Practical Decision tree analysis - Solutions

X. Pouwels

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```r
rm(list  = ls()) # clear environment
library(knitr)
```

Answers

The following code shows how to complete the R code.

```r
#----------------------------------#
#### Step 1: Define parameters ####
#----------------------------------#

# Probabilities
p_Rupture <- 0.3
p_Stable <- 0
p_DeathRupture <- 0.4
p_DisabledRupture <- 0.35
p_SurvivalRupture <- 0.25
p_Anxious <- 0.6
p_NotAnxious <- 0.4
p_Clipping <- 0.3
p_Coiling <- 0.7
p_DeathClipping <- 0
p_DisabledClipping <- 0.25
p_SurvivalClipping <- 0.65
p_DeathCoiling <- 0.05
p_DisabledCoiling <- 0
p_SurvivalCoiling <- 0.8

# Utility values
u_Healthy  <- 0.80 # Utility of patient in good health
u_Disabled <- 0.40 # Utility of disabled patient
u_Anxious  <- 0.70 # Utility of anxious patient
u_Death    <- 0    # Utility of dying

# Costs
c_Rupture   <- 50000 # Cost of aneurysm rupture
c_Clipping  <- 20000 # Cost of aneurysm clipping
c_Coiling   <- 13000 # Cost of aneurysm coiling
c_Disabled  <- 5000  # Cost of disabled patient
```

```r
#-----------------------------------------------------#
#### Step 2: Calculate probabilities of pathways ####
#-----------------------------------------------------#


## Calculate pStable, pDeathClipping and pDisabledCoiling, since these are set to 0 for now...
## Use the decision tree diagram and the above-defined probabilities

p_Stable <- 1 - p_Rupture
p_DeathClipping  <- 1 - p_DisabledClipping - p_SurvivalClipping
p_DisabledCoiling <- 1- p_DeathCoiling - p_SurvivalCoiling

## Calculate the probabilities of each pathway
## Use the above-define probabilities

p_path_A <- p_Rupture * p_DeathRupture
p_path_B <- p_Rupture * p_DisabledRupture
p_path_C <- p_Rupture * p_SurvivalRupture
p_path_D <- p_Stable * p_Anxious
p_path_E <- p_Stable * p_NotAnxious
p_path_F <- p_Clipping * p_DeathClipping
p_path_G <- p_Clipping * p_DisabledClipping
p_path_H <- p_Clipping * p_SurvivalClipping
p_path_I <- p_Coiling * p_DeathCoiling
p_path_J <- p_Coiling * p_DisabledCoiling
p_path_K <- p_Coiling * p_SurvivalCoiling

#------------------------------------------------------#
#### Step 3: Assign effects and costs to pathways ####
#------------------------------------------------------#

# These are the effects and costs that a person would incur if he/she follows a specific pathway!

## Assign the effects of each pathway
## Use the above-define utility parameters

e_path_A <- u_Death
e_path_B <- u_Disabled
e_path_C <- u_Healthy
e_path_D <- u_Anxious
e_path_E <- u_Healthy
e_path_F <- u_Death
e_path_G <- u_Disabled
e_path_H <- u_Healthy
e_path_I <- u_Death
e_path_J <- u_Disabled
e_path_K <- u_Healthy

## Calculate the costs of each pathway
## Use the above-define utility parameters

c_path_A <- c_Rupture
c_path_B <- c_Rupture + c_Disabled
```

```r
c_path_C <- c_Rupture
c_path_D <- 0
c_path_E <- 0
c_path_F <- c_Clipping
c_path_G <- c_Clipping + c_Disabled
c_path_H <- c_Clipping
c_path_I <- c_Coiling
c_path_J <- c_Coiling + c_Disabled
c_path_K <- c_Coiling

#-------------------------------------------------------------------#
#### Step 4: Calculate expected effects and costs of pathways ####
#-------------------------------------------------------------------#

# These are the effects and costs that a person would incur if he/she follows a specific pathway, weigh


## Calculate the expected effects of each pathway
## Use the above-defined utility and probabilities of each pathway

te_path_A <- p_path_A * e_path_A
te_path_B <- p_path_B * e_path_B
te_path_C <- p_path_C * e_path_C
te_path_D <- p_path_D * e_path_D
te_path_E <- p_path_E * e_path_E
te_path_F <- p_path_F * e_path_F
te_path_G <- p_path_G * e_path_G
te_path_H <- p_path_H * e_path_H
te_path_I <- p_path_I * e_path_I
te_path_J <- p_path_J * e_path_J
te_path_K <- p_path_K * e_path_K

## Calculate the expected costs of each pathway
## Use the above-defined costs and probabilities of each pathway

tc_path_A <- p_path_A * c_path_A
tc_path_B <- p_path_B * c_path_B
tc_path_C <- p_path_C * c_path_C
tc_path_D <- p_path_D * c_path_D
tc_path_E <- p_path_E * c_path_E
tc_path_F <- p_path_F * c_path_F
tc_path_G <- p_path_G * c_path_G
tc_path_H <- p_path_H * c_path_H
tc_path_I <- p_path_I * c_path_I
tc_path_J <- p_path_J * c_path_J
tc_path_K <- p_path_K * c_path_K

#------------------------------------------------------------------------#
#### Step 5: Calculate expected effects and costs of each strategy ####
#------------------------------------------------------------------------#

## Calculate the expected effects and costs of each strategy
## Sum the expected costs and effects of the pathways that belong to each strategy
```

```
te_ww  <- sum(te_path_A, te_path_B, te_path_C, te_path_D, te_path_E) # expected effects watchful waitin
tc_ww  <- sum(tc_path_A, tc_path_B, tc_path_C, tc_path_D, tc_path_E) # expected costs watchful waiting

te_trt <- sum(te_path_F, te_path_G, te_path_H, te_path_I, te_path_J, te_path_K) # expected effects trea
tc_trt <- sum(tc_path_F, tc_path_G, tc_path_H, tc_path_I, tc_path_J, tc_path_K) # expected costs treatm

#------------------------------------------------------------------------------------------------------
#### Step 6: Calculate incremental effects, costs, and incremental cost-effectiveness ratio of the trea
#------------------------------------------------------------------------------------------------------

## Calculate the incremental effects and costs of each the treatment strategy versus watchful waiting
## Calculate the incremental cost-effectiveness ratio
## Use the total effects and costs defined in previous step

inc_e_trt <- te_trt - te_ww
inc_c_trt <- tc_trt - tc_ww
icer <- inc_c_trt / inc_e_trt
```

1. Look at your final results.

   1.a. What is your conclusion?

   Answer: From the results we can conclude that the Aneurysm Treatment strategy results in additional health gain at additional costs compared to the Watchful waiting strategy.

   1.b. Which strategy has the most favorable cost-effectiveness if we are willing to pay €20,000 for a gain in utility of 1 (or 1 additional QALY if we assume a one-year time horizon for this decision tree)?

   Answer: The Aneurysm Treatment strategy has the most favorable cost-effectiveness if we apply a willingness-to-pay threshold of €20,000/QALY.

   1.c. How does the utility of patients with an untreated aneurysm (`u_Anxious`) affect the cost-effectiveness results? What happens if you disregard any potential anxiety and set uAnxious equal to u_Healthy?

   Answer: When `u_Anxious` is set to values much lower then uHealthy than the Watchful waiting strategy results in less and less QALYs. Therefore, the cost-effectiveness of the Aneurysm Treatment strategy compared to the Watchful waiting strategy becomes more and more favorable. If, on the other hand, we set `u_Anxious` equal to `uHealthy` then NOT treating a patient with a stable aneurysm is a good strategy, as apparently these patient do not suffer from their untreated stable aneurysm in any way. Consequently, the cost-effectiveness of the Aneurysm Treatment strategy compared to the Watchful waiting strategy deteriorates, and we find: incremental costs = €475, incremental effects = 0.014 utility, and incremental cost-effectiveness ratio = €33,928.57 per QALY. This indicates that the cost-effectiveness of the Aneurysm Treatment strategy compared to the Watchful waiting strategy is no longer acceptable if we apply a willingness-to-pay threshold of €20,000/QALY.

   1.d. In the past, aneurysm coiling, which is an endovascular procedure was not yet available in all hospitals. What would you advise to a hospital which only offers aneurysm clipping, should they go with the Watchfull Waiting strategy or with the Aneurysm Treatment (100% clipping) strategy?

   Answer: To answer this question, set `p_Clipping` to 1 and `p_Coiling` to 0 (= all aneurysm treated with clipping). This results in the following outcomes: incremental costs = 5,725 eurors, incremental effects = 0.0 utility, and incremental cost-effectiveness ratio = `Inf` euros per QALY (cannot be calculated because difference in effect is 0). Thus, there is no difference in health outcomes between AneurysmTreatment-ClippingOnly and Watchful Waiting, but the former strategy is much more expensive than the latter! We would therefore advise hospitals which do not perform coiling to follow the Watchful Waiting strategy.

   1.e. And what would you advise to new patients with a detected unruptured aneurysm?

   Answer: Find a hospital in which your aneurysm can be coiled. Coiling provides better health outcomes (and is cheaper) than Watchful Waiting or Clipping.

2. If you consider extending this decision tree model

   2.a. How would you include evidence suggesting that intracranial aneurysms may remain stable for several years but then start to increase in size and rupture?

   Answer: Incorporating time explicitly in a decision tree model is hard and will make your model very complex. To allow aneurysms to remain stable and to increase in size and rupture later on chance nodes would need to be added for each separate year in the time horizon. This means the entire model (now defined for 1 year) would needs to be extended to 10 times its current size to allow a time horizon of 10 years.

   2.b. It is known that individuals with an unruptured intracranial aneurysm are at increased risk of developing new intracranial aneurysms, regardless of whether the first aneurysm ruptures or remains stable. How would you include the aspect of new aneurysm development in the model?

   Answer: Development of new aneurysm would require additional branches to be added to the tree. A new branch would need to be added for patients with 2 aneurysm, another for patients with 3 aneurysms etc. This extension would therefore only be feasible for patients with 1, 2, or 3+ aneurysms and even then the resulting decision tree would be huge.