Applying Probability theory in Medical Decision Making

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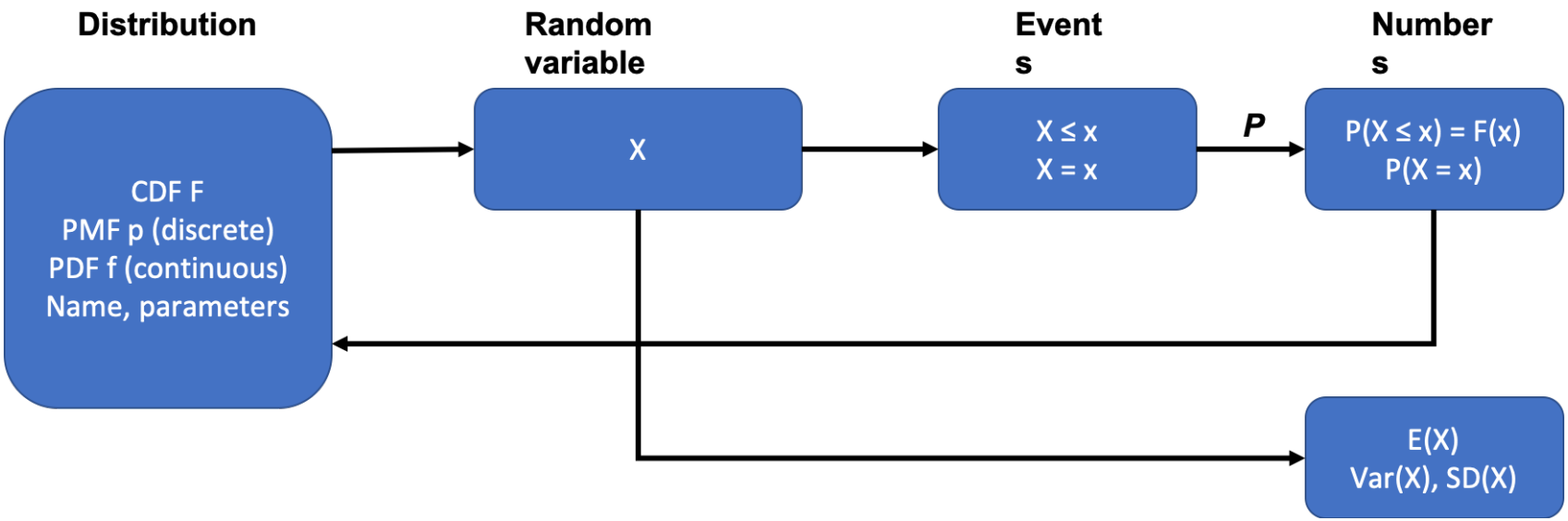
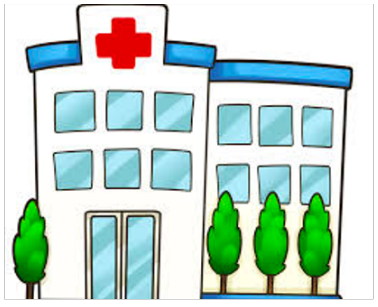
29-07-2020

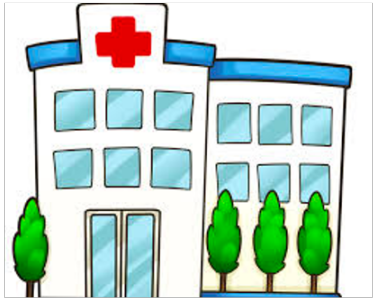
Recap


Distribution
Random variable
Event s
Number s
CDF F
PMF p (discrete)
PDF f (continuous)
Name, parameters
X
X ≤ x
X = x
P
P(X ≤ x) = F(x)
P(X = x)
E(X)
Var(X), SD(X)

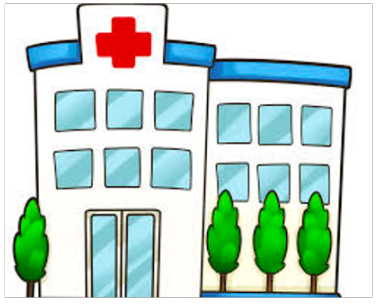
Clinical scenario

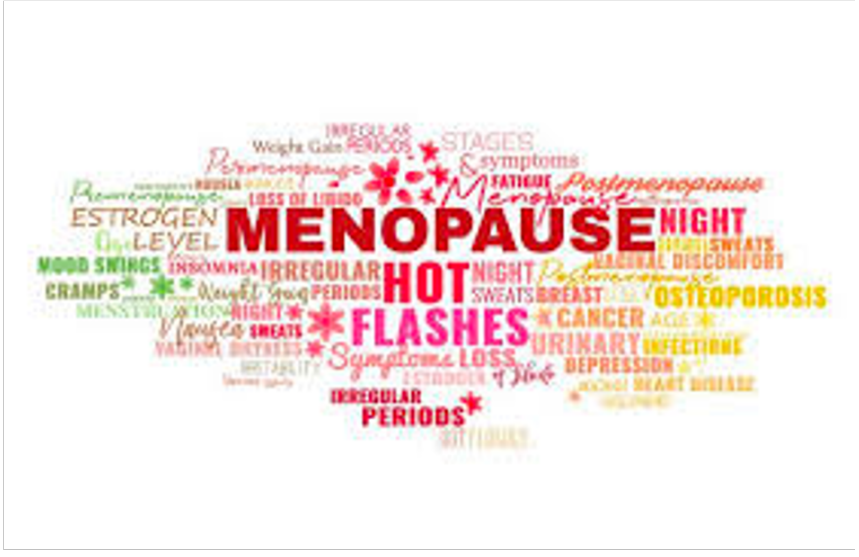


Clinical scenario

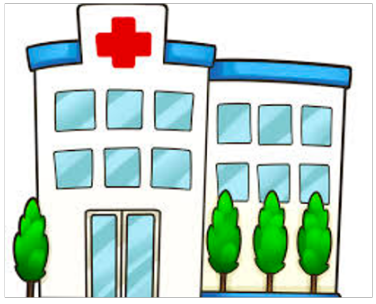


Clinical scenario

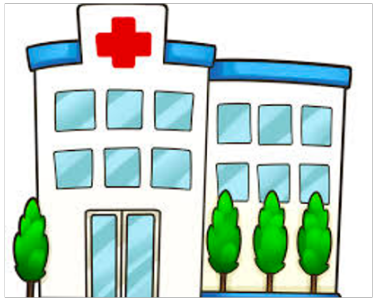




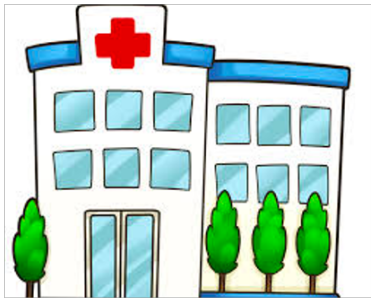
Clinical scenario

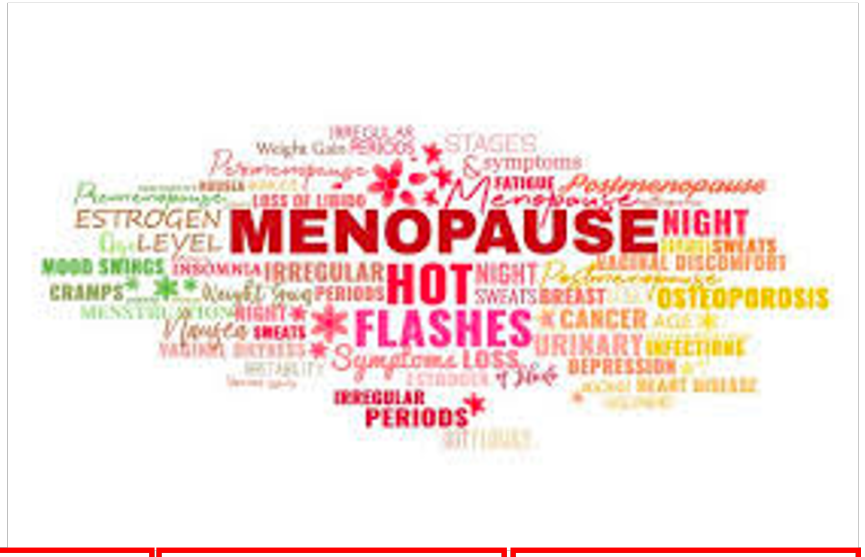


Clinical scenario



Clinical scenario





Decision analysis

- Decision making problem

Decision analysis

- Decision making problem
- Steps
  1. Define the problem
  2. Structure the decision
  3. Assess the probability of different outcomes
  4. Measure patient utility
  5. Identify the 'best' option
  6. Assess the sensitivity of the decision model

1. Define the decision problem

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When is decision analysis appropriate?

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- There is uncertainty about the appropriate decision.

1. Define the decision problem

When is decision analysis appropriate?

- There is uncertainty about the appropriate decision.
- There is a meaningful tradeoff in the problem

2. Structure the decision

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- Outline the decision problem

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- Outline the decision problem
- Ill-defined problem into set of well-defined elements

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- Outline the decision problem
- Ill-defined problem into set of well-defined elements
- Balance sheets & Decision trees

Balance sheets

- List all different options or actions (choices)
- Consider possible benefits and risks of each choice

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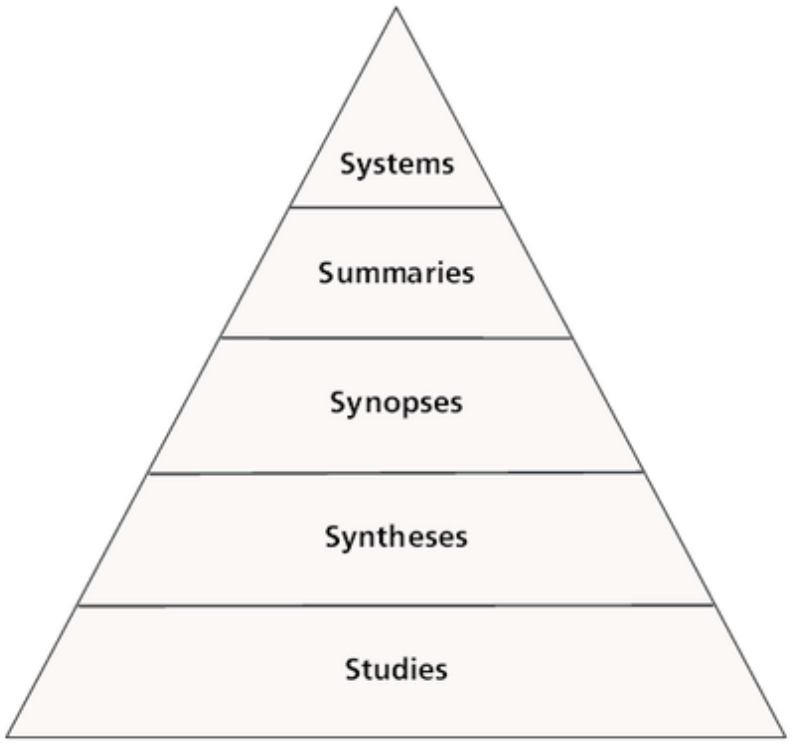
Examining the research literature

5S approach



Examples

Computerized decision-support systems (e.g., electronic health records)

Evidence-based textbooks (sources include online summary publications such as *Dynamed* and *ClinicalEvidence*)

Evidence-based journal abstracts (sources include *ACP Journal Club*, *Evidence-Based Medicine*)

Systematic reviews (sources include Cochrane Database of Systematic Reviews and DARE [Cochrane Database of Abstracts of Reviews of Effects])

Original journal articles (sources include Cochrane Central Register of Controlled Trials, PubMed Clinical Queries, MEDLINE)

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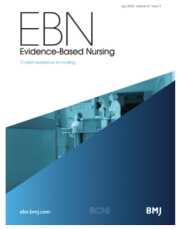

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Evidence-based nursing

Search results

63 results for term "menopause"

Results/page 10 Order by Best Match

Women kept up appearances and developed multiple coping strategies to deal with menopause FREE

Evidence Based Nursing Apr 1999, 2 (2) 62; DOI: 10.1136/ebn.2.2.62

...Kittell LA, Kernoff Mansfield P, Voda AM. Keeping up appearances: the basic social process of the **menopausal** transition. Qual Health Res 1998 Sep;8:61833. Question What are womens experiences of the **menopausal** transition and how do they interpret and respond to the changes they experience? Design ...

Review: sparse good quality evidence supports the use of alternative therapies for menopausal symptoms

Evidence Based Nursing Jan 2007, 10 (1) 14; DOI: 10.1136/ebn.10.1.14

...Nedrow A, Miller J, Walker M, et al. Complementary and alternative therapies for the management of **menopause**-related symptoms: a systematic evidence review. Arch Intern Med 2006 ...

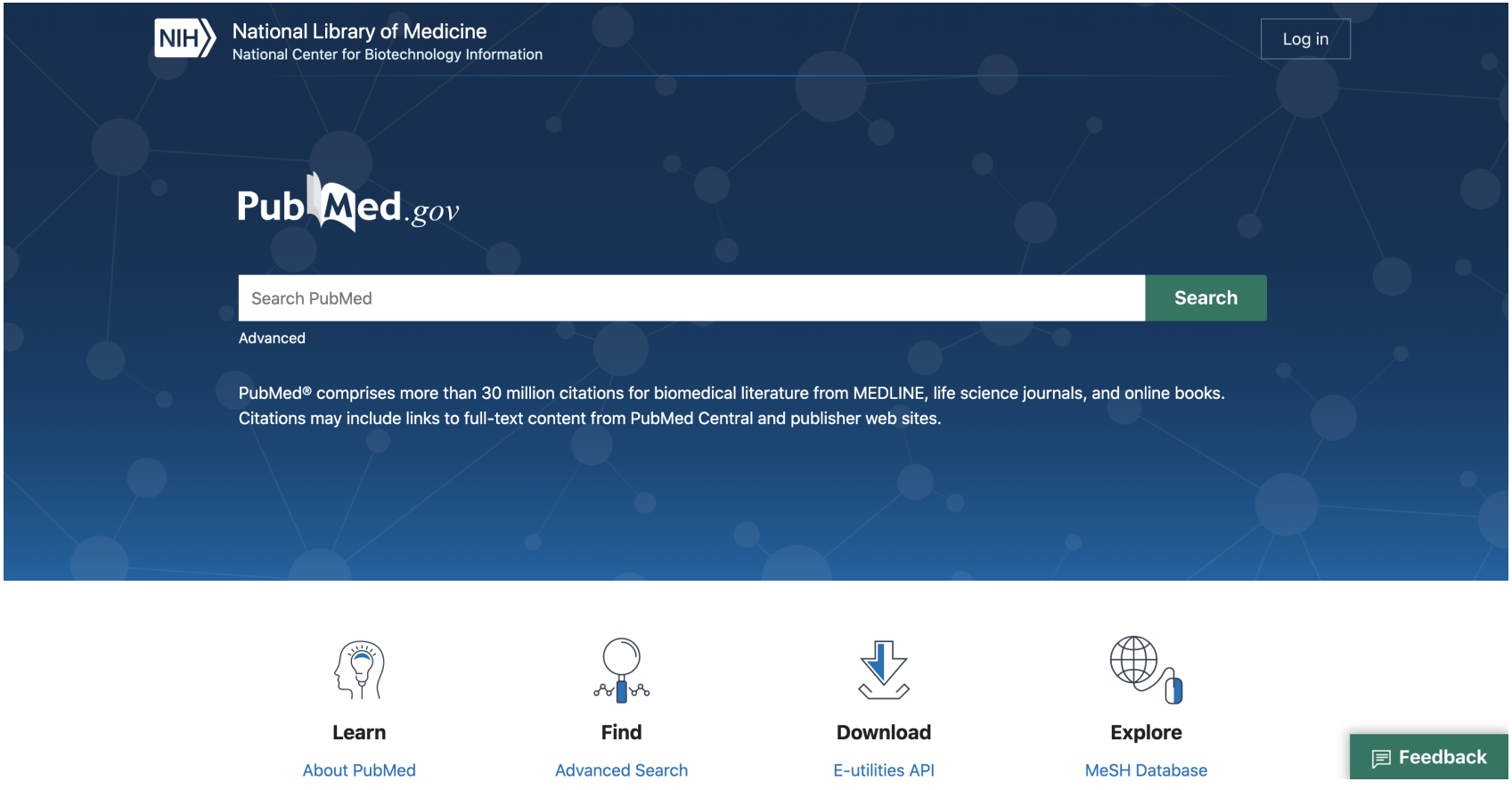
Review: plant based oestrogens do not relieve hot flushes or other menopausal symptoms FREE

Evidence Based Nursing Jul 2005, 8 (3) 83; DOI: 10.1136/ebn.8.3.83

...Krebs EE, Ensrud KE, MacDonald R, et al. Phytoestrogens for treatment of **menopausal** symptoms: a systematic review. Obstet Gynecol 2004 ...

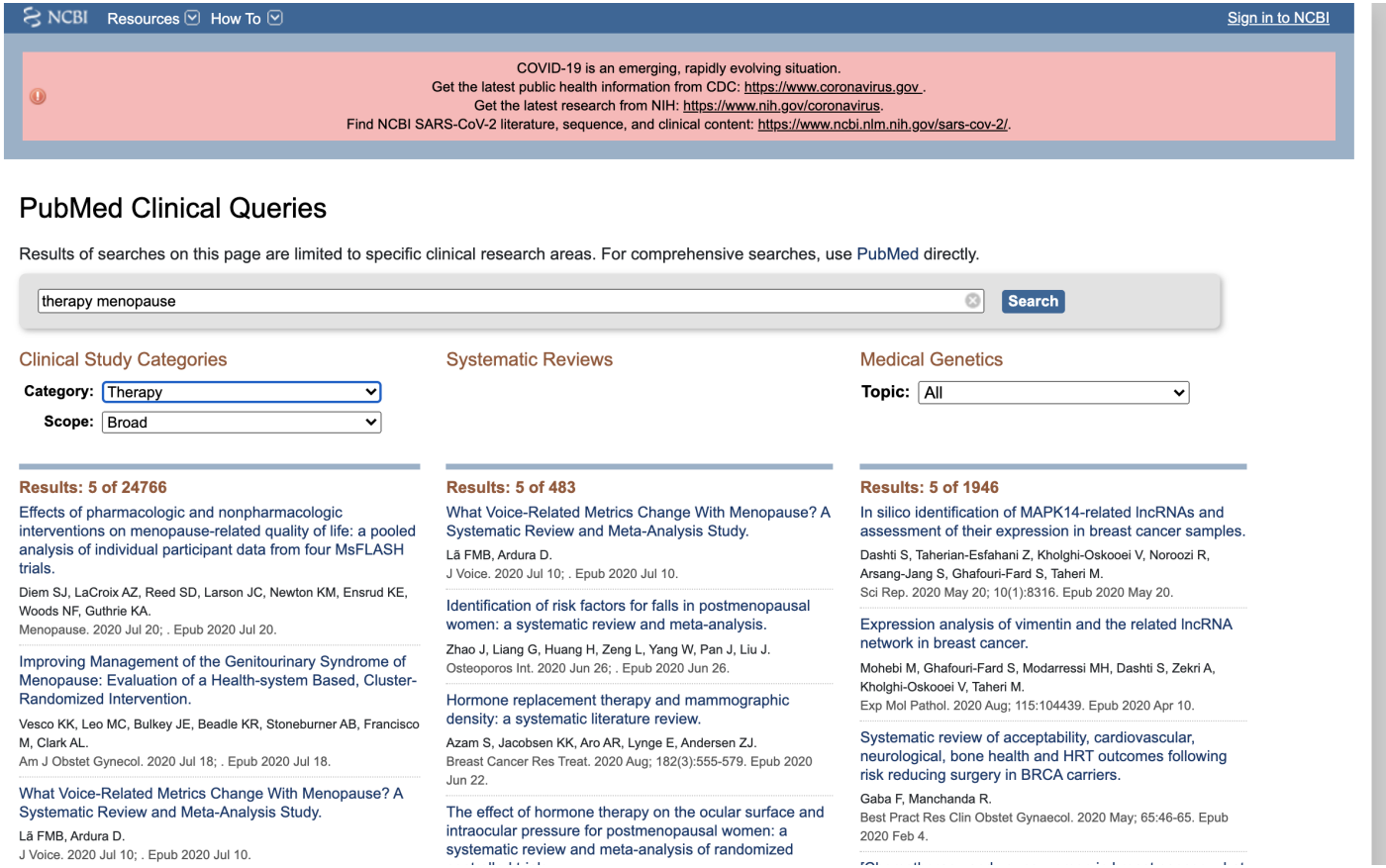
PubMed

https://pubmed.ncbi.nlm.nih.gov/



PubMed

PubMed Clinical Queries



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Get the latest public health information from CDC: https://www.coronavirus.gov .
Get the latest research from NIH: https://www.nih.gov/coronavirus.
Find NCBI SARS-CoV-2 literature, sequence, and clinical content: https://www.ncbi.nlm.nih.gov/sars-cov-2/.

PubMed Clinical Queries

Results of searches on this page are limited to specific clinical research areas. For comprehensive searches, use PubMed directly.

therapy menopause Search

Clinical Study Categories

Category: Therapy

Scope: Broad

Systematic Reviews

Medical Genetics

Topic: All

Results: 5 of 24766

Effects of pharmacologic and nonpharmacologic interventions on menopause-related quality of life: a pooled analysis of individual participant data from four MsFLASH trials.
Diem SJ, LaCroix AZ, Reed SD, Larson JC, Newton KM, Ensrud KE, Woods NF, Guthrie KA.
Menopause. 2020 Jul 20; . Epub 2020 Jul 20.

Improving Management of the Genitourinary Syndrome of Menopause: Evaluation of a Health-system Based, Cluster-Randomized Intervention.
Vesco KK, Leo MC, Bulkey JE, Beadle KR, Stoneburner AB, Francisco M, Clark AL.
Am J Obstet Gynecol. 2020 Jul 18; . Epub 2020 Jul 18.

What Voice-Related Metrics Change With Menopause? A Systematic Review and Meta-Analysis Study.
Lã FMB, Ardura D.
J Voice. 2020 Jul 10; . Epub 2020 Jul 10.

Results: 5 of 483

What Voice-Related Metrics Change With Menopause? A Systematic Review and Meta-Analysis Study.
Lã FMB, Ardura D.
J Voice. 2020 Jul 10; . Epub 2020 Jul 10.

Identification of risk factors for falls in postmenopausal women: a systematic review and meta-analysis.
Zhao J, Liang G, Huang H, Zeng L, Yang W, Pan J, Liu J.
Osteoporos Int. 2020 Jun 26; . Epub 2020 Jun 26.

Hormone replacement therapy and mammographic density: a systematic literature review.
Azam S, Jacobsen KK, Aro AR, Lynge E, Andersen ZJ.
Breast Cancer Res Treat. 2020 Aug; 182(3):555-579. Epub 2020 Jun 22.

The effect of hormone therapy on the ocular surface and intraocular pressure for postmenopausal women: a systematic review and meta-analysis of randomized

Results: 5 of 1946

In silico identification of MAPK14-related lncRNAs and assessment of their expression in breast cancer samples.
Dashti S, Taherian-Esfahani Z, Kholghi-Oskooei V, Noroozi R, Arsang-Jang S, Ghafouri-Fard S, Taheri M.
Sci Rep. 2020 May 20; 10(1):8316. Epub 2020 May 20.

Expression analysis of vimentin and the related lncRNA network in breast cancer.
Mohebi M, Ghafouri-Fard S, Modarressi MH, Dashti S, Zekri A, Kholghi-Oskooei V, Taheri M.
Exp Mol Pathol. 2020 Aug; 115:104439. Epub 2020 Apr 10.

Systematic review of acceptability, cardiovascular, neurological, bone health and HRT outcomes following risk reducing surgery in BRCA carriers.
Gaba F, Manchanda R.
Best Pract Res Clin Obstet Gynaecol. 2020 May; 65:46-65. Epub 2020 Feb 4.

Balance sheets

Table 11.1 Balance sheet for menopausal decision

Intervention	*Benefit*	*Harm*
Provide lifestyle advice	Might be sufficient to help manage hot flushes and anxiety symptoms	None from intervention itself. Long-term consequences of the menopause: increased risk of osteoporosis, urogenital atrophy, cardiovascular disease, stroke
Hormone replacement therapy (provision of oestrogen with a progestogen in women with a uterus)	Relief of menopausal symptoms; hot flushes, night sweats, urogenital atrophy Decreased risk of osteoporosis Decreased risk of colorectal cancer	Increased risk of breast cancer Increased risk of stroke Increased risk of venous thromboembolism
Non-hormonal alternatives that contain phytoestrogens (e.g. soy foods)	May reduce symptoms such as hot flushes	None known

Decision trees

Decision trees

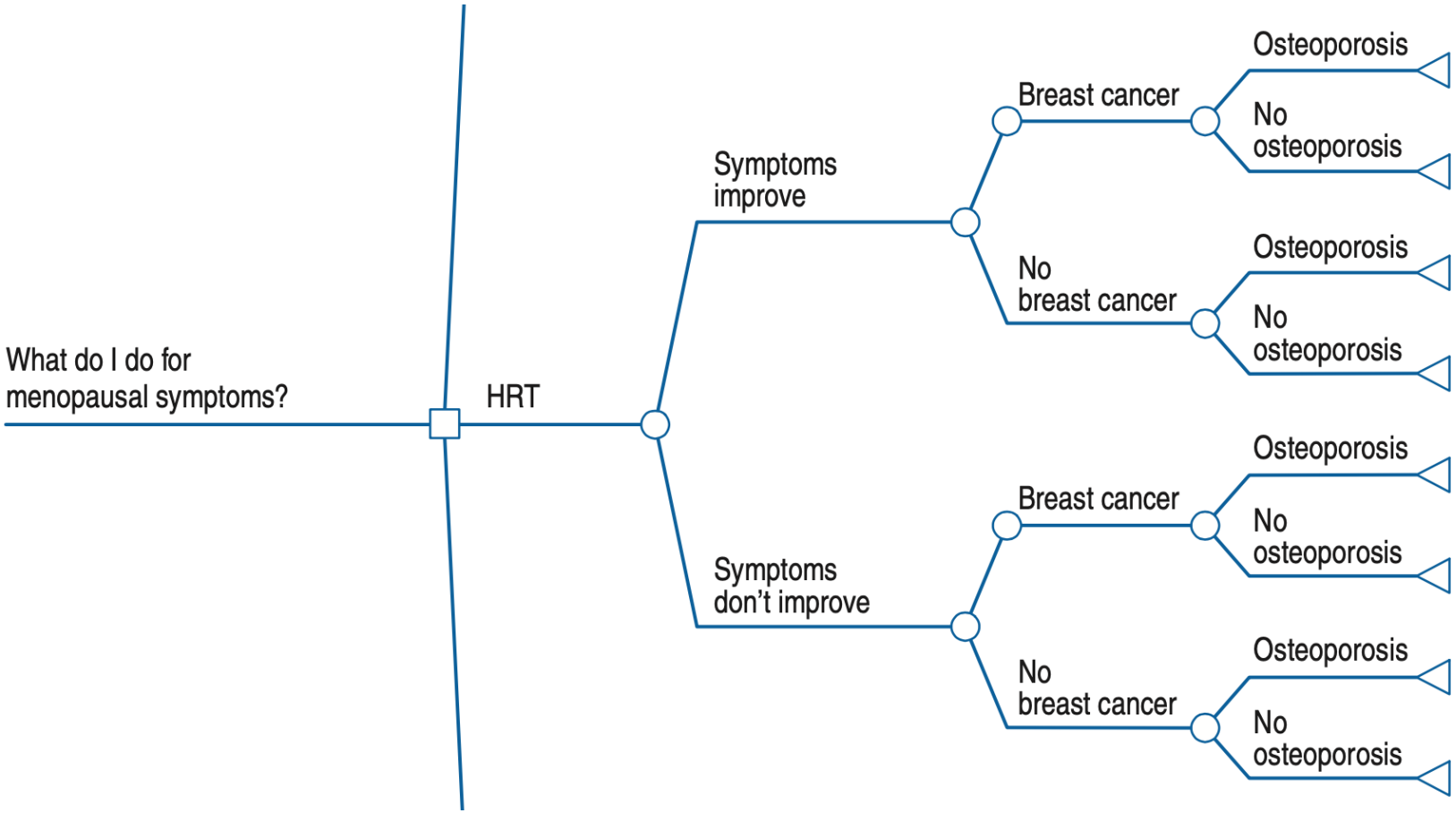
A simplified model of the actual decision situation.

Decision trees

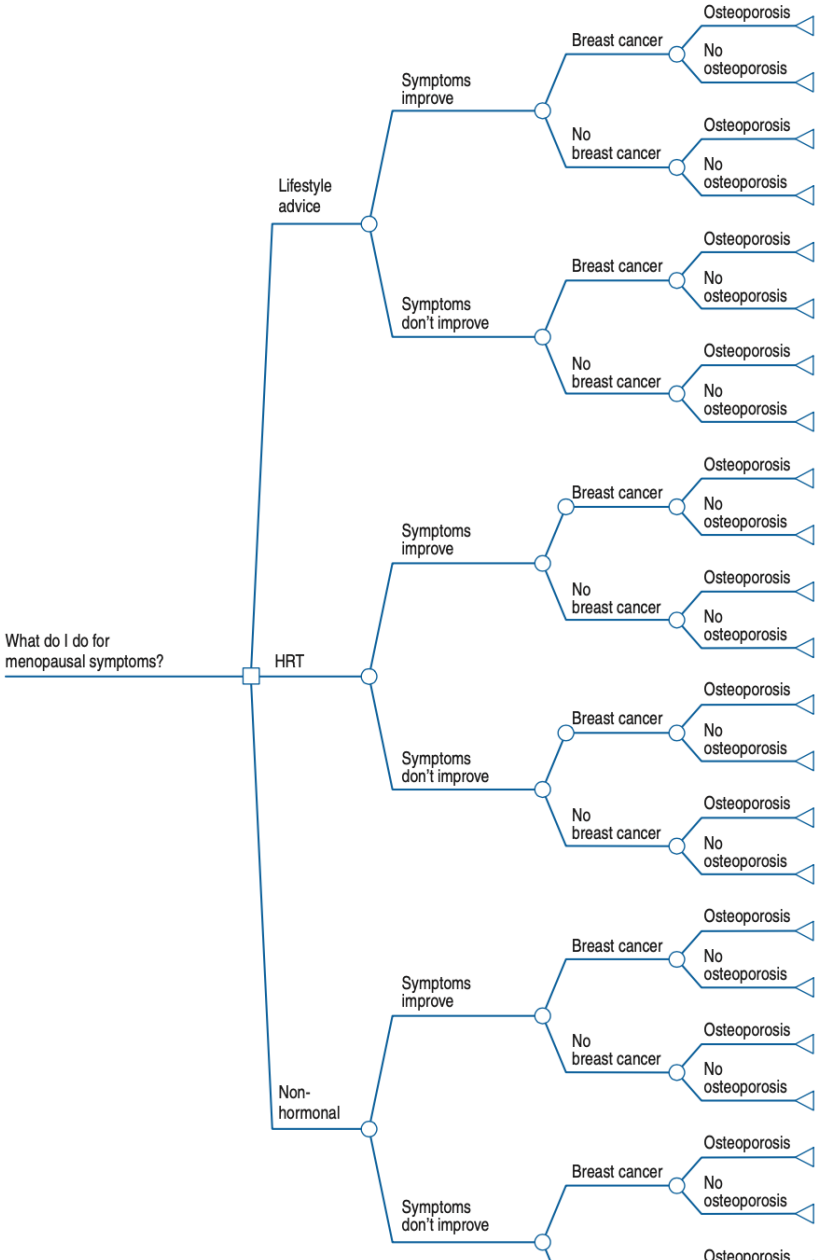
A simplified model of the actual decision situation.
Represent:

- The decision options (decision node, square node)
- Uncertainty associated with each option (chance node, circular node)

Decision trees



Decision trees



Decision trees

Recommendation

- The tree must have balance
- Only two branches after each chance node
- No embedded decision node
- The tree must have symmetry
- Don't worry about order

Decision trees

Recommendation

- The tree must have balance
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Comprehensive vs. Understandable

3. Assessing the probability of different outcomes

3. Assessing the probability of different outcomes

- Estimate how likely of each outcome occurrence

3. Assessing the probability of different outcomes

- Estimate how likely of each outcome occurrence
- Adding probabilities into the decision model

Estimating probabilities

Estimating probabilities

- Using research evidence

Estimating probabilities

- Using research evidence
- Asking expert estimates (+ your own personal 'confidence intervals')

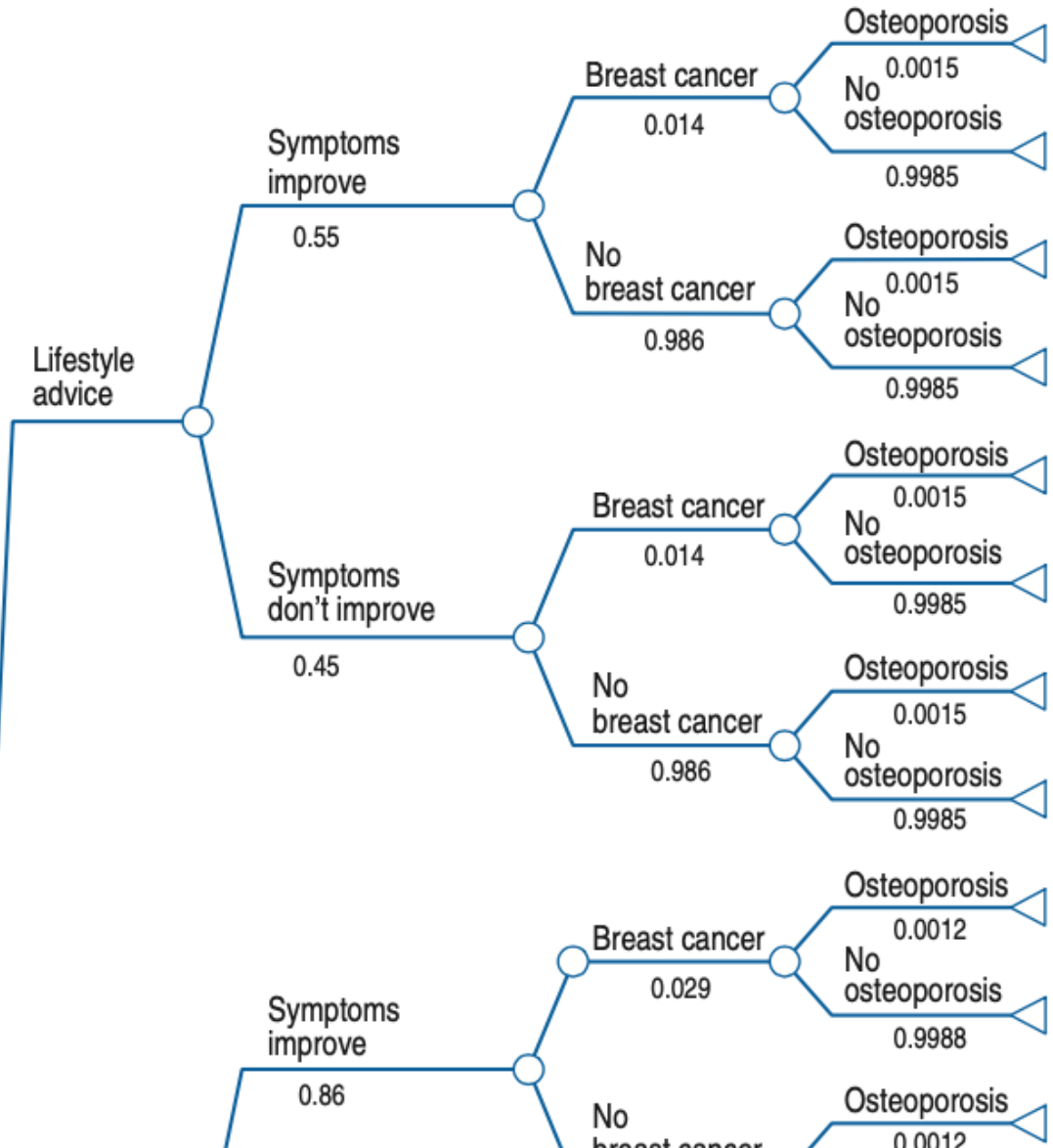
Estimating probabilities

Table 11.3 Probability table for menopausal decision

Outcome	*Probability estimate*	*Range*
Symptoms improve with lifestyle advice*	0.55	0.2–0.705
Symptoms improve with HRT	0.86	0.706–0.96
Symptoms improve with non-hormonal treatment	0.43	Not known
Risk of developing breast cancer over 5 years with no treatment	0.014	0.013–0.014
Risk of developing breast cancer over 5 years with HRT	0.028	0.028–0.031
Risk of developing breast cancer over 5 years with non-hormonal treatment	0.014	0.013–0.014
Risk of hip fracture (osteoporosis) over 5 years with no treatment	0.0015	0.0005–0.0025
Risk of hip fracture (osteoporosis) over years with HRT	0.0012	0.0002–0.0022
Risk of hip fracture (osteoporosis) over 5 years with non-hormonal treatment	0.0015	0.0005–0.0025

Adding probabilities

For each branch, the probability values should add up to 1



4. Measure patient utility

Utility

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Utility

- Numeric measure of the value an individual/group place on the different outcomes
- Measured on an interval scale, from 0 to 1
- 0 = the worst possible health state and 1 = the best possible health state
- Measured at the individual patient level or at a population level

Estimating utility

Possible strategy

Estimating utility

Possible strategy

- Arbitrarily assigned value

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- Ask a group of experts

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Estimating utility

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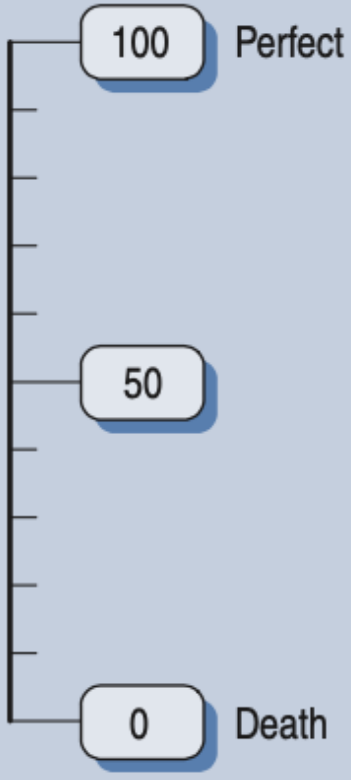
- Arbitrarily assigned value
- Ask a group of experts
- Use relevant utility values in published literature
- Measure utility values directly
  - Rating scales
  - Standard gamble
  - Time trade-off

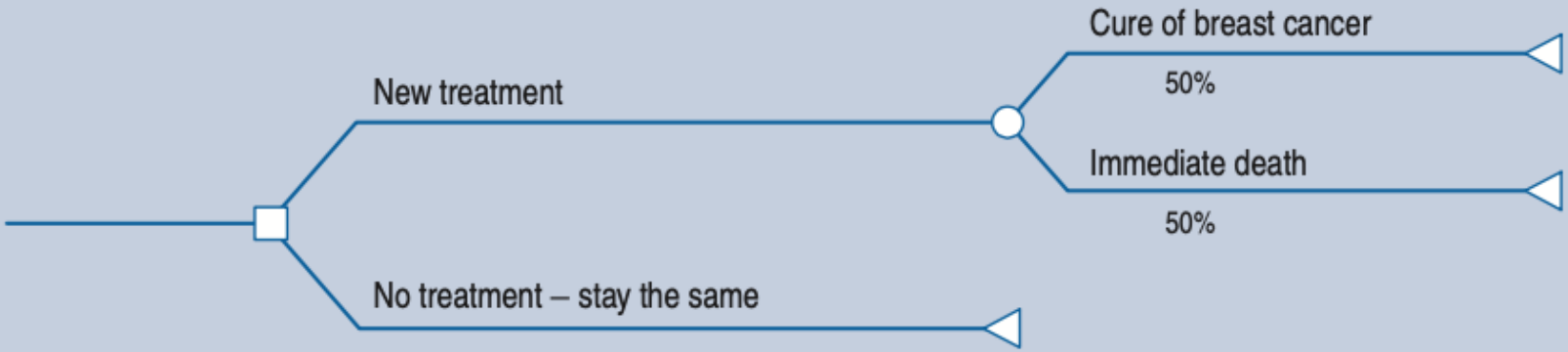
Rating scales

On a scale where 0 represents death and 100 represents excellent health, what number would you say best describes how you would feel about developing breast cancer over the next 5 years (Figure 11.3)?



Standard gamble

Imagine that you will develop breast cancer over the next 5 years. You are told that there is a new treatment available to you, which has a 50% probability of completely curing you of cancer. However, the treatment also has a 50% probability of causing immediate death. Would you have the treatment (Figure 11.4)?



Standard gamble

If your answer was 'No', would you be prepared to have the new treatment if there was a 60% chance of the cure and a 40% chance of death?

If your answer was 'Yes', would you be prepared to have the new treatment if there was a 40% chance of the cure and a 60% chance of death?

Alter the values up or down until the person is at a point where she cannot decide (i.e. both options are equal). The person's utility for having breast cancer is the probability of having a cure for breast cancer. So say, for instance, that the patient would accept the treatment when it had a 90% chance of cure and a 10% chance of death, her utility for breast cancer is 0.9.

Time trade-off

Imagine that you have 40 years of life expectancy, living with breast cancer. Now imagine that someone can give you a cure for your cancer but you will only live 20 more years, instead of 40. Would you take the cure?

Depending on the answer, alter the amount of time traded. So if the answer is 'No', would they accept the treatment if it cured them and they lived 39 years? If the answer was 'Yes', would the patient accept the treatment if she lived 10 more years?

Continue until the two options are the same (living with breast cancer or being cured). At this point, the utility for breast cancer would be the ratio of the length of life in perfect health to the length of life in the health state being evaluated.

Measure utility values directly

Measure utility values directly

- Vary between methods

Measure utility values directly

- Vary between methods
- Whose preferences or values? from person who will be affected most

Using utility measures in a decision tree

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Combination of states: Decomposed approach

Using utility measures in a decision tree

Combination of states: Decomposed approach

- Utility of each separate outcome

Using utility measures in a decision tree

Combination of states: Decomposed approach

- Utility of each separate outcome
- Short-term outcome vs. long-term outcome

Using utility measures in a decision tree

Combination of states: Decomposed approach

- Utility of each separate outcome
- Short-term outcome vs. long-term outcome
- Utility of long-term outcome - Disutility of short-term outcome

Using utility measures in a decision tree

Combination of states: Decomposed approach

- Utility of each separate outcome
- Short-term outcome vs. long-term outcome
- Utility of long-term outcome - Disutility of short-term outcome
- $(U_{LT1} \times U_{LT2} \times \ldots) - (DU_{ST1} + DU_{ST2} + \ldots)$

Using utility measures in a decision tree

Combination of states: Decomposed approach

- Utility of each separate outcome
- Short-term outcome vs. long-term outcome
- Utility of long-term outcome - Disutility of short-term outcome
- $(U_{LT1} \times U_{LT2} \times \ldots) - (DU_{ST1} + DU_{ST2} + \ldots)$
- Check (ranking)

Using utility measures in a decision tree

Short-term outcomes	*Utility value*	*Disutility*
HRT*	0.98	0.02
Non-hormonal therapy*	0.99	0.01
Symptoms improve	1	0
Menopausal symptoms (Brazier et al 2005)	0.81	0.19
Long-term outcomes	Utility value	
Breast cancer	0.8 (CEAR)**	
Fractured hip	0.63 (CEAR)†	

Using utility measures in a decision tree

Lifestyle branch – outcomes	Utility
Symptoms improve, breast cancer, fractured hip	$(0.8 \times 0.63) - 0 = 0.504$
Symptoms improve, breast cancer	$0.8 - 0 = 0.8$
Symptoms improve, fractured hip	$0.63 - 0 = 0.63$
Symptoms improve	1
Symptoms the same, breast cancer, fractured hip	$(0.8 \times 0.63) - 0.19 = 0.314$
Symptoms the same, breast cancer	$0.8 - 0.19 = 0.61$
Symptoms the same, fractured hip	$0.63 - 0.19 = 0.44$
Symptoms the same	0.81

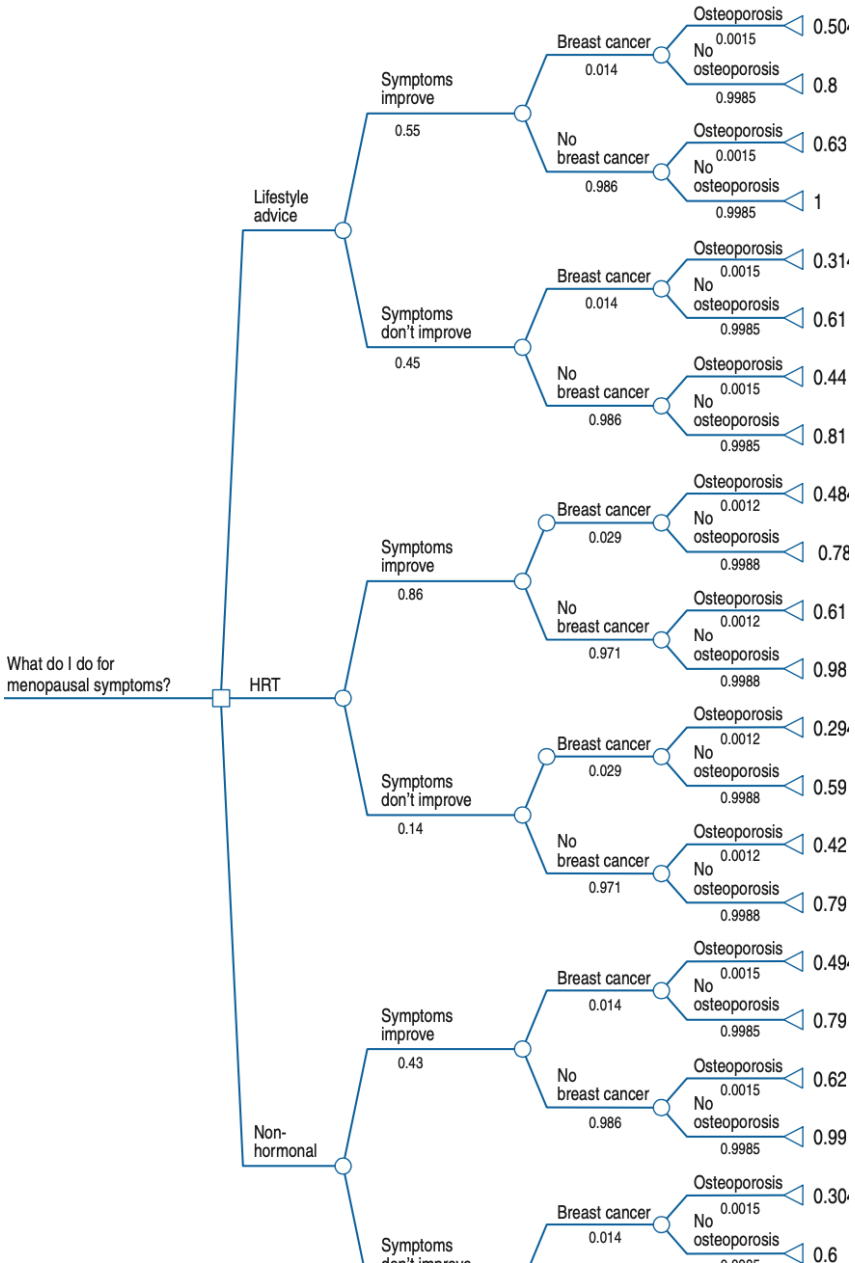
Using utility measures in a decision tree

HRT branch – outcomes	Utility
Take HRT, symptoms improve, breast cancer, fractured hip	$(0.8 \times 0.63) - (0.02 + 0) = 0.484$
Take HRT, symptoms improve, breast cancer	$0.8 - (0.02 + 0) = 0.78$
Take HRT, symptoms improve, fractured hip	$0.63 - (0.02 + 0) = 0.61$
Take HRT, symptoms improve	0.98
Take HRT, symptoms the same, breast cancer, fractured hip	$(0.8 \times 0.63) - (0.02 + 0.19) = 0.294$
Take HRT, symptoms the same, breast cancer	$0.8 - (0.02 + 0.19) = 0.59$
Take HRT, symptoms the same, fractured hip	$0.63 - (0.02 + 0.19) = 0.42$
Take HRT, symptoms the same	$1 - (0.02 + 0.19) = 0.79$

Using utility measures in a decision tree

Non-hormonal therapy branch – outcomes	Utility
Take non-hormonal therapy, symptoms improve, breast cancer, fractured hip	$(0.8 \times 0.63) - (0.01 + 0) = 0.494$
Take non-hormonal therapy, symptoms improve, breast cancer	$0.8 - 0.01 = 0.79$
Take non-hormonal therapy, symptoms improve, fractured hip	$0.63 - 0.01 = 0.62$
Take non-hormonal therapy, symptoms improve	0.99
Take non-hormonal therapy, symptoms the same, breast cancer, fractured hip	$(0.8 \times 0.63) - (0.01 + 0.19) = 0.304$
Take non-hormonal therapy, symptoms the same, breast cancer	$0.8 - (0.01 + 0.19) = 0.6$
Take non-hormonal therapy, symptoms the same, fractured hip	$0.63 - (0.01 + 0.19) = 0.43$
Take non-hormonal therapy, symptoms the same	$1 - (0.01 + 0.19) = 0.8$

Using utility measures in a decision tree



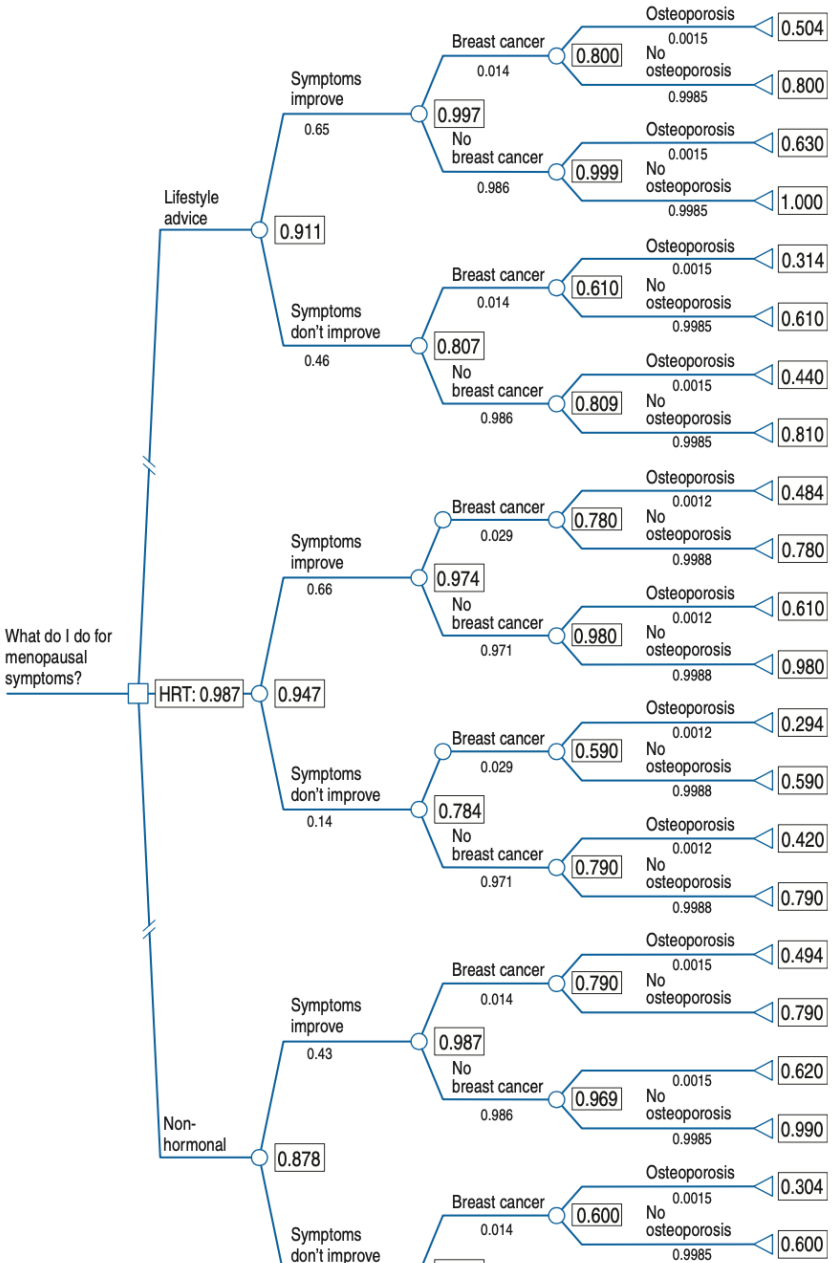
5.Identify the 'best' option

- Calculate "Expected utility"

$$\text{Expected utility} = P(\text{O}_1) \times U(\text{O}_1) + \ldots + P(\text{O}_n) \times U(\text{O}_n)$$

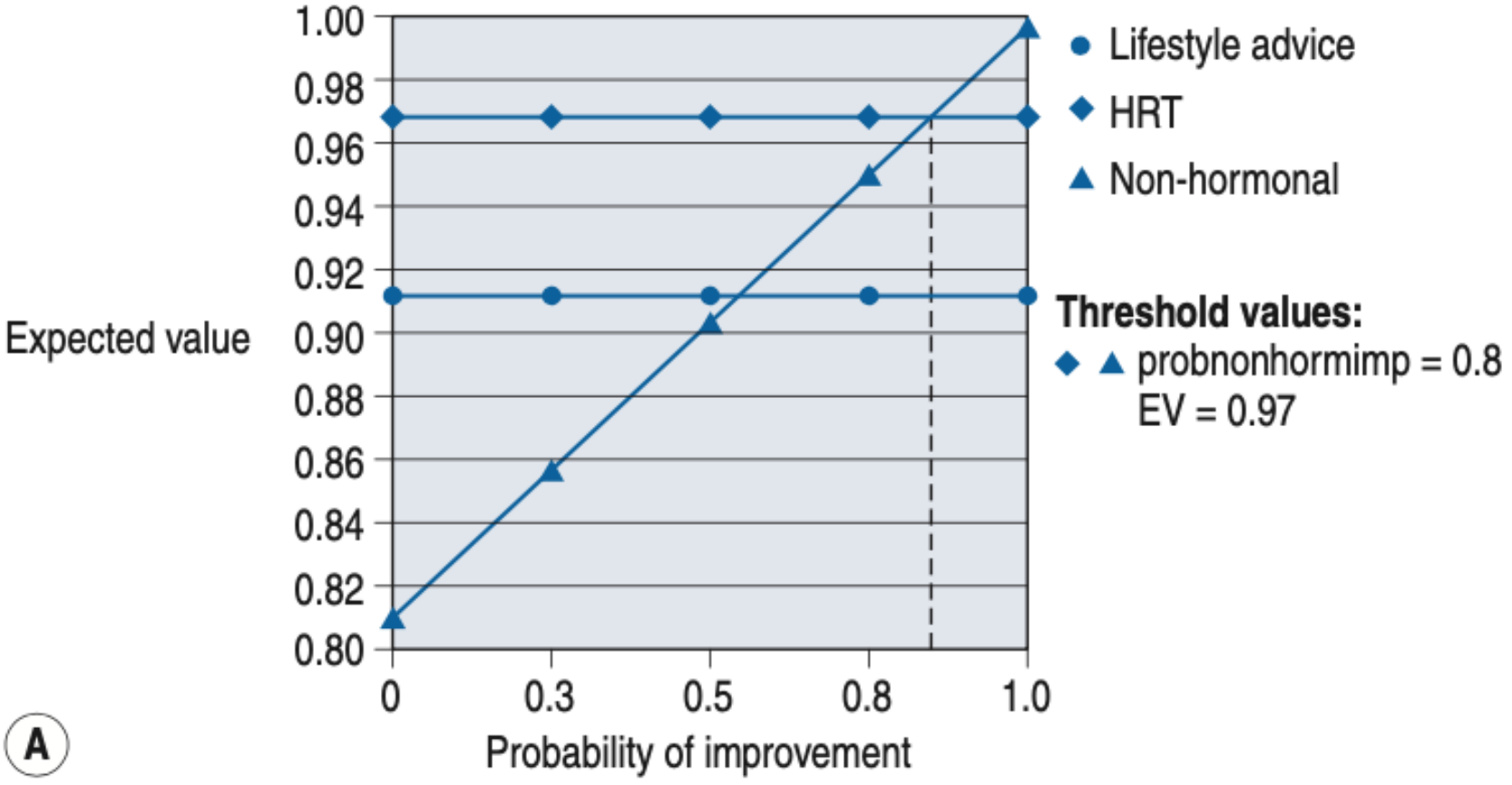
- Compare expected utility between options

Identify the 'best' option



6. Assess the sensitivity of the decision model

- Assessing the 'robustness' of your decision analysis
- Alter the probabilities and/or utilities in your decision model



Recap

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- Decision analysis

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Recap

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Pros

- Useful technique for assisting complex and uncertain decisions
- Provide evidence-based decisions
- An explicit and systematic approach to decision making
- Patients are more involved & directly influence decision

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Pros

- Useful technique for assisting complex and uncertain decisions
- Provide evidence-based decisions
- An explicit and systematic approach to decision making
- Patients are more involved & directly influence decision

Cons

- Subjective estimates of probability
- Subjective estimates of utility
- Time consuming
- Artificially simplifying complex decision problems

Further readings

- "Primer on medical decision analysis" by Detsky AS et al. *Medical Decision Making*
- Dawn Dowding Carl Thompson (2009) Essential Decision Making and Clinical Judgement for Nurses. Chapter 11. http://booksite.elsevier.com/samplechapters/9780443067273/9780443067237_11.pdf

Practice

Identify a recent decision that you found difficult.

- Very complex
- Uncertain
- you and your patient had different views about what might be the best thing to do

What was your decision?

Exercise 1: Structuring decisions

1. Describe the decision situation (identify key features that made it difficult)
2. List all options, and the risks/benefits associated with each option
3. Put this into a balance sheet
4. Represent as a decision tree
5. Simplify the situation by focusing on the key outcomes

Exercise 2: Assessing the probability of different outcomes

Take the decision tree that you constructed in Exercise 1

1. List all possible outcomes in a table
2. Search research evidence to estimate probability of each outcome occurrence
3. Summarise the evidence
4. Put probability estimates into the table
5. Put probability estimates into the decision tree

Exercise 3: Measuring utility

Take the decision tree you have constructed

1. List all the possible outcomes
2. Separate the outcomes into short-term & long-term outcomes
3. Estimate the value or preference individuals attach to each outcome
4. List all of the possible combinations of outcomes in a table
5. Calculate the 'disutility' of all short-term health states
6. Calculate the utility for each possible combination of outcomes

Exercise 4: Calculating a decision tree

Take the decision tree with both your probability and utility values that have been constructed

1. Calculate the 'expected utility' for each choice option in your tree
2. Look to see which branch has the highest value
3. How does this option compare with your actual decision?