	0.15	0.06	0.06¶	0.06¶	0.06¶	0.06¶	0.06¶
Stroke [33]	0.03¶	0.03	0.08	0.03¶	0.03¶	0.03¶	0.03¶	0.03¶
Heart failure [33]	0.01¶	0.04	0.09	0.01¶	0.01¶	0.01¶	0.01¶	0.01¶
Fracture	0.40 [34]	0.40 [35]	0.45 [35]	0.66 [36]	0.59+	0.59 [35]	0.89#	0.89 [35]
3-mo transient AE probabilities (%)								
Dyspepsia	7.52¶ [33]	12.45 [33]	14.96 [33]	7.52¶ [33]	7.52¶ [33]	7.52¶ [33]	7.52¶ [33]	7.52¶ [33]
Nausea	8.30*	2.80**	5.00**	7.90 [37]	37.20+	37.20**	21.00 [38]	19.10*
Diarrhea	5.70*	4.40**	4.10**	3.90 [37]	5.90+	5.90**	0.50 [38]	6.10
Constipation	7.60*	1.80**	3.30**	5.30 [37]	38.20+	38.20**	17.00 [38]	15.10
Insomnia	3.70*	2.30**	1.10**	1.10††	7.30+	7.30**	4.00 [38]	7.30
Pruritus	0.60*	1.80**	2.10**	0.60††	13.70+	13.70**	5.00 [38]	8.60
Vomiting	0.30*	1.30**	0.70**	3.90 [37]	17.10+	17.10**	8.00 [38]	6.90
Dizziness	5.40*	1.70**	1.30**	35.50 [37]	20.7+	20.7**	17.00 [38]	15.20
Somnolence	4.00*	0.30**	0.30**	19.70 [37]	21.30+	21.30**	12.00 [38]	9.40
Opioid abuse	0.00	0.00	0.00	0.00	3.34+	3.34 [39]	3.34 [38]	0.04
Relative risk with PPI usage								
Symptomatic ulcer	0.49‖ [40]	0.25 [33]	0.37 [33]	0.49‖ [40]	0.49‖ [40]	0.49‖ [40]	0.49‖ [40]	0.49‖ [40]
Complicated GI bleed	0.49‖ [40]	0.25 [33]	0.46 [33]	0.49‖ [40]	0.49‖ [40]	0.49‖ [40]	0.49‖ [40]	0.49‖ [40]
Dyspepsia	0.49‖ [40]	0.25 [33]	0.43 [33]	0.49‖ [40]	0.49‖ [40]	0.49‖ [40]	0.49‖ [40]	0.49‖ [40]

AE, adverse event; APAP, acetaminophen; BID, twice a day; CLBP, chronic low back pain; discon, discontinuation; ER, extended release; GI, gastrointestinal; IR, immediate release; OA, osteoarthritis; PDT, postdiscontinuation therapy; PPI, proton pump inhibitor; QD, once a day; Q6h, every 6 hours; RCT, randomized controlled trial.

* Meta-analysis of CLBP RCTs.

§ Assumed the same as duloxetine.

\+ Assumed the same as oxycodone.

§ Meta-analysis of OA RCTs.

‖ Expert opinion.

nt.

comparator.

Table 2 – Persistent AE characteristics.

	Adverse event					
	Symptomatic ulcer	Complicated GI bleed	Myocardial infarction	Stroke	Heart failure	Fracture
Cost (3 mo) ($)						
During	1,868 [33,41,42]	10,403 [41,42]	29,345 [43,44]	19,109 [43,44]	11,006 [43,45]	5,044 [46,47]
Post	252 [41,42]	238 [42]	750 [48]	616 [49]	1,867 [50]	247 [46,47]
Utility weight						
During	0.550 [51]	0.460 [51]	0.370 [33]	0.350 [33]	0.710 [33]	0.880 [46,52]
Post	0.978 [33]	0.978 [33]	0.878 [33]	0.708 [33]	0.998 [33]	0.952 [46,52]
Excess mortality (3 mo) (%)						
During	0.00 [33]	4.30 [51]	16.15 [53]	15.80 [54]	7.48 [55]	0.210 [46,56]
Post	0.00 [33]	1.107 [51]	4.32 [53]	1.69 [54]	2.61 [55]	0.025 [46]
Age-related relative risk						
<65 y	1.00 [33]	1.00 [33]	1.00 [33]	1.00 [33]	1.00 [33]	1.00 [46]
65 y +	2.93 [57]	2.93 [57]	2.45 [58]	2.45 [58]	2.45 [58]	1.61 [46]

AE, adverse event; GI, gastrointestinal.

Table 3 – Transient AE characteristics.

	Event cost ($)	3-mo costs ($)	Cost of physician visit ($) [31]	Utility weight during event	Days of treatment*	Duration-adjusted cost ($)
Dyspepsia	28	49 [41,42]	76	0.730 [33]	27.8	119
Nausea	0	6† [29]	76	0.887 [59]	12.5	77
Diarrhea	0	6† [29]	76	0.900 [59]	18.6	77
Constipation	539 [60]	66† [29]	76	0.888 [59]	39.1	720
Insomnia	0	282† [29]	76	0.887 [59]	34.5	259
Pruritus	0	47† [29]	76	0.958 [59]	31.8	169
Vomiting	0	6† [29]	76	0.887 [59]	3.8	76
Dizziness	0	0	76	0.887 [59]	15.5	76
Somnolence	0	0	76	0.887 [59]	28.8	76
Opioid abuse	5471 [60]	NA	NA	0.800 [61]	91.0	5471

AE, adverse event; NA, not applicable.

* Expert opinion.

† Treatment and dosing from Lilly September 8, 2011.

Table 4 – Base-case incremental results.

Treatment	Total cost ($)*	QALYs†	Life years†	Incremental cost ($)*	Incremental QALYs†	ICER
Tapentadol ER	54,559	12.2029	17.3682			Dominated
Oxycodone ER	52,820	12.1974	17.3644			Dominated
Oxycodone/APAP	51,834	12.1973	17.3654			Dominated
Duloxetine	51,450	12.2123	17.3682	1,333	0.0224	$59,473
Pregabalin	51,338	12.1884	17.3696			Dominated
Tramadol IR	51,218	12.2043	17.3675			Dominated (extended)
Celecoxib	50,438	12.1887	17.3166			Dominated
Naproxen	50,117	12.1899	17.3252			

APAP, acetaminophen; ER, extended release; ICER, incremental cost-effectiveness ratio; IR, immediate release; QALYs, quality-adjusted life-years.

* Costs discounted at 3%.

† Life years and QALYs discounted at 3%.

$$\frac{\text{Cost Duloxetine (51,450)} - \text{Cost Naproxen (50,117)}}{\text{QALY of Duloxetine (12.2123)} - \text{QALY of Naproxen(12.1899)}} = 1{,}333/0.0224 = \$59{,}473/\text{QALY}$$

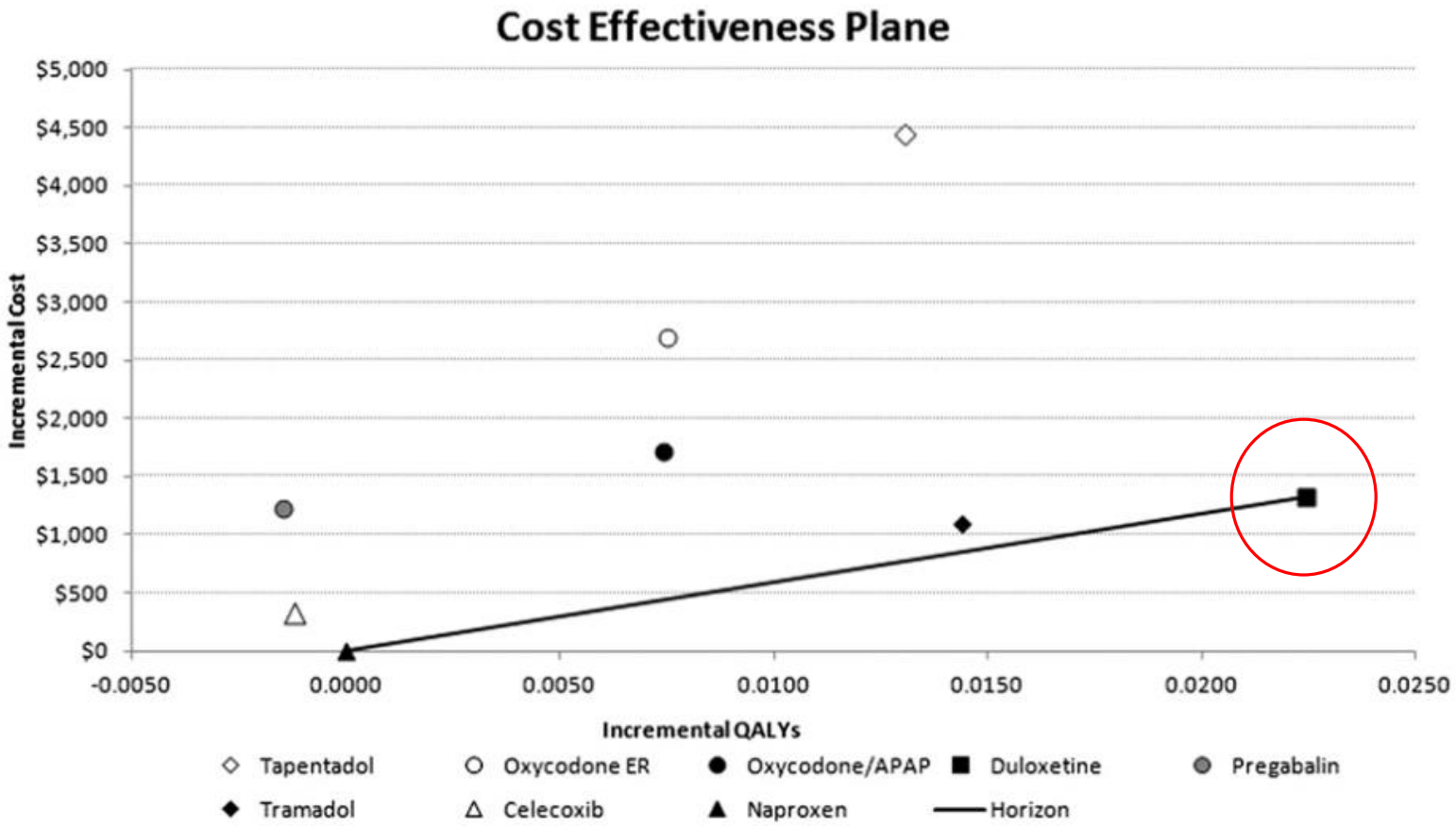


Fig. 2 – Cost-effectiveness plane with naproxen and duloxetine on the cost-effectiveness horizon. APAP, acetaminophen; ER, extended release; QALY, quality-adjusted life-year.

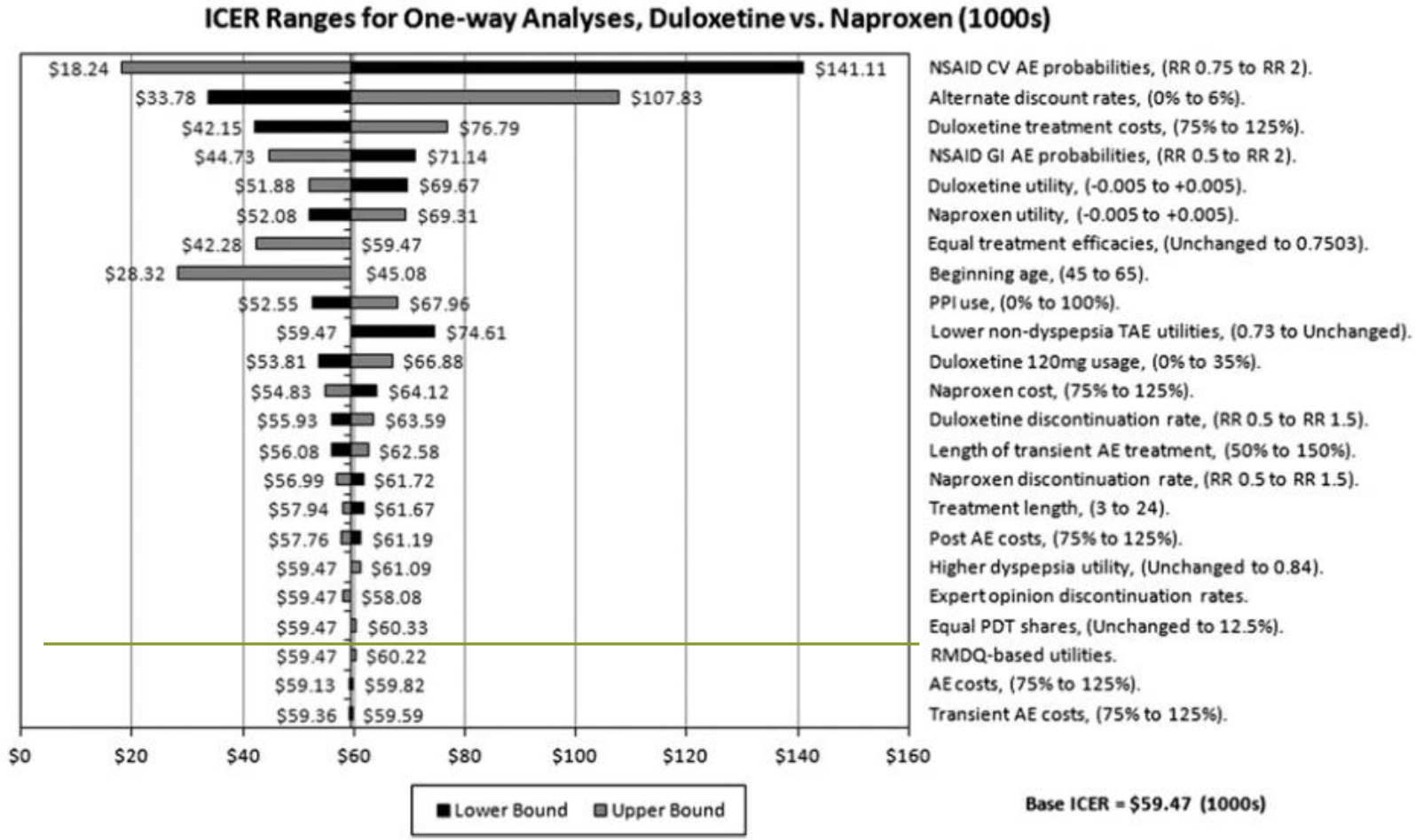
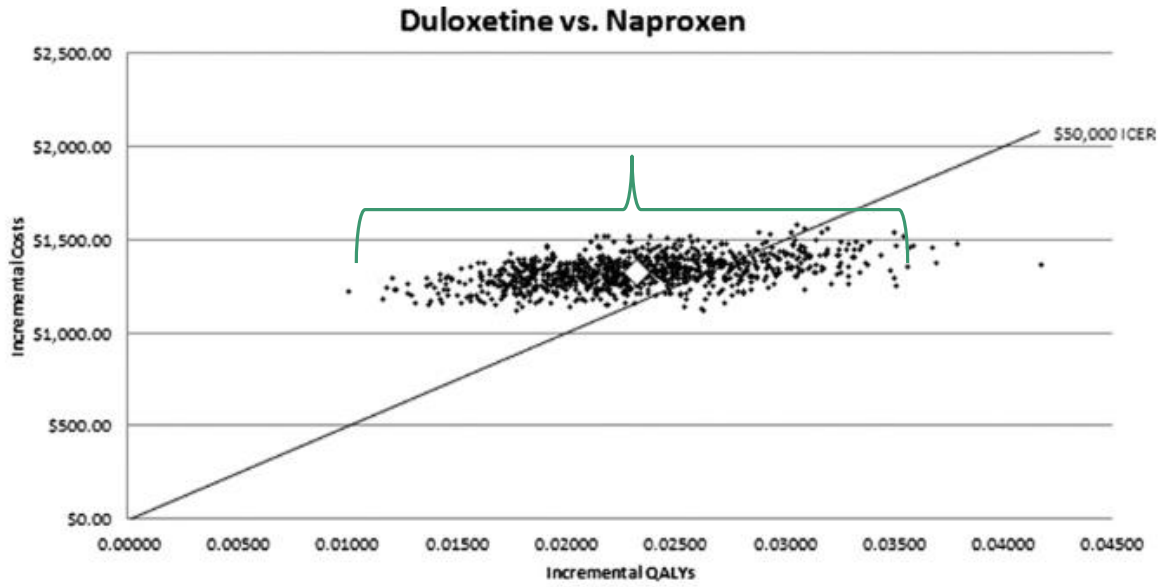


Fig. 3 – Tornado diagram of one-way sensitivity analyses. AE, adverse event; CV, cardiovascular; GI, gastrointestinal; ICER, incremental cost-effectiveness ratio; NSAID, nonsteroidal anti-inflammatory drug; PDT, postdiscontinuation therapy; PPI, proton pump inhibitor; RMDQ, Roland Morris Disability Questionnaire; RR, relative risk; TAE, transient adverse event.



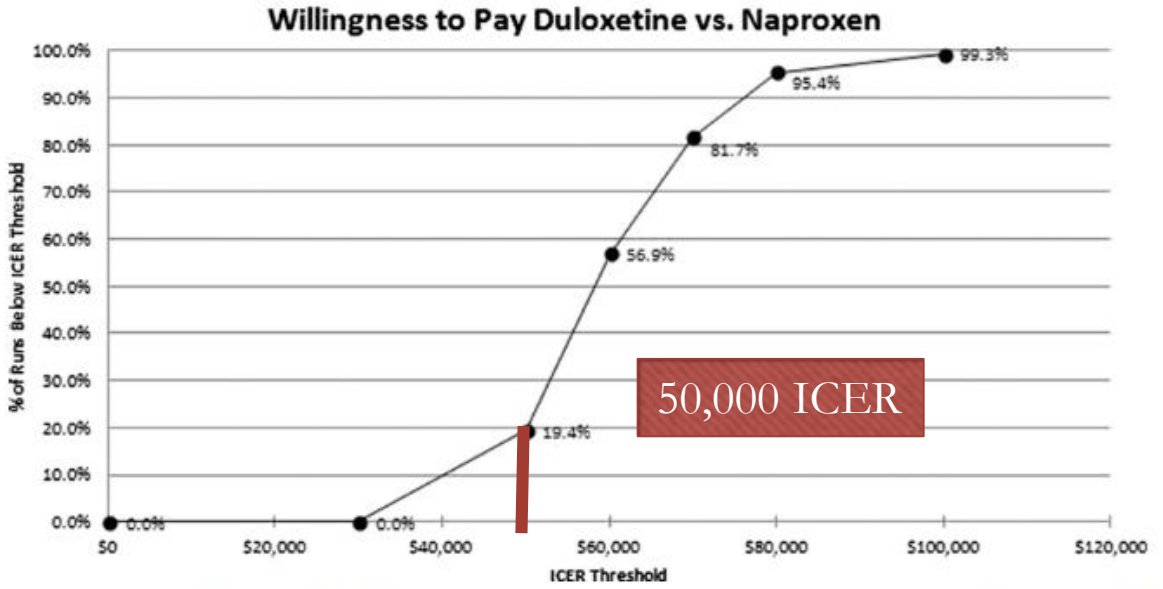
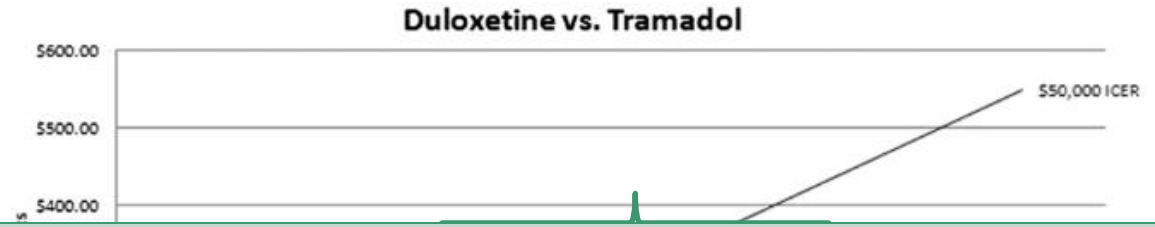
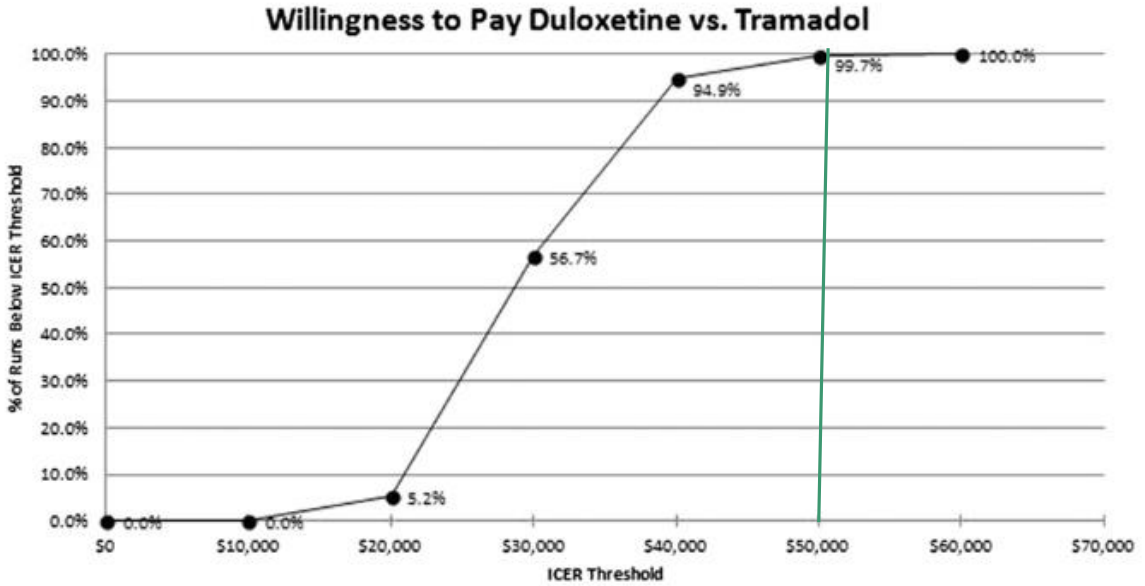


Fig. 4 – Probabilistic sensitivity analysis of duloxetine versus naproxen. ICER, incremental cost-effectiveness ratio; QALY, quality-adjusted life-year.



1.The model estimated an ICER of $59,473 for duloxetine over naproxen.
2. ICER under $30,000 were estimated for duloxetine over non-NSAIDs (Opioids)
3. In the higher risk of NSAID-related AEs, the ICER over naproxen was $33,105 or lower.

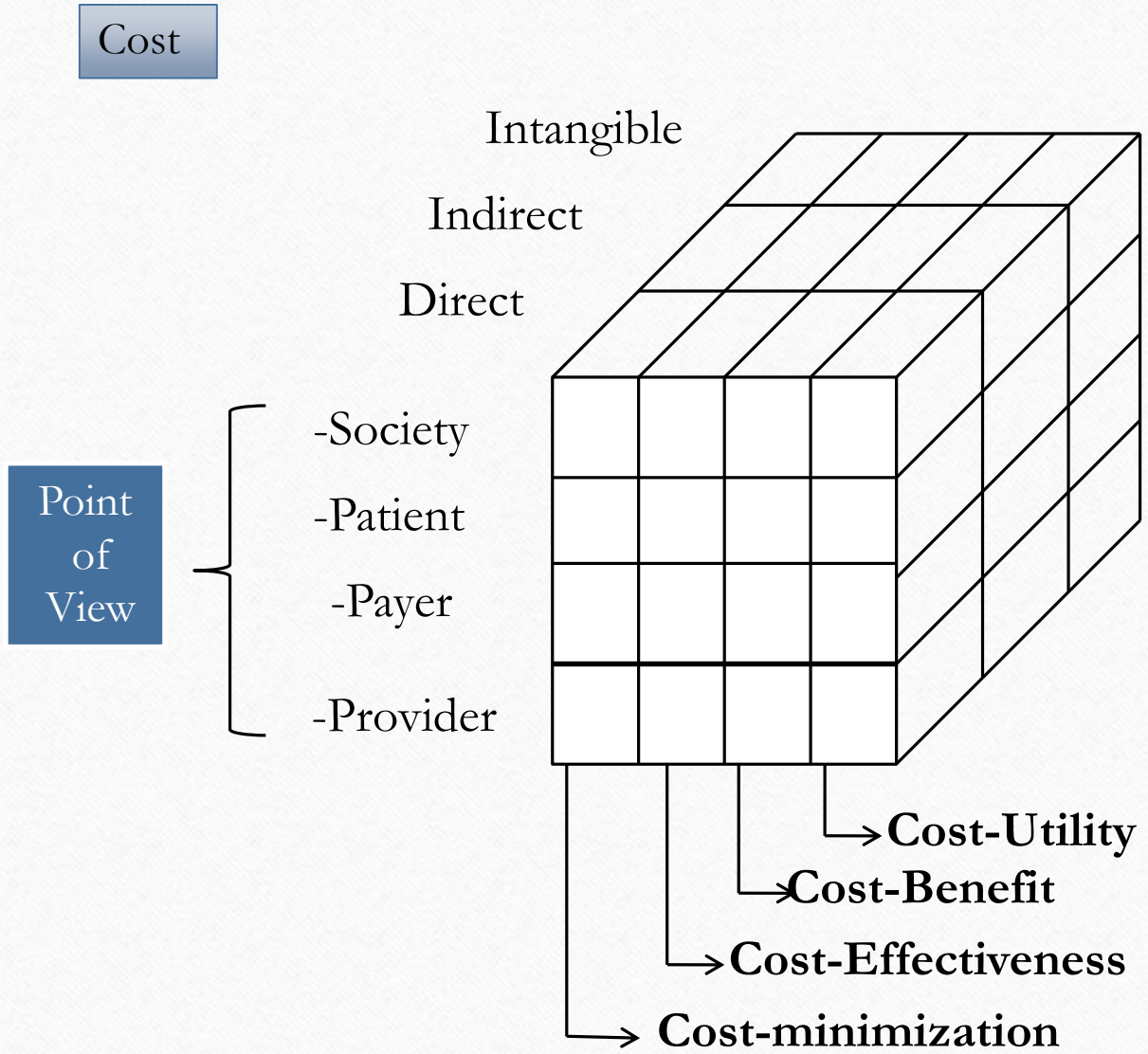
Duloxetin appears to be a cost-effective post-first-line treatment for CLBP compared with all but generic NSAIDs.



Probabilistic sensitivity analysis of duloxetine versus tramadol. ICER, incremental cost-effectiveness ratio; QALY, -adjusted life-year.

Topics of my talk

- What is Health and Clinical Economics and its principles.
- Types of Health Economics
- Costs and types and Discounting
- Decision analysis
- Types of economic evaluation
- Sensitivity analysis



เศรษฐศาสตร์สาธารณะสุข
(Health Economics)

ธรรมชาติย่อมเป็นไปได้หลายหลาก ข้อมูลแม้มีมากหาพอไม่

ประเมินค่าได้หลายอย่างต่างกันไป ทรัพยากรที่หาได้ไม่เคยพอ

ตัดสินใจบางคราวยากลำบากยิ่ง ก็เนื่องจากความจริงทั้งสี่ข้อ

ตัดสินใจเพื่อคนไข้ไม่อาจรอ แต่ละข้อควรวิเคราะห์ให้เหมาะเอยฯ


TOM CRUISE
MISSION: IMPOSSIBLE
ROGUE NATION

Arthritis Care & Research
Vol. 66, No. 5, May 2014, pp 702–708
DOI 10.1002/acr.22224

ORIGINAL ARTICLE

Cost Effectiveness of Duloxetine for Osteoarthritis: A Quebec Soc

RONALD C. WIELAGE,[1] AN ...E,[2]
ROBERT W. KLEIN,[1] AND M...

Table 1. Treatments*

Therapy	Drug class	Dose
Duloxetine	SSNRI	60 mg every day
Celecoxib	COX-2 inhibitor NSAID	200 mg
Diclofenac	Nonselective NSAID	100–150 mg
Naproxen	Nonselective NSAID	750 mg
Hydromorphone	Strong opioid	3–9 mg twice a day
Oxycodone	Strong opioid	10–30 mg twice a day

* SSNRI = selective serotonin and norepinephrine reuptake inhibitor; COX-2 = cyclooxygenase 2; NSAID = nonsteroidal antiinflammatory drug.

Table 2. Treatment costs

Treatment	First 3-month drug cost	First 3-month physician cost	Subsequent 3-month cost	Discontinuation drug cost	Discontinuation physician cost
Duloxetine 60 mg	$335.26*	$65.32†	$340.31‡	$0.00§	$44.63†
Celecoxib 200 mg	$126.04‡	$0.00	$126.04‡	$0.00	$0.00
Diclofenac 100–150 mg	$47.78‡	$0.00	$47.78‡	$0.00	$0.00
Hydromorphone 3–9 mg twice a day	$83.43‡	$83.63†	$94.26‡	$27.73§	$63.46†
Naproxen 750 mg	$36.14‡	$0.00	$36.14‡	$0.00	$0.00
Oxycodone 10–30 mg twice a day	$224.87‡	$83.63†	$257.22‡	$99.19§	$63.46†

* Provided by Lilly Canada.
† Calculated from the Ministry of Health and Long-Term Care (2010) (34), guided by expert opinion solicited by questionnaire.
‡ Calculated from IMS-Brogan (2010) (33).
§ Calculated from IMS-Brogan (2010) (33), using tapering calculated by the Washington State Department of Social and Health Services, 2010 (32).

Table 3. Results of the base-case incremental cost-effectiveness analysis*

Treatment	Cost over naproxen†	QALYs over naproxen†	ICER vs. baseline‡	Incremental cost§	Incremental QALYs‡	ICER
Oxycodone	$1,722	0.0173	$99,456			Dominated
Hydromorphone	$1,394	0.0165	$84,636			Dominated
Duloxetine	$937	0.0284	$32,960	$806 vs. celecoxib	0.0222 vs. celecoxib	$36,291 vs. celecoxib
Celecoxib	$131	0.0062	$21,056	$68 vs. diclofenac	0.0024 vs. diclofenac	$28,258 vs. diclofenac
Diclofenac	$63	0.0038	$16,491	$63 vs. naproxen	0.0038 vs. naproxen	$16,491 vs. naproxen
Naproxen (baseline)	–	–	–	–	–	–

* QALYs = quality-adjusted life years; ICER = incremental cost-effective ratio.
† Costs and QALYs discounted at 5.0%. "Baseline" is the least expensive treatment.
‡ "Baseline" is the least expensive treatment.
§ Costs and QALYs discounted at 5.0%.

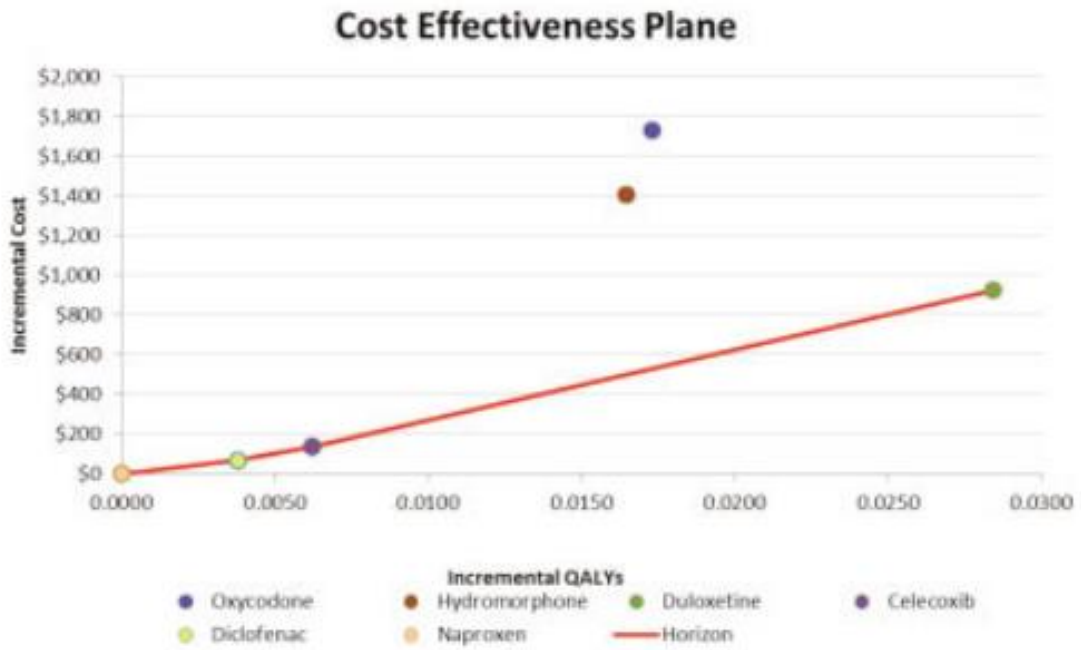


Figure 1. Cost-effectiveness plane of the base-case analysis based on the Quebec societal perspective. QALYs = quality-adjusted life years.

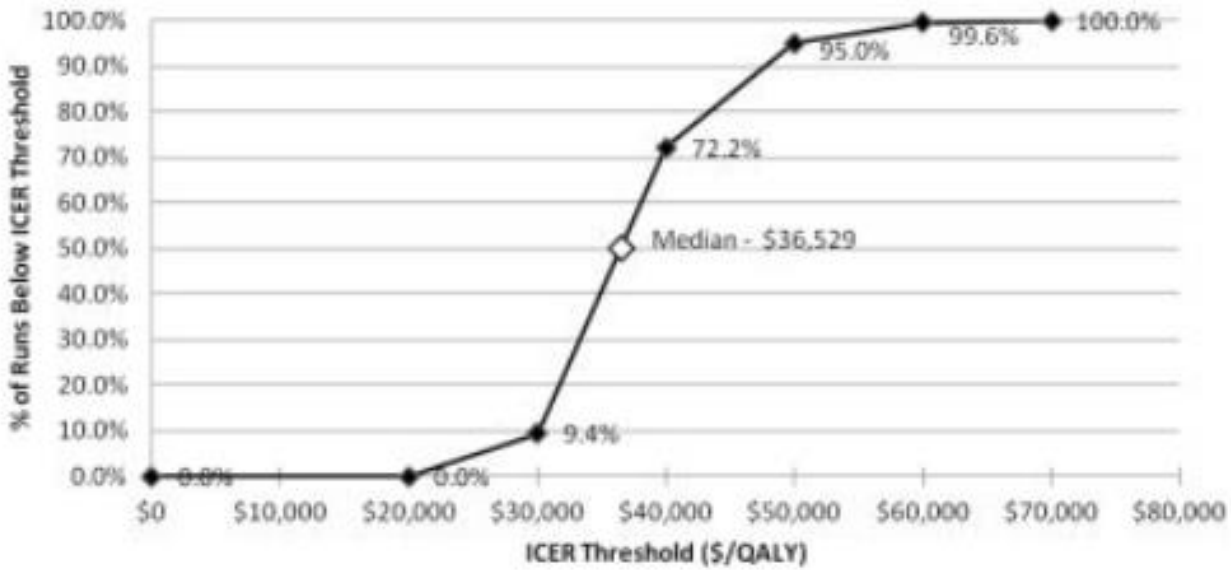


Figure 3. Cost-effectiveness acceptability curve for the base-case analysis showing willingness to pay for duloxetine versus celecoxib. ICER = incremental cost-effective ratio; QALY = quality-adjusted life year.

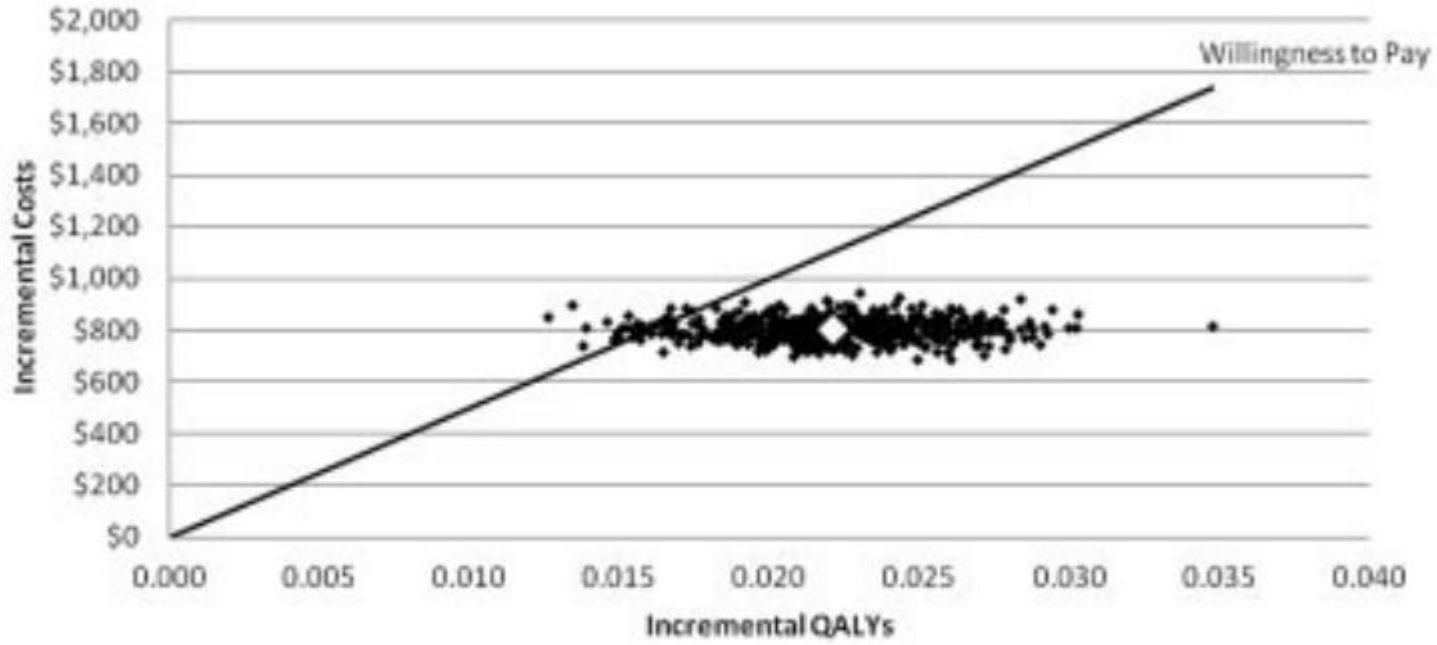


Figure 2. Probabilistic sensitivity analysis of duloxetine versus celecoxib, with the white diamond showing the base-case scenario. QALYs = quality-adjusted life years.

Hopkins *et al. BMC Musculoskeletal Disorders* 2011, **12**:209
http://www.biomedcentral.com/1471-2474/12/209

BMC
Musculoskeletal Disorders

RESEARCH ARTICLE Open Access

The relative efficacy of nine osteoporosis medications for reducing the rate of fractures in post-menopausal women

Robert B Hopkins[1,2*], Ron Goeree[1,2,3], Eleanor Pullenayegum[1,3,4], Jonathan D Adachi[5], Alexandra Papaioannou [5], Feng Xie[1,2,3] and Lehana Thabane[1,3,4]

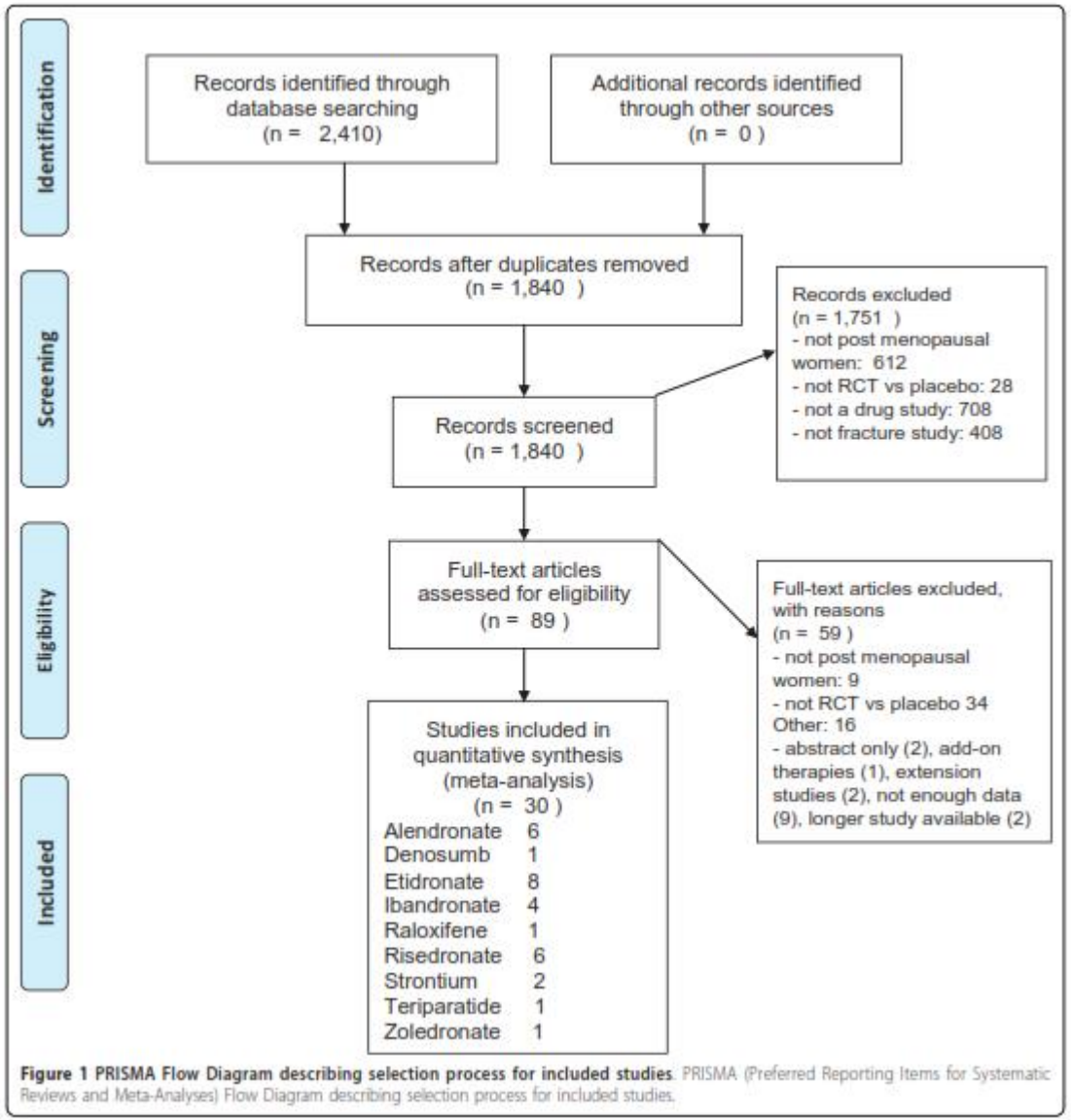


Figure 1 PRISMA Flow Diagram describing selection process for included studies. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Flow Diagram describing selection process for included studies.

Table 1 Description of Study and Baseline Characteristics for Included Studies

Drug	Author Year	Study Duration (years)	Country/Region	Number of Centres	Age (yrs) Mean (SD)	Years Menopause Inclusion Criteria	Years Since Menopause Mean (SD)	BMD Hip g/cm² Mean (SD)	Prior Vertebral Fracture %
Alendronate	Ascott Evans 2003	1	International	18	67.3 (6.6)	3	11.5 (7.3)	nr	0
Alendronate	Black 1996	3	North America	11	71.0 (5.6)	2	NR (NR)	0.57 (0.07)	100
Alendronate	Cummings 1998	4	North America	11	67.6 (6.1)	2	NR (NR)	0.84 (0.13)	0
Alendronate	Greenspan 1998	2.5	North America	1	70.0 (4.6)	NR	NR (NR)	0.57 (0.11)	NR
Alendronate	Liberman 1995	3	International	NR	64.0 (7.0)	5	16.5 (NR)	0.71 (NR)	21
Alendronate	Pols 1999	1	International	153	62.8 (7.4)	3	15.9 (1.5)	0.72 (0.08)	NR
Denosumab	Cummings 2009	4	North America	11	67.7 (6.6)	2	NR (NR)	0.84 (0.13)	0
Etidronate	Lyritis 1997	4	Europe	1	72.0 (0.4)	NR	25.8 (1.7)	0.57 (NR)	100
Etidronate	Meunier 1997	4	Europe	1	52.7 (4.0)	0.5	2.4 91.8)	0.90 (NR)	NR
Etidronate	Montesorri 1997	3	Europe	2	62.5 (6.2)	1	14.9 (6.1)	0.67 (NR)	29
Etidronate	Pacifici 1988	2	U.S.A	1	61.0 (7.8)	NR	13.8 (9.5)	0.79 (0.26)	100
Etidronate	Pouilles 1997	2	Europe	7	53.8 (3.1)	0.5	2.6 (1.4)	0.96 (NR)	NR
Etidronate	Storm 1990	3	Europe	1	68.3 (7.3)	NR	21.6 (10.2)	0.25 (0.07)	100
Etidronate	Watts 1990	2	U.S.A	7	65.1 (13.0)	1	17.9 (16.5)	0.86 (NR)	100
Etidronate	Wimalawansa 1998	4	NR	NR	64.9 (7.8)	NR	15.1 (6.8)	0.83 (NR)	100
Ibandronate	Chesnut 2004	3	Europe, U.S.A	73	69.0 (11.0)	5	21 (20.8)	0.78 (NR)	93
Ibandronate	Ravn 2002	1	Europe	1	64.5 (5.9)	10	NR (NR)	0.87 (0.13)	28
Ibandronate	Adami 2004	1	Europe	NR	65.9 (4.5)	5	17.9 (4.0)	0.77 (0.09)	45
Ibandronate	Recker 2004	3	Europe	NR	67.0 (5.1)	5	NR (NR)	0.80 (0.11)	54
Raloxifene	Ettinger 1999	3	International	180	66.1 (6.9)	2	18.6 (7.9)	0.58 (NR)	38
Risedronate	Fogelman 2000	2	Europe	13	64.7 (7.2)	1	17.7 (9.4)	0.74 (0.08)	30
Risedronate	Harris 1999	3	North America	110	69.0 (7.3)	5	24.0 (9.9)	0.83 (0.16)	81
Risedronate	Hooper 2005	2	Australia	11	52.6 (3.3)	0.5	3.9 (5.6)	1.08 (0.12)	18.3
Risedronate	McClung 2001	3	International	183	78.0 (9.7)	NR	31.8 (19.3)	NR (NR)	42
Risedronate	Mortenson 1998	2	International	2	51.2 (3.8)	0.5	2.7 91.7)	0.94 (0.11)	NR
Risedronate	Reginster 2000	3	Europe, Australia	80	71.0 (7.0)	5	24.4 (8.5)	0.79 (0.15)	100
Strontium	Meunier 2004	3	Europe, International	72	69.3 (7.3)	5	43.7 (8.7)	0.68 (0.11)	100
Strontium	Reginster 2008	3.5	International	75	76.7 (5.0)	0	28.4 (7.4)	0.55 (NR)	33.5
Teriparatide	Neer 2001	2	International	99	69.0 (7.0)	5	21.0 (8.0)	0.82 (0.17)	100
Zoledronate	Black 2007	3	U.S.A, Europe	60	73 (5.4)	0	NR (NR)	0.65 (0.91)	36.7

NR: Not reported. BMD: Bone Mineral Density. SD: Standard deviation. U.S.A: United States of America

Table 3 Odds Ratio for Fracture, Indirect Treatment Comparison between drugs (Bayesian analysis)

	Non-vertebral fracture		Vertebral fracture		Hip fracture		Wrist fracture	
	OR (95% CrI)	NNT	OR (95% CrI)	NNT	OR (95% CrI)	NNT	OR (95% CrI)	NNT
Denosumab vs Alendronate	0.99 (0.72, 1.42)	1,063	0.63 (0.38, 0.97)	26	1.30 (0.38, 3.35)	-180	NR	NR
Denosumab vs Etidronate	1.26 (0.59, 2.69)	-42	0.58 (0.26, 1.15)	23	1.43 (0.13, 5.97)	-126	NR	NR
Denosumab vs Ibandronate	0.89 (0.61, 1.31)	96	0.67 (0.35, 1.19)	30	NR	NR	NR	NR
Denosumab vs Raloxifene	0.87 (0.59, 1.30)	81	0.51 (0.29, 0.83)	20	0.71 (0.14, 1.89)	184	NR	NR
Denosumab vs Risedronate	1.04 (0.76, 1.54)	-267	0.53 (0.32, 0.82)	21	0.94 (0.27, 2.24)	893	NR	NR
Denosumab vs Teriparatide	1.29 (0.73, 2.26)	-38	1.06 (0.50, 1.99)	-169	3.24 (0.17, 16.89)	-25	NR	NR
Denosumab vs Zoledronic Acid	1.08 (0.73, 1.62)	-134	1.16 (0.66, 1.88)	-65	1.36 (0.30, 3.48)	-150	NR	-14
Etidronate vs Alendronate	0.79 (0.38, 1.61)	50	1.22 (0.54, 2.28)	-48	1.91 (0.20, 7.43)	-60	3.48 (0.22, 16.27)	NR
Ibandronate vs Alendronate	1.13 (0.82, 1.60)	-83	1.00 (0.54, 1.69)	20,428	NR	NR	NR	NR
Ibandronate vs Etidronate	1.44 (0.68, 3.06)	-25	0.92 (0.37, 1.95)	121	NR	NR	NR	-22
Raloxifene vs Alendronate	1.12 (0.82, 1.55)	-90	1.28 (0.78, 1.98)	-38	2.47 (0.71, 6.55)	-38	2.60 (0.08, 11.84)	-39
Raloxifene vs Etidronate	1.41 (0.68, 2.96)	-27	1.17 (0.53, 2.29)	-62	2.76 (0.24, 11.66)	-32	1.87 (0.03, 9.82)	NR
Raloxifene vs Ibandronate	1.02 (0.70, 1.49)	-533	1.36 (0.71, 2.38)	-29	NR	NR	NR	-108
Risedronate vs Alendronate	0.95 (0.71, 1.23)	212	1.21 (0.79, 1.79)	-50	1.47 (0.62, 3.31)	-115	1.31 (0.10, 5.21)	3,328
Risedronate vs Etidronate	1.19 (0.57, 2.49)	-57	1.11 (0.52, 2.18)	-95	1.65 (0.18, 6.64)	-84	0.99 (0.03, 4.68)	NR
Risedronate vs Ibandronate	0.85 (0.60, 1.15)	70	1.29 (0.71, 2.19)	-36	NR	NR	NR	-25
Risedronate vs Raloxifene	0.84 (0.57, 1.15)	65	0.98 (0.61, 1.51)	622	0.79 (0.23, 1.96)	254	2.39 (0.05, 11.67)	-10
Strontium vs Alendronate	1.06 (0.81, 1.44)	-178	1.18 (0.78, 1.71)	-58	1.89 (0.61, 4.70)	-61	4.78 (0.14, 21.71)	NR
Strontium vs Denosumab	1.08 (0.75, 1.53)	-134	1.95 (1.20, 2.99)	-12	1.98 (0.44, 5.03)	-56	NR	-13
Strontium vs Etidronate	1.36 (0.65, 2.86)	-31	1.08 (0.51, 2.07)	-127	2.09 (0.20, 8.75)	-50	3.72 (0.05, 17.44)	NR
Strontium vs Ibandronate	0.95 (0.69, 1.34)	212	1.26 (0.70, 2.15)	-40	NR	NR	NR	-4
Strontium vs Raloxifene	0.94 (0.66, 1.34)	176	0.96 (0.60, 1.46)	243	1.03 (0.23, 2.66)	-1,789	10.85 (0.08, 41.99)	-6
Strontium vs Risedronate	1.12 (0.86, 1.57)	-90	0.99 (0.67, 1.43)	1,890	1.37 (0.44, 3.10)	-146	8.00 (0.15, 38.56)	-3
Strontium vs Teriparatide	1.38 (0.80, 2.35)	-29	1.99 (0.95, 3.66)	-11	4.92 (0.26, 24.44)	-15	19.69 (0.12, 80.47)	NR
Strontium vs Zoledronic Acid	1.17 (0.83, 1.66)	-64	2.17 (1.34, 3.34)	-10	1.93 (0.47, 4.98)	-59	NR	-49
Teriparatide vs Alendronate	0.77 (0.46, 1.31)	45	0.65 (0.31, 1.26)	28	1.35 (0.07, 5.71)	-154	1.69 (0.04, 8.09)	-102
Teriparatide vs Etidronate	0.98 (0.40, 2.30)	531	0.70 (0.39, 1.45)	24	1.54 (0.03, 9.01)	-100	1.33 (0.02, 6.65)	NR
Teriparatide vs Ibandronate	0.69 (0.40, 1.22)	33	0.53 (0.25, 0.98)	32	NR	NR	NR	-13
Teriparatide vs Raloxifene	0.68 (0.39, 1.19)	32	0.55 (0.26, 0.98)	21	0.76 (0.03, 3.27)	223	3.68 (0.02, 15.16)	-16
Teriparatide vs Risedronate	0.81 (0.49, 1.41)	55	0.55 (0.34, 1.04)	22	1.00 (0.05, 4.18)	NR	3.20 (0.04, 14.42)	NR
Zoledronic Acid vs Alendronate	0.91 (0.66, 1.30)	117	0.56 (0.34, 0.88)	22	1.24 (0.39, 3.16)	-225	NR	NR
Zoledronic Acid vs Etidronate	1.16 (0.55, 2.45)	-68	0.52 (0.23, 1.04)	20	1.38 (0.12, 5.70)	-142	NR	NR
Zoledronic Acid vs Ibandronate	0.82 (0.56, 1.19)	58	0.60 (0.31, 1.06)	25	NR	NR	NR	NR
Zoledronic Acid vs Raloxifene	0.81 (0.54, 1.19)	55	0.46 (0.26, 0.74)	18	0.68 (0.15, 1.78)	167	NR	NR
Zoledronic Acid vs Risedronate	0.96 (0.71, 1.41)	265	0.48 (0.29, 0.74)	18	0.91 (0.28, 2.07)	595	NR	NR
Zoledronic Acid vs Teriparatide	1.19 (0.68, 2.08)	-57	0.95 (0.45, 1.83)	216	3.11 (0.17, 16.12)	-26	NR	NR

NR: Not reported. Results are reported as Odds ratio.

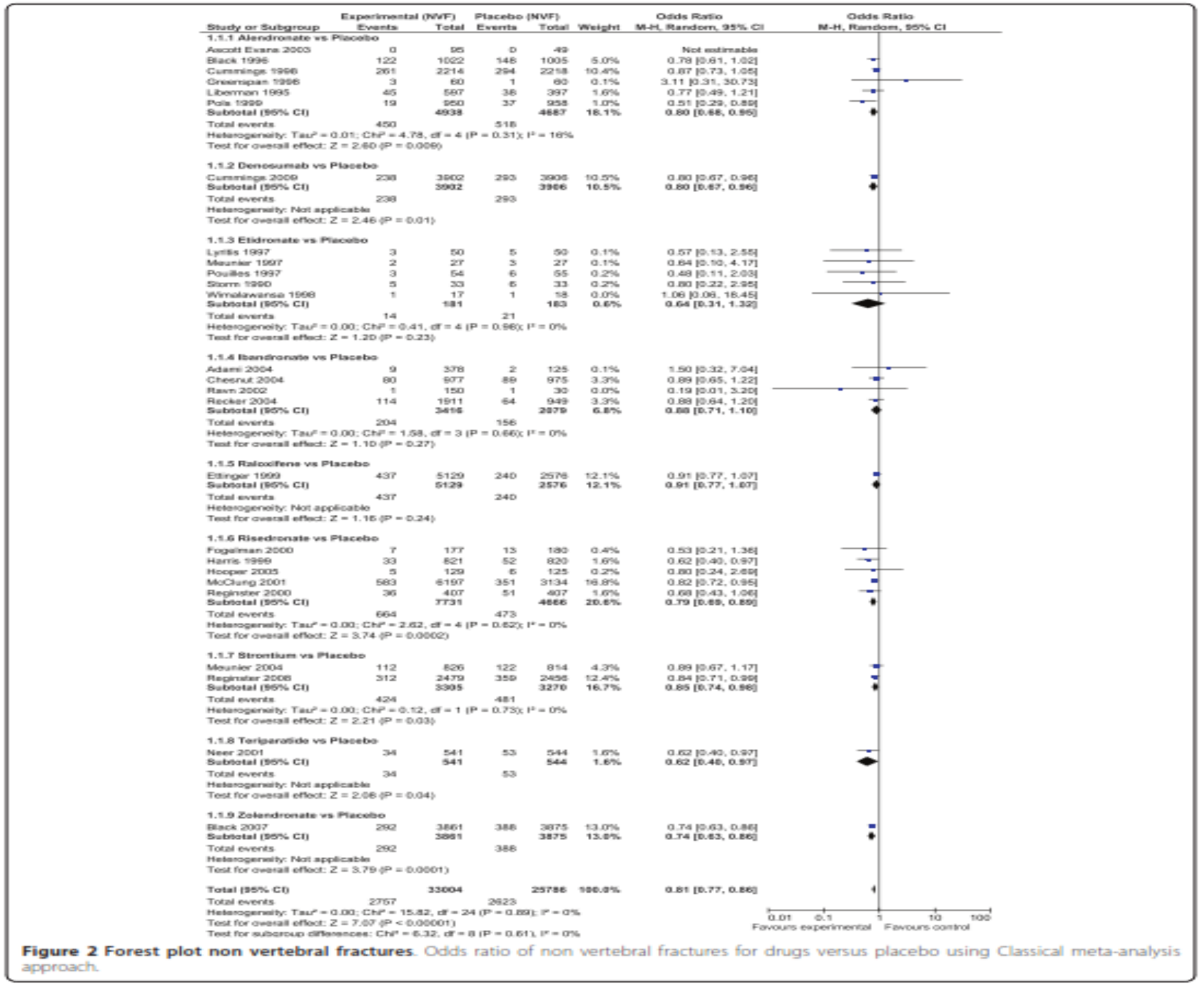


Figure 2 Forest plot non vertebral fractures. Odds ratio of non vertebral fractures for drugs versus placebo using Classical meta-analysis approach.

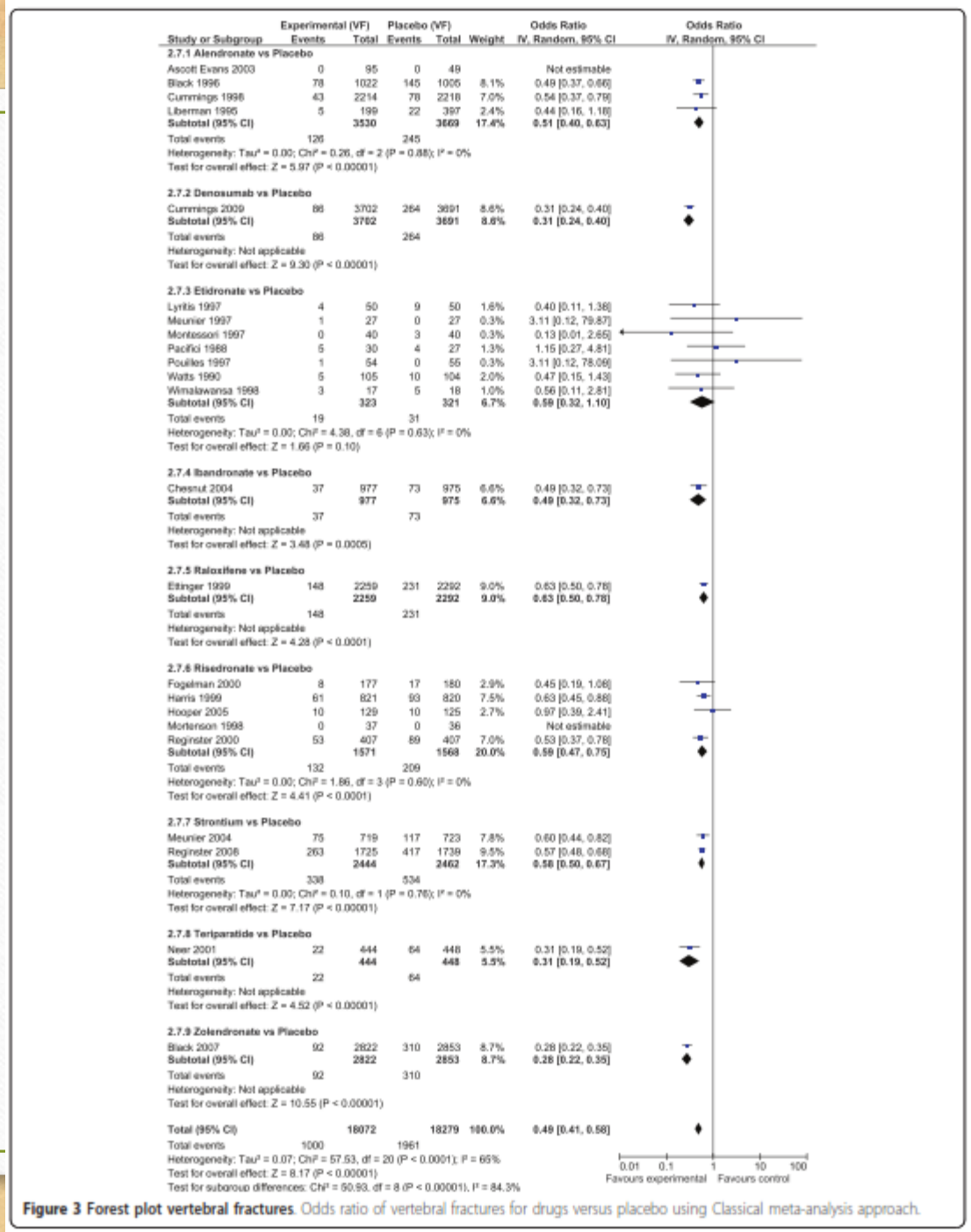


Figure 3 Forest plot vertebral fractures. Odds ratio of vertebral fractures for drugs versus placebo using Classical meta-analysis approach.