Markov models in cardiac surgery

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Abstract

Spinal cord ischemia remains a dreadful complication after thoracoabdominal aortic aneurysm repair. The role of cerebrospinal fluid drain in such patients needs further clarifications. Tam and colleagues carried out an interesting decision analysis study that supports the routine use of the cerebrospinal fluid drain after thoracoabdominal aneurysm repair. They also demonstrated that the use of the cerebrospinal drain was safe. Here, we firstly discuss the paper's finding and methodology and, secondly, we try to simply explain what a decision analysis study is and, broadly, and how to construct a Markov model.

There is still uncertainty whether the use of cerebrospinal fluid (CSF) drain is associated with a reduction in the incidence of post-operative spinal cord ischemia (SCI) in patients undergoing repair of thoracoabdominal aortic aneurysm (TAAA)[1-2].

Tam and colleagues[3] utilized a Markov state-transition cohort model that compared TAAA repair with adjunctive CSF drain insertion to TAAA repair without drain insertion. They demonstrated that the use of CSF drain was associated with improved 5-year life expectancy and also it reduced the incidence of SCI related mortality and morbidity without complication from the CSF drain itself.

Authors have to be commended for this interesting study for two main reasons: first, they contributed to further explore and clarify the role of CSF in the setting of TAAA surgery; second, they shed light to a specific tool analysis model (Markov process) that not very often is encountered in cardiac surgery, yet it can be a powerful mathematical model for decision making in complex scenarios.

What are Markov processes? How can they be simply explained? Why are they useful?

The Markov processes and/or models are named after Andrey Markov (1856-1922), a Russian mathematician. A Markov process is a series or, betters, a chain of events, that is 'memory-less'; in simple words the next event that will happen depends only on what is happening 'now' (current event) and not on what has happened before (previous event).

In the simulation study, Tam and colleagues considered three states: a) 'alive and well'; b) 'alive with SCI' and c) 'death'. In the two alive states, patients can either remain in that state of the end of a specified observation period or transition to the dead state (absorbing state). Transition probabilities (from one state to the other) tell us which state the patients is likely to move to, given where he is. Every time we observe the outcome of interest and the patients 'travels' from one state to the other, we call that a transition event. After TAAA with or without CSF, the patient has a certain probability to move to state 'a' or 'b', or 'c'. All the transition probabilities summed together are equal to 1 (or 100%) and all the transition probabilities going out from a state should always sum to 1.

How can we choose the transition probabilities? Rather the observing in prospective way the events and their frequency, we can inform the system with numbers already available in literature.

In the Tam's decision analysis study, the model inputs were obtained from relevant meta-analyses that have pooled observational data and randomized trials data on morbidity and mortality associated with TAAA repair with or without the use of CSF drain. Once all the probabilities are obtained, the model can be constructed. The transition probabilities are entered in a matrix where the columns represent the state where the patient 'came from' and the rows represent the state the patient is 'moving to'. By using the matrix it is possible to compute different sorts of calculation. In order to use the matrix we need a starting probability vector (that represents what we know about patients' starting state in terms of probability); if we multiply our transition matrix by the probability vector we obtain a new vector that represents the prediction for the next level (one event in the future); if we keep multiply the transition matrices we can make reasonable prediction which state the patient will be at any time in the future (theoretically even if the time approaches infinity).

Nevertheless, Markov process accounts for different models (chain / decision process / hidden model / partially observable model) that can be used situationally.

Are the Markov model used frequently in cardiac surgery context? Regrettably, besides the Tam's example, only few solid studies have been published. A noteworthy micro-simulation / state-transition study, for example, was conducted by Ferket and colleagues; they used data from the Cardiothoracic Surgical Trials Network to estimate long-term predictions of costs and QALYs[4].

Other relevant studies on Markov simulation are also from Tam et all[5,6].

Nevertheless, the newest decision analysis study from the Tam and colleagues has some limitations.

As already underscored by the Authors, some of the crucial and pivotal parameters (transition probabilities) were informed by meta-analyses of observational studies that can be undermined by biases inherent to the study design. The three states considered ('a', 'b', 'c') where perhaps very simplified, since patients may be alive but in many various other states. Lastly, the model time horizon was only 60 months and that was because of the limited follow-up of the studies included; hence this study cannot predict complication beyond the 60 months time horizon.

Nevertheless, Markov models are valid and useful scientific and mathematical tools that can definitively help physicians and surgeons during the decision making process.

Abbreviation

CSF= cerebrospinal fluid

SCI= spinal cord ischemia

TAAA= thoraco-abdominal aneurysm

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