Lifetime costs of hospitalised cardiovascular disease in Australia: an incidence-based estimate

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Abstract

Objectives: To estimate the incidence-based, lifetime costs of healthcare and productivity losses associated with cardiovascular disease (CVD) using hospital admission data from Queensland, Australia.

Methods: Retrospective analysis of data on CVD healthcare use sourced from Queensland Hospital Admitted Patient Data Collection (QHAPDC), Emergency Department Data Collection (EDDC), Medicare Benefits Schedule (MBS) and the Pharmaceutical Benefits Scheme (PBS). Costs were estimated from the societal perspective.

Study participants included patients who were first admitted to any Queensland hospital in 2010 for a CVD-related treatment. Subsequent admissions of these patients were followed until December 2015. The present value of incidence-based lifetime costs per patient were used to estimate the total costs for Australia. All costs were presented in Australian dollars at 2019 prices.

Results

The estimated lifetime healthcare cost of CVD was $65,700 per person. Productivity loss cost was higher at $75,200 per person, and total indirect lifetime costs were $140,900 per person. Scaling these costs up for the Australian population, the estimated incidence-based lifetime CVD costs for Australia were $60.5 billion ($28.2 billion in direct costs and $32.3 billion in indirect costs).

Conclusions
Incidence-based lifetime indirect costs of CVD were higher than the direct costs. The life-time cost structure suggests that economic benefits of healthcare interventions for cardiovascular diseases from a societal perspective should be at least twice larger than that from a health service perspective.

**Introduction**

Cardiovascular disease (CVD) remains a public health concern in Australia, affecting 17% of the population, and accounting for 34% of all-cause mortality. CVD also incurs substantial healthcare costs; the estimated annual healthcare expenditure related to CVD in Australia in 2008-2009 was $7.6 billion. Given that CVD contributed to 11% of hospitalisations, and hospital spending accounted for 40% of the total health expenditure, an updated estimate of hospitalisation costs alone for CVD in 2018, adjusting for inflation and population growth, would be $8.2 billion.

Most cost-of-illness studies have used a prevalence-based, top-down approach, which focus on estimating direct cotemporaneous costs of CVD for a given period, typically one year. The prevalence-based costs reveal the current flow of resources into CVD-related healthcare, but it does not provide information on the full costs of the disease to an average patient over the course of the disease. An incidence-based approach provides a bottom-up estimate of direct and indirect lifetime costs of CVD. Thus, the incidence-based approach is useful to predict the cost-savings from early detection, prevention and CVD management programs. This study uses a record linkage longitudinal admission data set in Queensland to estimate the costs of CVD using an incidence-based approach.

To our best knowledge, this is the first study to estimate the lifetime costs of CVD since a patients’ first hospitalisation using a record linkage longitudinal data set. The present-value lifetime costs of CVD provide crucial input to assess the cost-effectiveness of health service intervention programs for this disease and assessing the full burden of disease.
Methods

Data source
We used a longitudinal administrative data set collected from various sources: Queensland Hospital Admitted Patient Data Collection (QHAPDC), Emergency Department Data Collection (EDDC), the Registrar General Deaths Database (RG), and the National Hospital Cost Data Collection (NHCDC). These data cover all episodes of care in Queensland, including all admissions to any hospital, outpatient visit and emergency department attendances. We linked admission data with Medicare Benefits Schedule (MBS) and the Pharmaceutical Benefits Scheme (PBS) data obtained from the Australian Institute of Health and Welfare (AIHW). The MBS and PBS data include all medical services and pharmaceuticals dispensed in the community (a detailed linkage process was presented in Byrnes et al.7).

Study population
The study population includes individuals aged 18 years and over who were admitted to healthcare facilities in Queensland for CVD-related treatments in 2010 with follow-ups until 2015. To apply an incidence-based cost estimate, we included only those with the first admission for CVD in 2010. CVD episodes were identified with ICD-10 codes in the range of I00-I99. The sample in this analysis consists of 75,829 CVD patients who were hospitalised for the first time in 2010.

Cost components
The estimated lifetime CVD costs include two components: direct and indirect costs. Direct costs include hospital costs, health services and prescription medication expenditures outside hospitals. Hospital costs were obtained from the linked NHCDC data; these data include the costs of delivering in-patient, outpatient, emergency care and overhead costs. The remaining direct costs, collected from the linked PBS and MBS data, include medications and the use of healthcare services such as general practitioners, specialists, and other healthcare services.

Indirect costs or productivity loss costs were defined as foregone income due to illness-caused, work absence and premature death (i.e., morbidity and mortality costs). The morbidity costs were estimated using the average earnings and the duration of work absence, which include hospital stay and potential recuperation period after hospital discharge. Mortality costs were estimated using average earnings and the duration of productive ages (18-65 years old) lost by premature death. For those who were alive at the end of the observation period
(December 2015), predicted death age, obtained from a parametric survival regression, was used to calculate mortality costs.

**Statistical analysis**

Parametric survival analysis with the Gompertz distribution assumption was conducted to estimate the survival probabilities in each year of the study period. The direct lifetime costs include observed costs incurred in the observed period and the present value of average yearly direct costs of the remaining survival years. The lifetime morbidity costs were estimated using the observed hospital length of stay during the observed period and expected hospital length of stay in the remaining survival years.

The lifetime mortality costs were estimated using the duration between death age and the retirement age of 65 years. The effects of inflation were adjusted by the consumer price index\(^6\) using the price level of 2019 as the base. Future costs were converted to present values using an annual discount rate of 5%, which is the preferred rate in Australia\(^7,8\). Productivity growth was accounted for using the labour productivity growth rate of 1% in the study period\(^9\). The indirect costs were estimated using the average weekly earnings of $1,485\(^10\), the labour force participation rate of 64.5% and an unemployment rate of 6%\(^11\). Income gaps between sexes, ethnic groups and socio-economic status were adjusted according to the observed data from the Household, Income, Labour Dynamics in Australia (HILDA) Survey - Release 16\(^12\). For example, compared to those in the middle of socio-economic groups (SEIFA Quintile 3), the average income of those in SEIFA quintile 1 (most disadvantage) was 24% lower while the respective figure of those in SEIFA Quintile 5 (most advantage) was 45% higher. Likewise, the average income of females was 5% lower than that of males, and 13% lower for indigenous people when compared with non-indigenous people. The ethnic gap in employment was also adjusted to reflect a lower labour force participation rate (55.7% vs 64.5%) and higher unemployment rate (18.2% vs 6%) among indigenous Australians\(^13\). A series of robustness tests were conducted to investigate the robustness of results to changes in parameters and key assumptions. Cost projections for Australia were estimated as the product of average cost per person, incidence rate and the Australian population by age groups.
Results

CVD Incidence
The estimated hospitalisation incidence rate was 2.58% [95% CI: 2.54-2.62] for all new Queensland CVD related hospitalisations in 2010 (see Appendix 1). The incidence rate increased with age, ranging from 0.53% [0.51-0.56] for those less than 25 years to 8.48% [8.36-8.60] for the 75+ years. Both sexes experienced increased incidence rates with age, and this increase was greater for males, especially those aged 35 years and over.

Cost Analysis
The average present-value lifetime CVD direct costs were $61,800/person for females and $69,300/person for males (Table 1). Patients in the oldest age group (75 years and over) incurred the lowest direct lifetime costs, which could be due to their higher risk of mortality. For the remaining age groups, the direct lifetime costs increased with age. The exception was for patients in the youngest age group (<25 years old), whose direct lifetime costs were higher than most other groups. However, the CVD incidence was lowest for this age group and hence their contribution to the overall lifetime CVD costs is insubstantial. The average lifetime indirect costs were higher than direct costs for both males and females. Particularly, the average indirect cost for females was $73,600, while the respective figure for males was $76,700. As expected, the cost of productivity loss (indirect costs) was highest for the youngest group (less than 25 years), declining rapidly to zero for those age 65 years and over. Those admitted from emergency departments incurred higher costs, both direct costs ($93,860 vs $34,817) and indirect costs ($80,379 vs $69,887). Between the two components of indirect costs, mortality costs were higher than morbidity costs.

The predicted present-value annual direct costs per person increased sharply in the first six years and diminished rapidly to zero by Year 20 because of the rapid decline in the survival rate and the effect of discounting over time (Figure 1). In contrast, indirect costs peaked by Year 19 and gradually decreased to zero by Year 47, even when the youngest patient at admission (age 18) is predicted to reach the retirement age of 65 years.
Table 1. Lifetime costs estimates by age groups

| Age | Direct costs | | | Indirect costs | | |
|-----|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
|     | Females      | Males        | All          | Females      | Males        | All          | Females      | Males        | All          |
| <25 | 103.6        | 135.8        | 118.3        | 499.3        | 552.8        | 523.6        | (88.7, 118.4)| (109.2,162.5)| (103.7,132.9)| (489.5,509.1)| (538.4,567.1)| (515.1,532.2)|
|     | 76.8         | 92.8         | 84           | 427.1        | 481.1        | 451.5        | (68.7, 84.9)| (80.5, 105.1)| (76.9, 91.1)| (421.2,433.1)| (472.7,489.5)| (446.4,456.6)|
| 25-34| 75.1         | 71.4         | 73.2         | 245.2        | 275.5        | 260.8        | (69, 81.2)| (66.2, 76.6)| (69.2, 77.2)| (240.9,249.4)| (271.0,280.0)| (257.7,263.9)|
| 35-44| 63.6         | 73.4         | 69           | 83.1         | 104.8        | 95.1         | (60.0, 67.2)| (69.1, 77.7)| (66.1, 71.9)| (79.9, 86.3)| (101.6,108.0)| (92.8, 97.4)|
| 45-54| 58.5         | 69           | 64.5         | 11.0         | 14.6         | 13.0         | (55.7, 61.3)| (66.3, 71.8)| (62.5, 66.5)| (9.9, 12)| (13.5, 15.7)| (12.2, 13.8)|
| 55-64| 68.6         | 71.3         | 70.1         | (65.8, 71.4)| (68.9, 73.6)| (68.3, 71.9)| (47.5)| 53.2         | 50.1         |
| 65-74| 64.5         | 71.3         | 70.1         | (46.2, 48.9)| (51.4, 55.5)| (49, 51.2) | 0(0, 0)| 0(0, 0)| 0(0, 0)| 0(0, 0)| 0(0, 0)|
| 75+ | 61.8         | 69.3         | 65.7(64.7)| 73.6         | 76.7         | 75.2         | (60.5, 63.1)| (67.8, 70.7)| (66.7)| (72.0, 75.2)| (75.2, 78.3)| (74.1, 76.3)|

95% CI are in parentheses

Figure 1. Annual direct and indirect costs per person since the first hospitalisation
The detailed disaggregation of costs by sex, ethnicity and CVD conditions showed that indigenous patients incurred higher hospital costs and mortality costs (Figure 2a). Males incurred higher costs than females, with the sex gap being larger among indigenous patients. Among the ten major CVD groups, acute rheumatic fever, chronic rheumatic heart diseases and pulmonary diseases were the costliest with the respective average lifetime costs of
$430,000, $260,000 and $240,000. In contrast, ischaemic heart diseases incurred the lowest lifetime cost of $105,000 (Figure 2b). The cost structure varied by conditions: while mortality cost was highest in most CVD conditions, hospital cost accounted for the most lifetime cost of unspecified heart diseases.

The projected total lifetime CVD costs for Australia for each annual incident cohort was $60.5 billion, including $28.2 billion in direct costs and $32.3 billion in indirect costs (Table 2). The projected costs have been estimated using a series of one-way sensitivity tests with different choices of discount rates (0%, 3% and 7%), recuperation ratio (an increase from 0 to 2 times the hospital length of stay) and productivity growth rates (0% to 2%). The indirect cost estimate was most sensitive to the labour participation rate. Particularly, reducing the labour participation rate by 50% (Model 5) resulted in the same rate of reduction in lifetime indirect costs. The choice of discount rate also substantially affected the estimated indirect cost. For example, reducing a discount rate to 3% (Model 1) increased indirect costs to $42.8 billion (32.5%). However, the recuperation ratio had a modest impact on indirect costs; an increase in the recuperation rate to two times hospital stay (Model 4) increased morbidity costs to $34.8 billion (7.7%). An increase in labour productivity from 1% to 2% (Model 6) increased indirect costs to $37.2 billion (15.2%).

Table 2. Projected costs for Australia and sensitivity analysis ($A b., 2019 prices)

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* Key parameters for the main model were: discount rate of 5%, productivity growth=1%, participation rate=64.5% (55.7% for indigenous people), unemployment=6% (18.2% for indigenous people), recuperation =1. Income=1,485/wee (males earn 5% more than females; indigenous people earn 13% less than non-indigenous people, those in SFIFA Quintile 5 earn twice as those in SEIFA Quintile 1). Robustness test models are: 1) discount rate=3%; 2) discount rate=7%; 3) Discount rate=0%; 4) recuperation=2; 5) participation rate=32.25%; 6) productivity growth=2%; 7) productivity growth=0.
Discussion

This study has estimated the CVD costs in Australia using an incidence-based approach. On average, the lifetime costs of CVD since the first hospitalisation included $65,700 direct costs and $75,200 indirect costs. The largest component of direct lifetime costs was hospital spending, while the largest component of indirect costs was premature death. Direct costs associated with health services and medications contributed to the remaining direct costs. Among the range of CVD diseases, acute rheumatic fever, pulmonary diseases and chronic rheumatic heart diseases were the costliest conditions. The dominance of mortality costs suggest that patients with these conditions die at younger ages than those with other conditions. A significant higher mortality risk among those with such acute conditions is consistent with the literature\textsuperscript{14}. In contrast, hospital costs account for the largest proportion of total costs among patients with unspecified heart diseases, the fourth costly CVD condition, suggesting that they could be older and experienced longer hospital stays before death.

The size and cost structure also differed by sex and indigenous status. Indigenous patients incurred higher hospital costs and higher mortality costs, with indigenous patients spending two days longer in hospital and a shorter life expectancy than non-indigenous patients. The age gap between indigenous and non-indigenous patients at admission was 11 years (50 vs 61), and the mortality hazard ratio of indigenous patients was 1.34 [1.29-1.39] (see Appendix 2). The higher mortality cost of indigenous patients despite having a lower income suggests that the health effects outweigh the income effects among patients with cardiovascular diseases.

The lifetime CVD costs for Australia, assuming that the Queensland incidence rate is generalisable to Australia, was 56.9 billion, including 24.6 billion of direct costs and $32.3 billion of indirect costs. Compared to the micro-simulation study by Carter et al.\textsuperscript{15} ($2.7 bn), our incidence-base CVD cost estimate was substantially higher. There are three main factors that contribute to this difference. First, income and labour force participation rate ($77,220 per year and 64.5\%) used in this study were greater than twice those used by Carter et al.\textsuperscript{15} ($33,000 per year and 34\%, respectively). Second, Carter et al. estimated the lifetime cost using a 30-year horizon (i.e., 2001 to 2030) while we used a 47-year horizon so that the youngest patient group (age 18) reach retirement age of 65 years. Third, Carter et al.\textsuperscript{15} did not estimate the
productivity loss associated with work absence and did not include the labour force participation rate or unemployment rate in their analysis.

Our national cost estimates may represent a lower bound because the hospitalised incidence rate used in this study may not include all newly diagnosed CVD cases. However, the average lifetime costs per patient using the hospitalised incidence could be higher because of the shorter time horizon, and hence the effects of the discount rate were lower. The finding that indirect costs were twice more than direct costs suggests that the economic benefits from a societal perspective of CVD prevention should be at least twice that from a health service perspective. This ratio (2:1) can be a rule of thumb to convert benefits from a health service perspective to societal perspective in future cost-effectiveness analyses of CVD interventions.

The main limitation of this study is the lack of patient level data on income and employment, which we have attempted to address by using external data such as the ABS\textsuperscript{16,17} and the HILDA survey\textsuperscript{12}.

In conclusion, CVD continues to impose a tremendous financial burden on patients and society. Since CVD is incurable, government initiatives that reduce the incidence of CVD and disease progression would be the best strategy to reduce the high costs associated with this disease.
Conflict of interest

The authors declare no conflicts of interest.

Source of funding

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