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Introduction to decision modelling

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Learning objectives

Understand:

- the role of modelling in economic evaluation
- the construction and analysis of decision trees
- the design and interpretation of a simple Markov model
- the appropriate circumstances for their use

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Role of modelling in economic evaluation

- Extrapolate costs and effectiveness beyond trial data
- Reflect all appropriate evidence
- Compare all relevant options
- Link intermediate clinical endpoints to final outcomes
- Generalise results obtained in one clinical setting to other settings
- Inform resource allocation decisions in the absence of "hard data"
- Make head-to-head comparisons of alternative competing interventions when relevant trials do not exist

The main types of model

- Decision trees
- Markov models
- Other types of models beyond this lecture

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A decision model….

- has a structure to represent clinical pathways
- allows synthesis of evidence to estimate costs and effectiveness
- weighs up risks and benefits of an intervention
- can allow events occurring over time
- allows an assessment of different types of uncertainty
- can identify priorities for future research

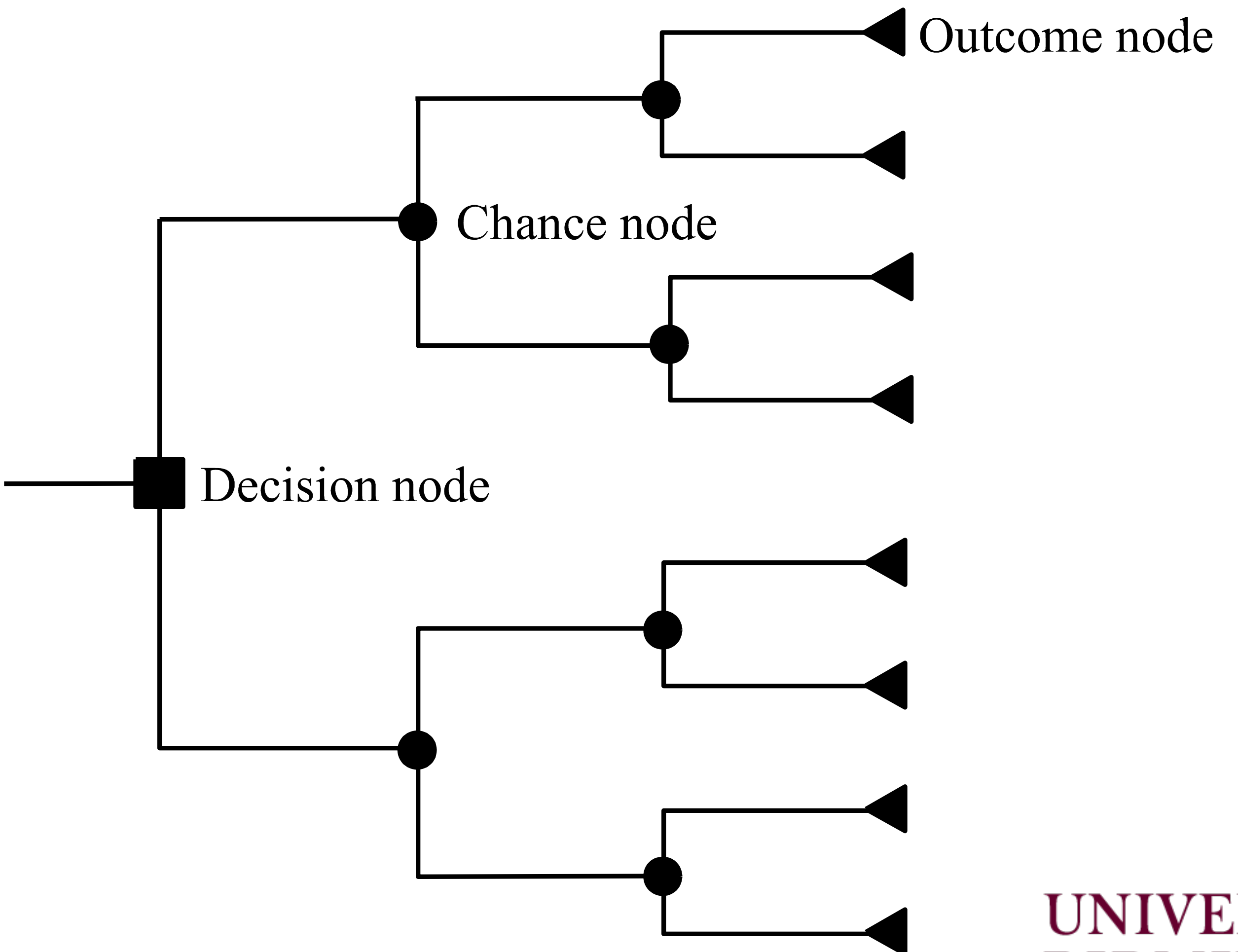
Decision Trees

- Use for “one off” decisions
- Particularly suited to
  - Acute care problems (“kill or cure”)
  - Once-only diseases
  - Short-term diagnostic/screening decisions

Steps in constructing and analysing decision trees

1. Structure the tree
2. Estimate probabilities
3. Estimate outcomes
4. Analyse the tree
5. Sensitivity analysis

Decision Tree Structure



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Elements of a tree

- Have one decision node at the root
- The branches off the initial decision node represent all the strategies that are to be compared
- A series of chance nodes off of each strategy branch
- The outcomes at the end of each pathway

Decision Tree Example

- Illustrative example: Heparin for the prevention of deep vein thrombosis (DVT) in hip replacement patients
- Patients are at risk of DVT (and pulmonary embolism) post-surgery
- Heparin can be injected pre-surgery and for 7-10 days post-surgery to try and prevent clots
- However, there are risks of bleeding
- The research question:
  - ‘Which is the more cost-effective treatment for hip replacement patients, heparin or conventional treatment?’

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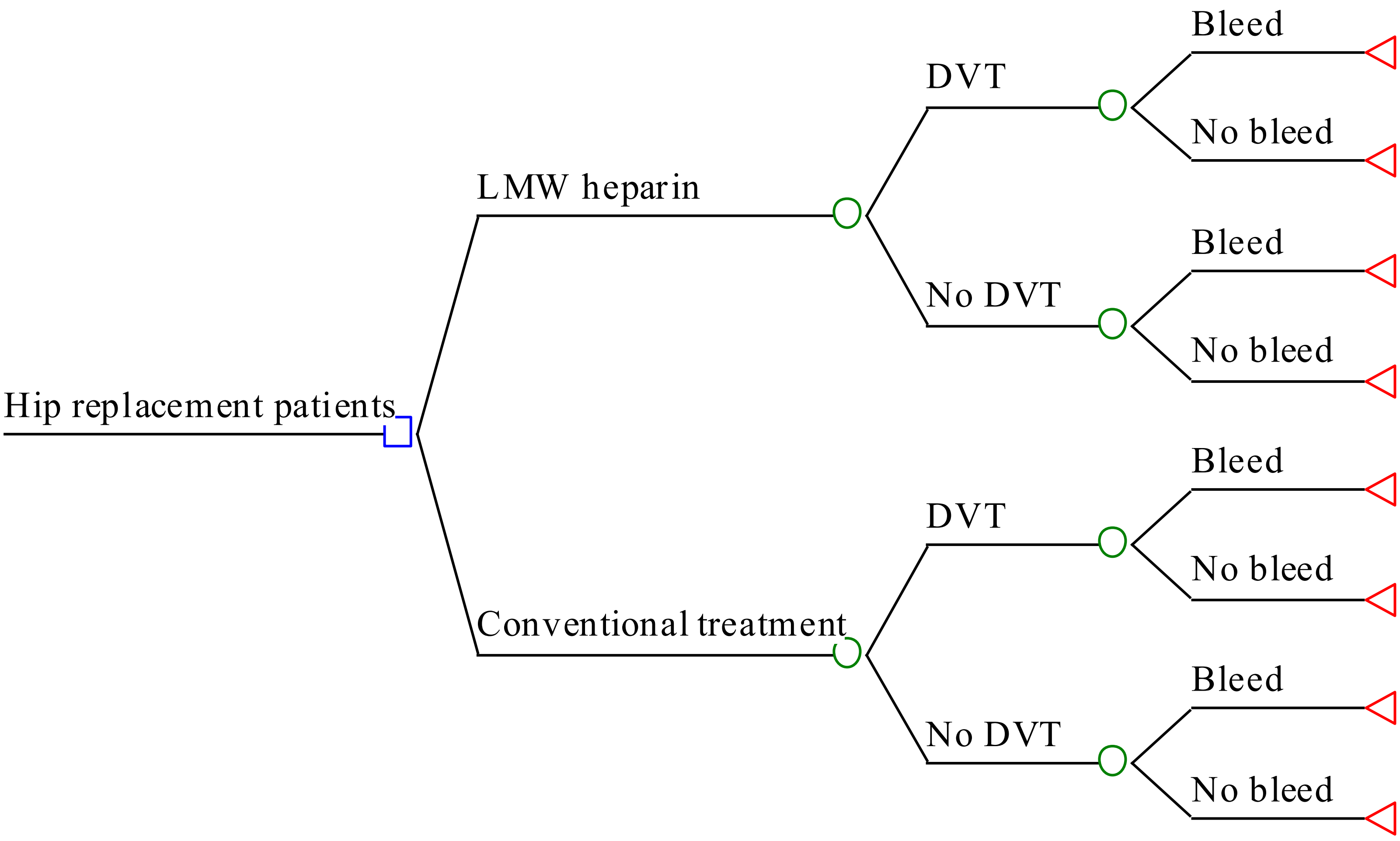
Decision tree for heparin



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Estimating probabilities

- Usually derived from published studies
  - Existing data: trial data or observational data
  - Meta analysis: aggregating from multiple sources

- For each branch following a chance node, the conditional probability *P* is needed:

$$P = \frac{\text{Number following that branch}}{\text{Number leaving chance node}}$$

- Probabilities are numbers between 0 and 1
- Probabilities for all branches out of a given chance node add to 1

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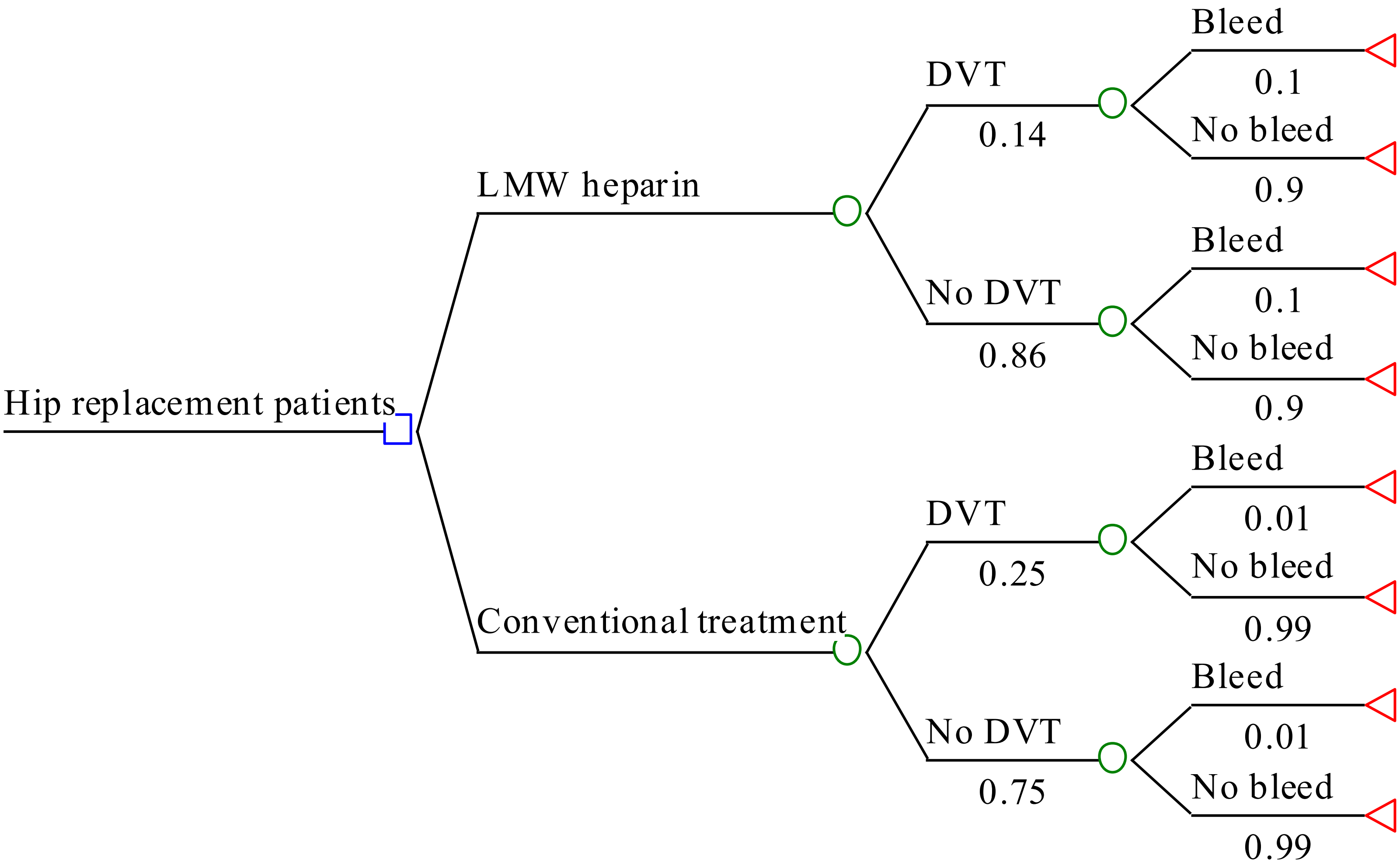
Entering probabilities



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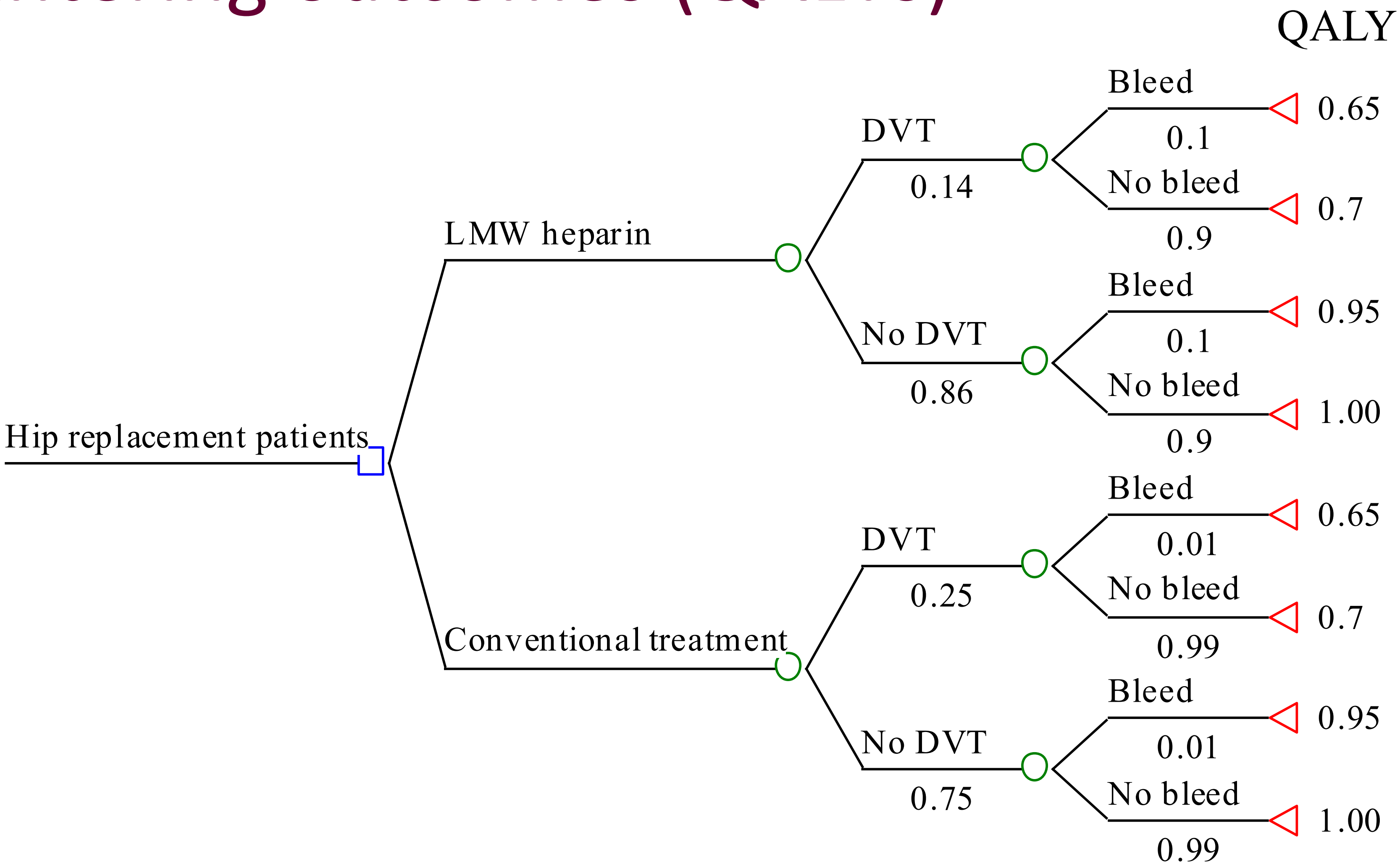
Estimating outcomes

- Outcomes include:
  - Total cost
  - Total utilities
  - Life years (LY)
  - Quality-adjusted life years (QALYs)
- Outcomes are entered at terminal nodes

Costs and Utilities

- Costs assumed for example here
  - Cost of heparin - £300
  - Cost of conventional treatment - £50
  - Cost of deep vein thrombosis event - £2000
  - Cost of bleed - £500
- Utilities assumed
  - DVT – 0.70
  - Bleed – 0.95
  - DVT & bleed – 0.65
  - No event – 1.00

Entering outcomes (QALYs)



Assume timeframe is one year

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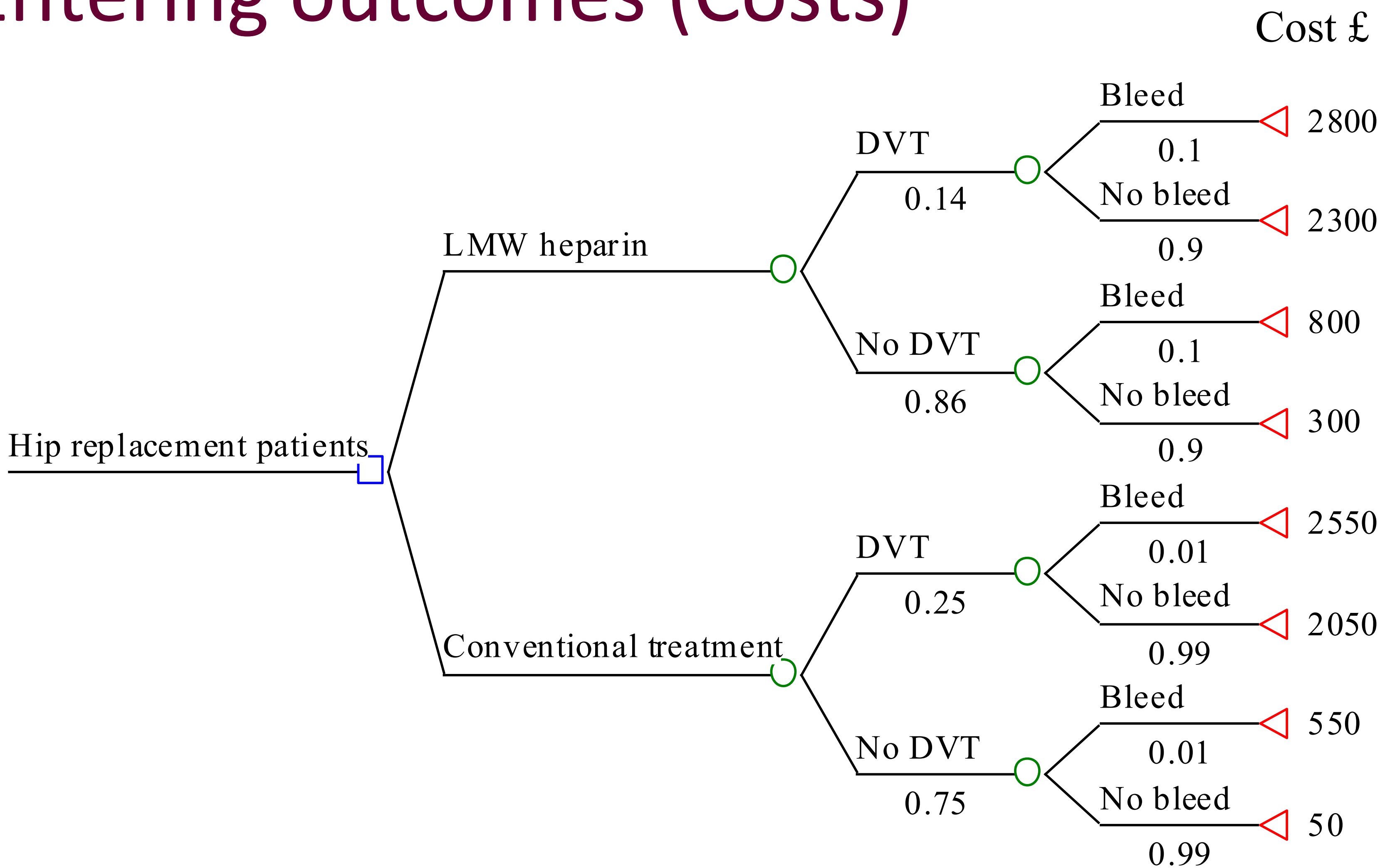
Entering outcomes (Costs)



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Analysing the decision tree

- Decision tree is averaged out and “rolled-back” to get the expected value for each strategy (work from terminal nodes towards decision nodes)

- Expected value is the sum of products of the estimates of the probability of events and their outcomes

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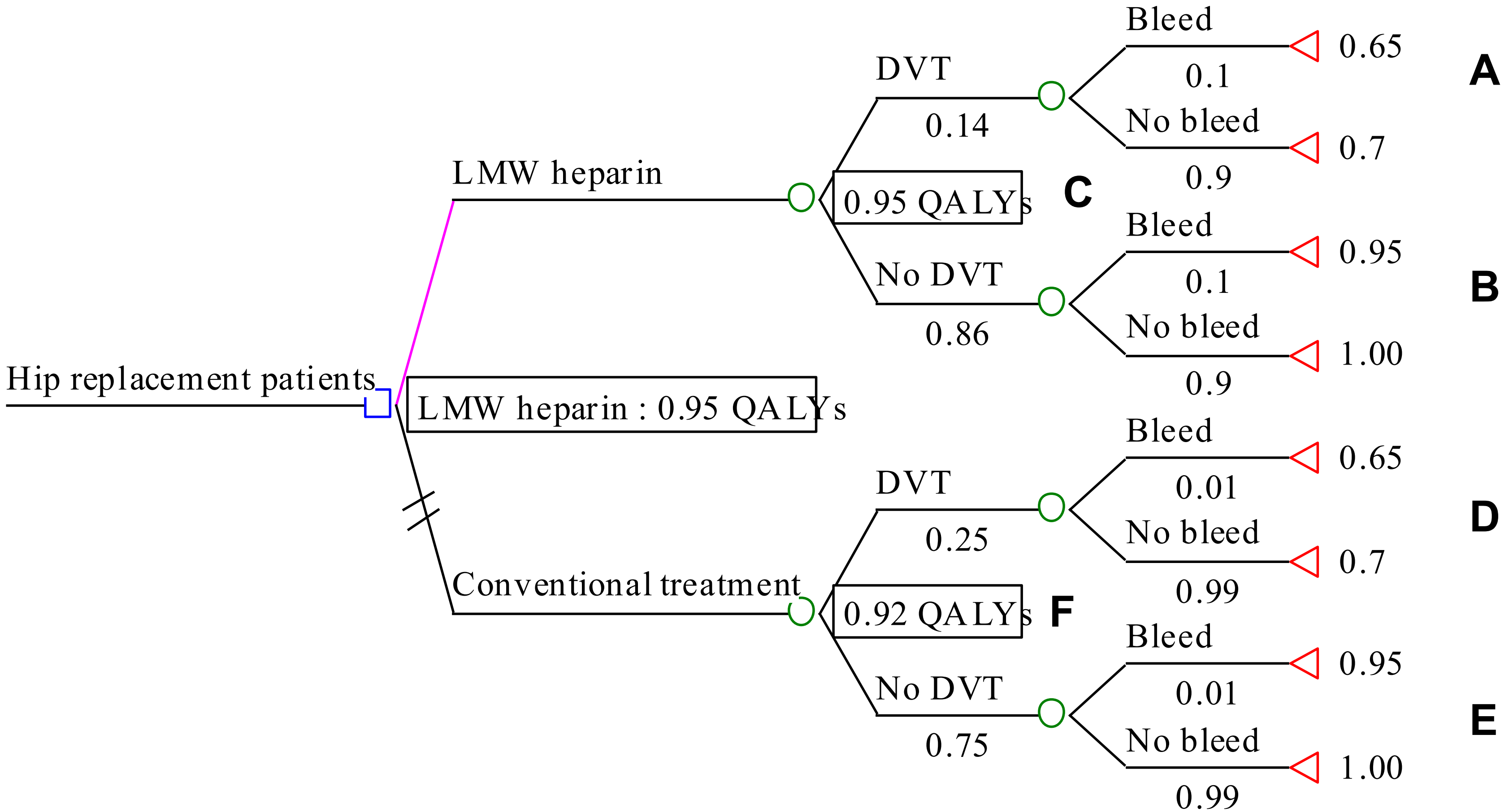
Example: analysing the tree (output as QALYs)



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Rollback Calculations

- Work from terminal nodes towards decision nodes
- QALYs of heparin arm is

Point A = (0.65*0.1) + (0.70*0.9) = 0.695

Point B = (0.95*0.1) + (1.0*0.9) = 0.995

Point C = (0.695*0.14) + (0.995*0.86) = 0.953

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Rollback Calculations

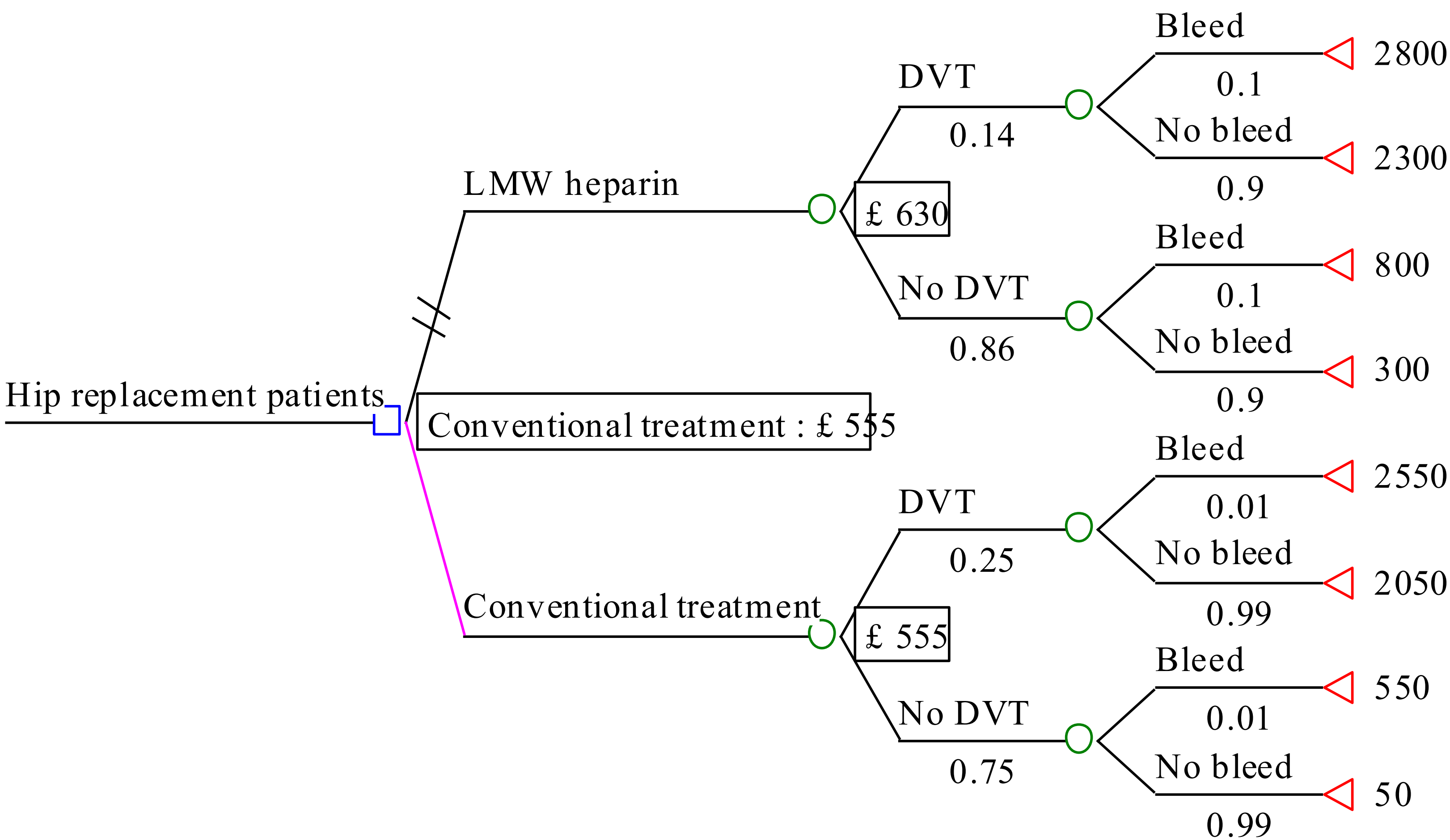
- QALYs of conventional treatment arm is

Point D = (0.65*0.01) + (0.70*0.99) = 0.6995

Point E = (0.95*0.01) + (1.0*0.99) = 0.9995

Point F = (0.6995*0.25) + (0.9995*0.75) = 0.9245

Example: analysing the tree (output as costs)



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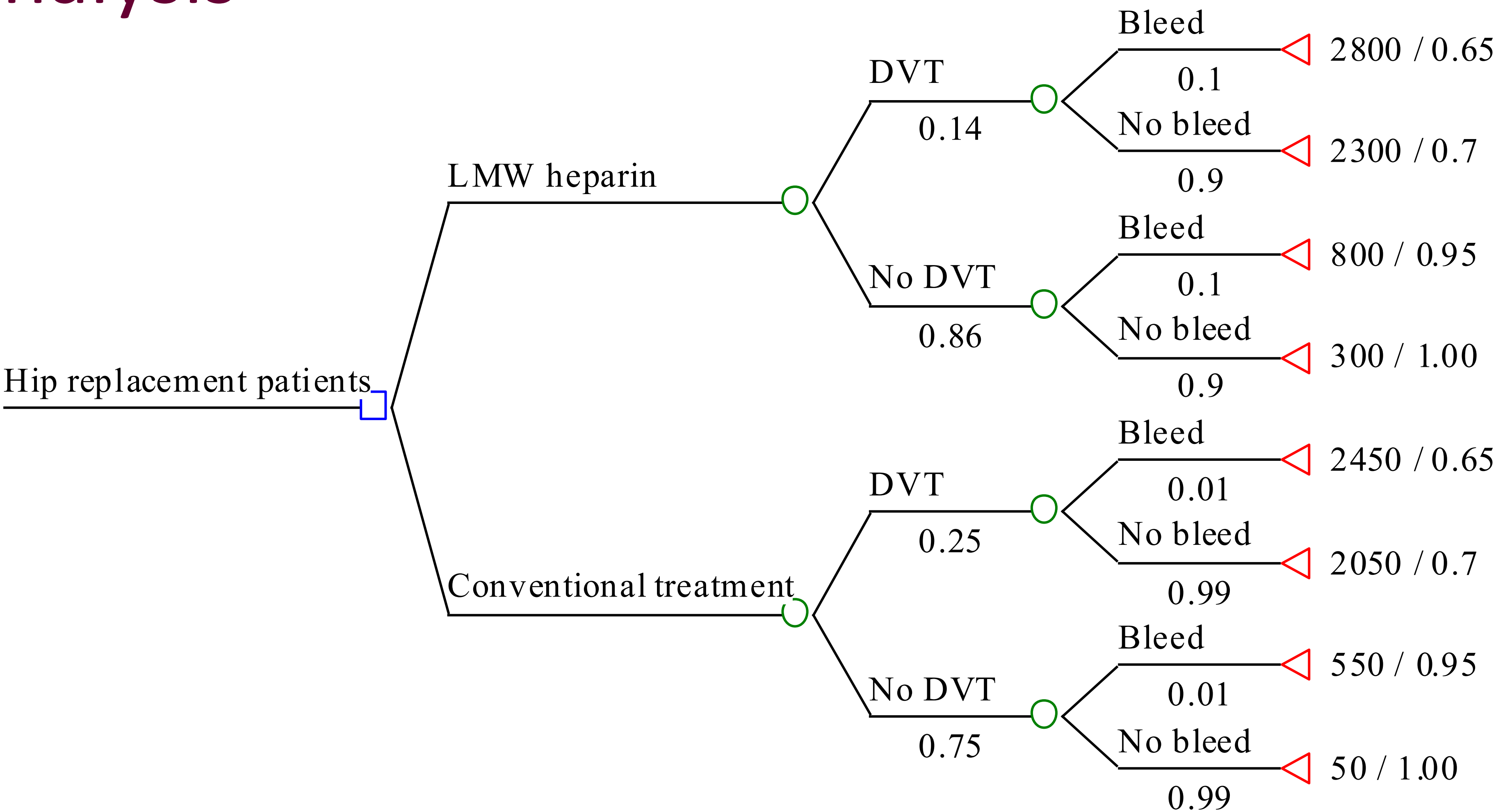
Full structure of cost-effectiveness analysis



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Example: Result from analysing the tree (CEA)

Strategy	Cost	Incremental Cost	QALY	Incremental QALY	ICER (£ per QALY)
Conventional Treatment	£555		0.92		
LMW heparin	£630	£75	0.95	0.03	£2500

$$\text{ICER} = \frac{630 - 555}{0.95 - 0.92} = \frac{75}{0.03} = £2500 \text{ per QALY}$$

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Sensitivity analysis

- Previous calculations assume that probabilities and costs are known exactly
- Suppose the cost of LMW heparin reduced to £200

Strategy	Cost	Incremental Cost	QALY	Incremental QALY	ICER
Conventional Treatment	£555		0.92		
LMW heparin	£530	- £25	0.95	0.03	Dominant

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Limitations of decision trees

- Need to be able to assess full implications of each possibility (patient pathway)
- Less suitable for longer-term outcomes
  - possible to add branches (not efficient)
- Difficult to handle recurrence

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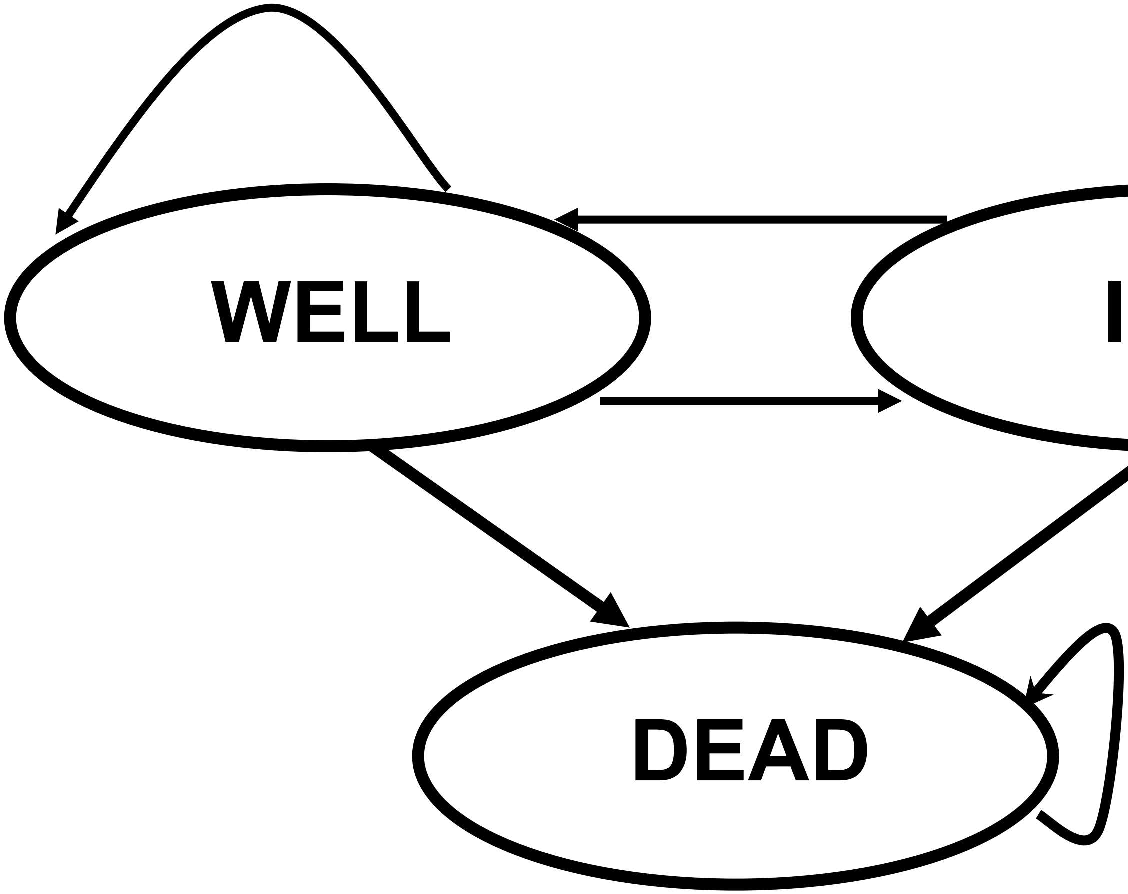
Markov models

- Markov models represent disease processes which evolve over time
- Suited to modelling the progression of chronic disease
- Can handle recurrence
- Estimate long term costs and life years gained/QALYs

Simple Markov model



Elements of Markov models

- Markov states should be mutually exclusive and exhaustive
- Markov cycle length: a fixed period of time
- Transition probabilities
  - Transition from one state to another at end of a single cycle
  - Fixed transition probabilities out of each state, adding up to 1
- Markov rewards
  - Values assigned to each health state that represent the cost and utility of spending one cycle in that state

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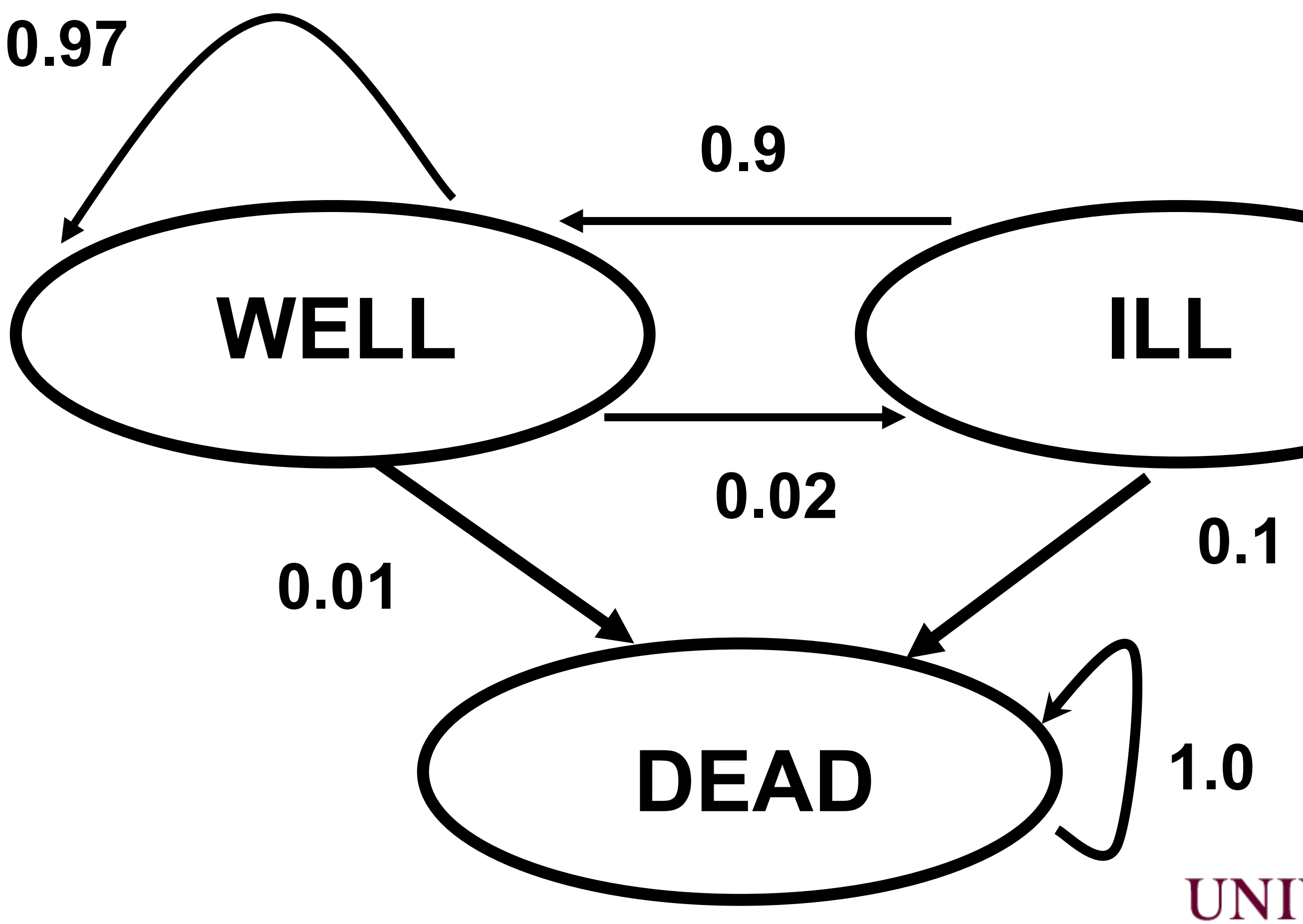
Simple Markov model



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Steps in constructing a Markov model

1. Define states and allowable transitions
2. Choose a cycle length
3. Specify a set of transition probabilities between states
4. Assign a cost and utility to each health state
5. Identify the initial distribution of the population
6. Methods of evaluation

Markov model: Simple example

- Stroke prevention model
  - Atrial fibrillation is a chronic heart arrhythmia which increases the risk of stroke (ischaemic)
  - Therapy available to reduce the risk of stroke - e.g. warfarin
  - Disabling stroke incurs costs over a long period of time and reduces quality of life
  - A Markov model is designed to evaluate the cost-effectiveness of treatments to prevent stroke in AF
  - Following example will concentrate on model structure

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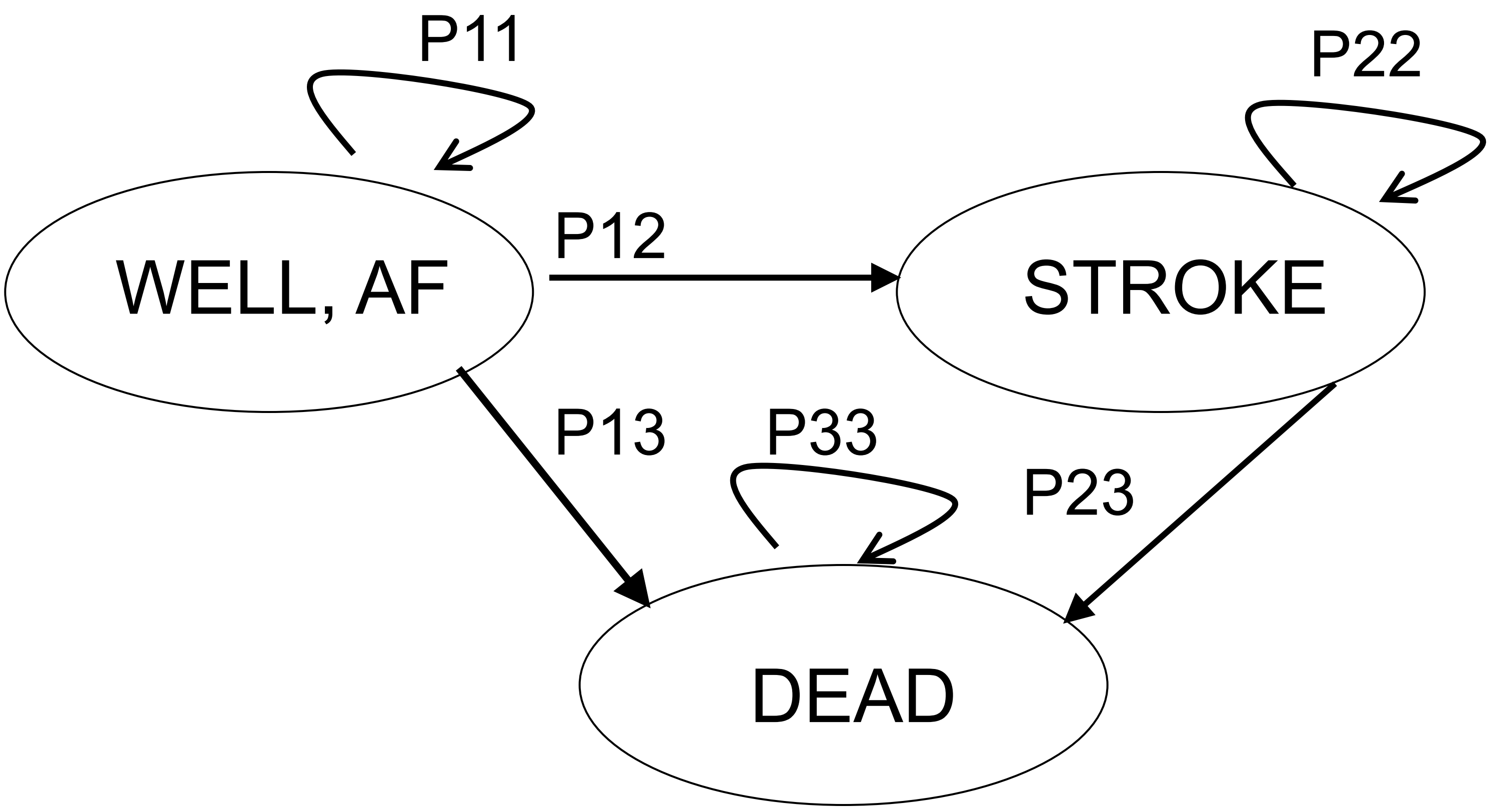
Markov states

- Patients are classified in one of three states
  - Well with atrial fibrillation (AF) (Health state 1)
  - Disabled from stroke (Health state 2)
  - Dead (Health state 3)

Stroke prevention: Markov states



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Decide on a cycle length

- Markov cycles - a constant increment of time
- Choice of cycle length should
  - depend on the timing of events in disease process
  - depend on the study question and available data

For stroke prevention example, time cycle could be one year

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Define transition probabilities

Transitions From time t to time t+1	Well (1)	Stroke (2)	Dead (3)
Well (1)	P11 (=1-P12-P13=0.92)	P12=0.07	P13=0.01
Stroke (2)	0	P22 (=1-P23=0.75)	P23=0.25
Dead (3)	0	0	1

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Attach costs and utilities to states

Each health state has a cost and utility attached

Markov state	Cost	Utility
Well, AF (on treatment)	£150	1
Disabling stroke	£10,000	0.40
Death	0	0

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Define initial distribution of population

- A set of starting probabilities is required to describe the initial distribution of the Markov cohort among the states
- Determined by modellers
  - Start all patients in the same state (1 0 0)
  - Different proportion in different states (0.90 0.10 0)

Methods of evaluation

- Cohort simulation
  - Hypothetical cohort of patients
  - Expected values
  - Deterministic

- Monte Carlo simulation
  - Sample one patient at a time, specify number of patients (“trials”)
  - Random, stochastic
  - More in later modules

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Stroke prevention: cohort analysis

Cycle	Well, AF	Disabled stroke	Dead	Total
Start	1000	0	0	1000
1	920 (1000 x 0.92)	70 (1000 x 0.07)	10 (1000 x 0.01)	1000
2	846 (920 x 0.92)	117 (920 x 0.07) + (70 x 0.75)	37 10+ (920 x 0.01) + (70 x 0.25)	1000
3	778 (846 x 0.92)	147 (846 x 0.07) + (117 x 0.75)	75 37+ (846 x 0.01) + (117 x 0.25)	1000
4	716 (778x 0.92)	165 (778 x 0.07) + (147 x 0.75)	119 75+ (778 x 0.01) + (147 x 0.25)	1000

Limitations of Markov models

- No account taken of history
- Assumes uniform population and equal and constant risk
- May overcome these limitations by using a larger number of states
- Alternatively use other methods (Individual sampling models, discrete event simulation)

Summary

- Models provide a practical method to synthesise information from multiple sources
- Decision trees suited to model one-off treatments and short-term effects
- Markov models allow recurring processes to be modelled