Analyising the Effects of a Disinvestment Decision in Breast Cancer Screening Programmes in Asia-Pacific Countries: A System Dynamics Modelling Approach

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Introduction

A number of modelling techniques have been used to evaluate health technologies and healthcare policies around the world. System dynamics has been widely used for the analysis of infectious diseases and other public health issues, but is not commonly used for health technology assessment purposes. This study aimed to create a tool for the analysis of disinvestment decisions in breast cancer screening with mammography in countries around the world. Breast cancer is the most prevalent cancer in women worldwide, with an incidence of new cases as high as 1.7 million in 2012. Screening with mammography is a technique aimed at identifying cancers at a very early stage when treatment is likely to be successful, but overdiagnosis is a relatively common phenomena.

Methods

A system dynamics approach was taken to develop the cost-effectiveness model. System dynamics modelling involves the development of a set of differential and algebraic equations to describe a system, and can be graphically represented by a stock-and-flow diagram.

- Stocks represent health states. Three types of health states are defined here: “Healthy” patients are those not diagnosed with breast cancer, “Pos” or positive patients are those with a positive test result from breast cancer screening with mammography, and “TruePos” or true positive patients. These 3 health states are replicated for different age groups based on the breast cancer screening policy in each country.
- Rates represent the set of patients that move from one health state to another.
- The initial values of the stocks and values of the rates – which can be defined as a function of time – must be country-specific and must be collected from published sources.
- The usefulness of this tool was initially tested to evaluate the demographic effects of disinvesting in breast cancer screening with mammography in women in the Republic of Korea, where the rate of false positive results is relatively high compared with other Asia-Pacific countries.

Results

A tool for the evaluation of costs and effects of disinvestment decisions in breast cancer screening with mammography was constructed.

- The time horizon was set at 10 years.
- Insight Maker was used for the initial description and visualisation of the model.
- The model consists of a set of stocks or health states based on the breast cancer screening policy applied in each country, and the arrows between these health states represent the flow of individual from one health state to another (Figure 1).
- An R package (deSolve) was used for a further characterisation of details needed for a cost-effectiveness analysis, such as:
  - the outcomes of interest – which can be modified upon researchers’ requirements;
  - the costs associated with each health state;
  - the integrated total cost over the pre-specified time horizon.

- As an example, the effects of a disinvestment decision in the population of the Republic of Korea were analysed.
- A set of health states was defined based on the breast cancer screening policy in the Republic of Korea and on the age groups reported by a cost-effectiveness study (Figure 2).
- In this example, the effects of a disinvestment decision in the number of people in each health state were calculated:
  - Cost data were not included in this initial pilot test, although the model allows their inclusion.
  - Death rates for each health state were taken from published sources.
  - The time horizon was set at 10 years.
  - As shown in Box 1, discrete events were manually entered into the differential and algebraic equations into R.
  - Figure 2 displays the number of positive screening results and false positive screening results under the breast screening with mammography programme between 2014 and 2024.
  - As also demonstrated by other studies, there is a large number of false positive results that incur a high cost for the healthcare system in the Republic of Korea.

Discussion

- The system dynamics model reported here is a comprehensive and adaptable tool that can be applied to a wide range of healthcare systems and policy environments.
- The flows between the health states have been shown to greatly vary from country to country and this tool would therefore be useful for the analysis of the demographic effects of disinvestment decisions between countries.
- The main limitation of the model was the impossibility to track the evolution of individual patients, as patients are modelled in groups (health states) and costs and outcomes are associated equally to all patients in each health state.
- This pilot test lacks cost data and therefore the cost-effectiveness of a disinvestment decision has not been analysed.
- Future steps include the addition of cost data and the analysis of the effects of disinvestment decisions in a variety of countries with different demographic, epidemicologic and economic characteristics.

Box 1. Set of equations useful in any given country for the analysis of demographic characteristics after disinvestment in breast cancer screening with mammography:

\[ dA1 = \lambda_1 A1 - (\lambda_2 + \lambda_3 + \lambda_4) A1 \]
\[ dB1 = \lambda_2 A1 - (\lambda_3 + \lambda_4 + \lambda_5) B1 \]
\[ dC1 = \lambda_3 A1 - (\lambda_4 + \lambda_5 + \lambda_6) C1 \]
\[ dA2 = \lambda_4 A2 - (\lambda_5 + \lambda_6 + \lambda_7 + \lambda_8 + \lambda_9) A2 \]
\[ dB2 = \lambda_5 A2 - (\lambda_6 + \lambda_7 + \lambda_8 + \lambda_9 + \lambda_10) B2 \]
\[ dC2 = \lambda_6 A2 - (\lambda_7 + \lambda_8 + \lambda_9 + \lambda_10 + \lambda_11) C2 \]
\[ dA3 = \lambda_7 A3 - (\lambda_8 + \lambda_9 + \lambda_10 + \lambda_11 + \lambda_12) A3 \]
\[ dB3 = \lambda_8 A3 - (\lambda_9 + \lambda_10 + \lambda_11 + \lambda_12 + \lambda_13) B3 \]
\[ dC3 = \lambda_9 A3 - (\lambda_10 + \lambda_11 + \lambda_12 + \lambda_13 + \lambda_14) C3 \]

References