HCM SCD risk algorithm cost-effectiveness analysis

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Introduction

Sudden cardiac death (SCD) risk score algorithm details see (O'Mahony et al. 2014).

There have been previous cost-effectiveness analyses (Magnusson and Wimo 2020; Boriani et al. 2014; Bryant et al. 2007; Caro et al. 2007; Cowie et al. 2009; García-Pérez et al. 2015; Mealing et al. 2016; Sanders, Hlatky, and Owens 2005; Smith et al. 2013)

Data

The main data set contains individual-level follow-up data of patients with HCM who may have been given an ICD due to some risk decision.

Health and cost data were obtained from literature and expert opinion. What values we wish to use will determine the form of the state model. For instance, if cost are only accrued on entry to a state then we may use a tunnel state. If cost depend on the patient history then we may need to duplicate a state.

Table 1 gives the unit cost and health values used in the model.

Table 1: Model parameter values. *either one-off/on state entry or recurring.

Description	Value*	Range	Source
Health			
Manage with ICD	0.637 QALY/year		Noyes et al. (2007)
Implantation procedure utility	-0.016		Smith et al. (2013)
Shock utility	-0.5		
HCM without ICD	1 QALY/year		
Death	0 QALY/year		
Cost			
ICD appointment	£10		
Perform risk score	£20?		
Implant ICD	£4,666		EY02B Tariffs
Implant replacement	£45,000		
Implant complication	£28,839		Smith et al. (2013)
Non-fatal shock	£22,880		UK Stroke Assoc.
HCM without ICD	0		
SCD	0		
All-cause death	0		
Probabilities			
Initial implant complication	0.047		Smith et al. (2013)
Replacement implant complication	0.032		Smith et al. (2013)

Description	Value*	Range	Source
Time horizon	12 years		
Implant replacement	10 years		
Annual number of appointments	2		

Table 2 gives the starting state populations for non-zero states.

Risk rule	State	Population
Observed	HCM ICD	559
-	HCM	3113
Score > 4%	HCM ICD	2561
-	HCM	1111
Score > 6%	HCM ICD	542
-	HCM	3130
Risk factor >0	HCM ICD	1785
-	HCM	1887
Risk factor >1	HCM ICD	481
-	HCM	3191
Risk factor >2	HCM ICD	78
-	HCM	3594

Methods

The individual-level patient data are first stratified in to two groups for each risk algorithm. These are

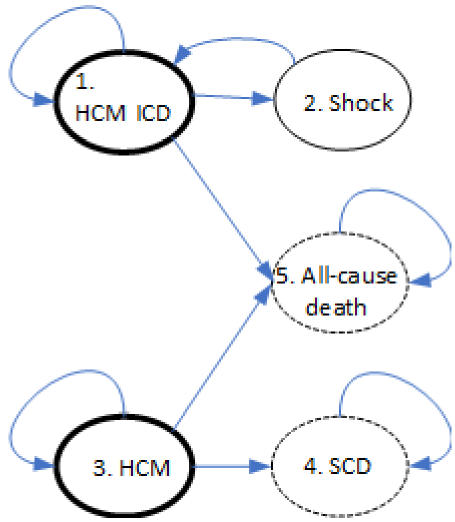
- Partition observed in data set
- ICD given if number of risk factors > 0, 1 or 2
- ICD given if risk score >6%
- ICD given if risk score >4%

We included the option of a fuzzy decision boundary such that near the threshold there is some random variation as to whether a patient received an ICD or not.

Markov model

Th patient data give us starting state populations for HCM with ICD and HCM without ICD which will be different for each risk decision rule. Further, the transition probabilities from these states will differ because of the case mixes.

A diagram of the current cohort model is given below.



Assuming that shocked patients return to the HCM ICD state then the transition matrix may look like the following.

$$\begin{pmatrix} p_{11} & p_{12} & 0 & 0 & p_{15} \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & p_{33} & p_{34} & p_{35} \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

We have used a year step size but if e.g. cost are accrued at different intervals then this can be adapted. The time horizon is set at 12 years from time of implant.

State health and cost equations

We assume that an ICD patient has 2 annual appointments. All shocks are treated the same in terms of costs and health impact. Implantation can have complications. The cost of an implant complication is taken as a weighted sum of infection and dislodgement cost with values from (Smith et al. 2013).

- Annual health:

$$e^0_{s=1}(t) = e^1_{s=1}(t) = u\_hcm + u\_icd$$

$$e^0_{s=2}(t) = e^1_{s=2}(t) = u\_shock$$

$$e^0_s(t) = e^1_s(t) = 0, \quad s = 3, 4, 5, 6$$

- Initial costs:

$$c^0_{s=1}(t = 0) = c\_icd + p\_compl \times c\_compl$$

$$c^1_{s=1}(t = 0) = c\_icd + c\_rscore + p\_compl \times c\_compl$$

- Annual cost:

$$c^0_{s=1}(t) = c^1_{s=1}(t) = 2c\_icd\_appt, \quad t \neq t\_repl$$

$$c^0_{s=2}(t) = c^1_{s=2}(t) = c\_nfatal$$

- Implant replacement cost

$$c^0_{s=1}(t = t\_repl) = c^1_{s=1}(t = t\_repl) = 2c\_icd\_appt + c\_icd\_repl + p\_compl \times c\_compl$$

Transition probability inference Using WinBUGS (Zhang 2014) called from R, each new data set is used to generate posterior samples of transition probabilities. Denote x as the observed number of transitions, p the probability of a transition and n as the total number of transitions from a given state. The hyperparameters α characterise the prior knowledge on p. Superscripts indicate the decision rule used.

$$x_{i.}^{(1)} \sim \text{Multinomial}(p_{i.}^{(1)}, n_i^{(1)}), \quad i = 1, 3$$
$$x_{i.}^{(2)} \sim \text{Multinomial}(p_{i.}^{(2)}, n_i^{(2)}), \quad i = 1, 3$$

$$p_{i.}^{(1)} \sim \text{Dirichlet}(\boldsymbol{\alpha}^{(1)}), \quad i = 1, 3$$
$$p_{i.}^{(2)} \sim \text{Dirichlet}(\boldsymbol{\alpha}^{(2)}), \quad i = 1, 3$$

For all sink states,

$$p_{ij}^{(s)} = \begin{cases} 1 & \text{if } i = j; \\ 0 & \text{if } i \neq j. \end{cases}$$

Workflow

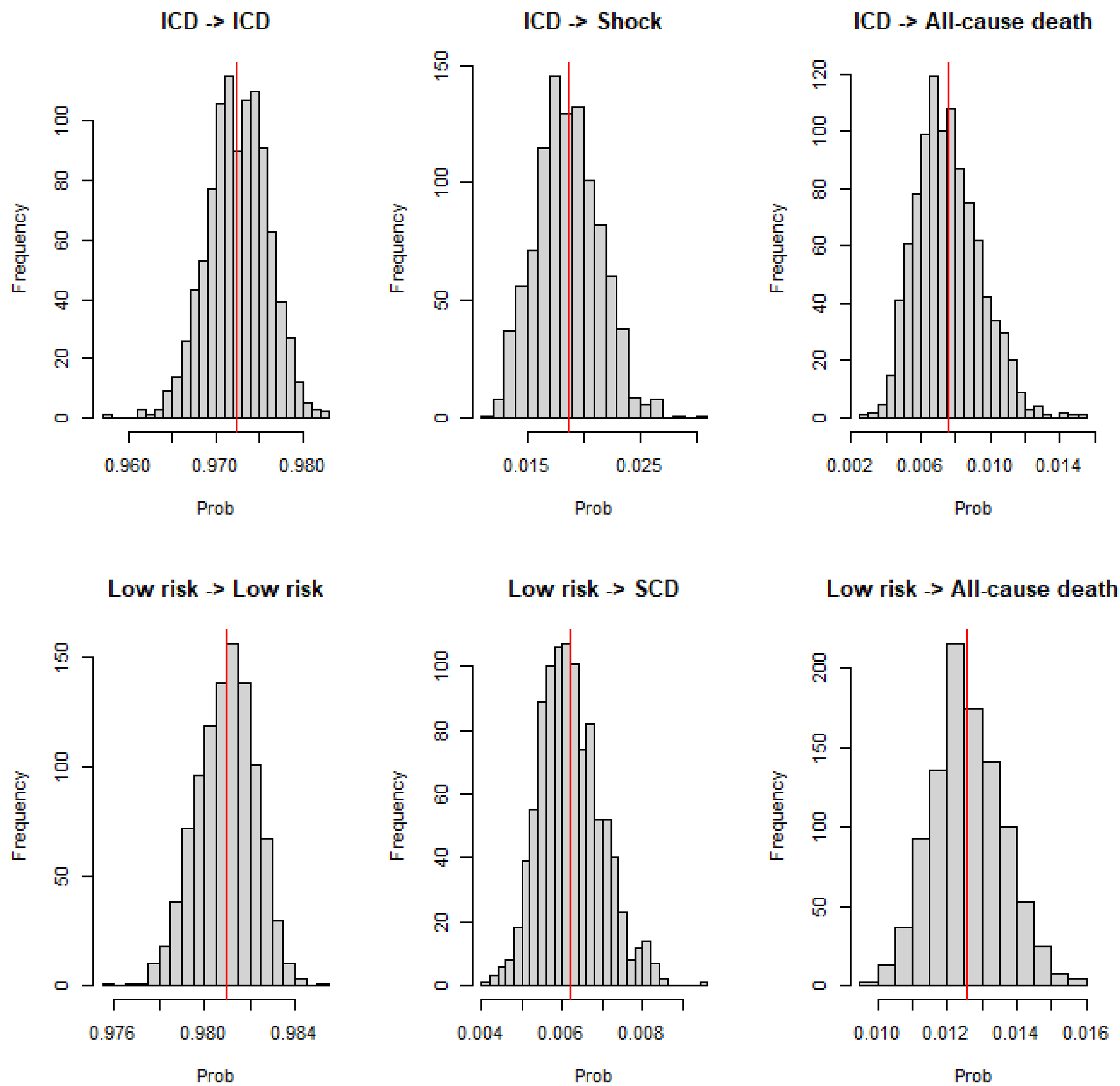
The main files to perform the analysis are:

- `prep_study_data.R` munges the raw data and save the input data in `data/`
- `BUGS/script.R` runs the BUGS code in `BUGS/model.txt`
- `main-ce-analysis.R` performs the cost-effectiveness analysis
- `pop_counts_plot.R` creates output plots

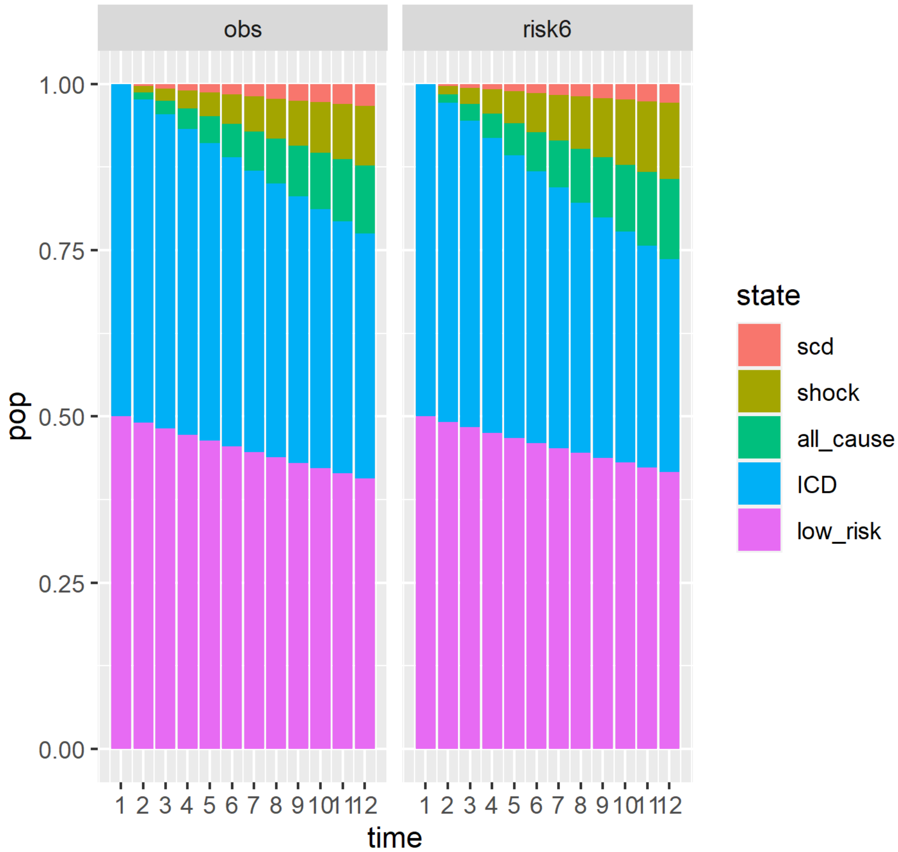
Results

We give some example output to demonstrate what will be produced with the final model.

Histogram of posterior distributions for state transition probabilities.



Below is an example of state occupancy over time plot. This shows that for the new algorithm there are fewer scd and more shocks.



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