ORIGINAL ARTICLE

Estimation of the Financial Burden to the National Health Insurance for Patients with Major Cancers in Taiwan

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Background/Purpose: Almost all countries that have national health insurance schemes face financial challenges. A better understanding of the financial burden that cancer places on Taiwan's National Health Insurance (NHI) is important for helping policy makers to plan under scarce healthcare resources. This study attempts to estimate lifetime health expenditure for patients with 17 types of major cancers.

Methods: A total of 425,294 patients, each of whom was registered in Taiwan during 1990 to 2001 as having one of 17 major types of cancers, were included. All of them were followed until the end of 2004. Monte Carlo simulation was used to extrapolate survival for up to 600 months to derive the life expectancy or lifetime survival function after diagnosis for different cancers. The average annual health expenditure per case for each cancer type was calculated by using data from the NHI's reimbursement database. The lifetime health expenditure per case was estimated by multiplying the monthly survival probability by the average monthly health expenditure, adjusting for the annual discount rate and the medical care inflation rate. By incorporating the number of annual incidence cases, the total lifetime health expenditure can also be estimated.

Results: Of the 17 cancers studied, it was found that leukemia had the highest average annual health expenditure per case (207,000 TWD) as well as the highest lifetime health expenditure per case (2,404,000 TWD, without discounting adjustment). Breast cancer had the highest total lifetime health expenditure (5046 million TWD) because of the longer life expectancy and chronic morbidity. Furthermore, colorectal cancer had the second highest total lifetime health expenditure (4995 million TWD) due to its high incidence.

Conclusion: The proposed method is a feasible way of estimating lifetime health expenditure for cancer patients even under high censoring rates. This would be helpful for cost-effectiveness assessment of cancer prevention programs and for policy planning. [*J Formos Med Assoc* 2008;107(1):54–63]

Key Words: cancer, health expenditure, health insurance, Monte Carlo method

Cancer is a major public health issue, due to both the suffering it causes and the financial burden that it places on patients and their families. In England, currently about one person in three develops a cancer in their lifetime, and cancer causes about one in four deaths.[1] In Taiwan, claims for the reimbursement of medical expenses for the diagnosis and treatment of cancer

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on the National Health Insurance (NHI) scheme were the second highest among major illnesses and injuries.[2] The amount of reimbursement represents a cause for concern regarding the maintenance of the NHI, given the scarce resources and increase in medical expenses for diagnosing and treating cancers. Measuring the financial burdens on patients with cancers could be helpful for financial planning,[3–5] as well as for the long-term maintenance of the NHI. However, previous studies have focused mostly on cross-sectional analysis of the financial burdens of cancer for a short period of time. The results of these studies may be useful for policymaking regarding cancer patients with short-term life expectancy.[6] However, there remains a need to estimate lifetime financial burdens,[7] which could be useful for the evaluation of the cost-effectiveness of prevention programs or new medical treatments.[8] The need for such evaluation is urgent in Taiwan, where all medical costs related to the diagnosis and management of cancer are reimbursed comprehensively by the NHI.

To estimate the lifetime health expenditure for cancer patients, the lifetime survival function must be calculated first. The Monte Carlo method can be used to estimate the lifetime survival function beyond the follow-up limit with a certain degree of accuracy.[9] It has been applied to patients who have serious diseases or conditions that lead to premature mortality, such as permanent occupational disabilities,[10] transfusion-dependent thalassemia,[11] and human immunodeficiency virus infection.[12]

In addition, the Taiwan NHI reimbursement database, which covers 97% of the population,[13] was used to estimate lifetime health expenditure for cancer patients. To the best of our knowledge, no previously published study has estimated lifetime health expenditure for cancer patients in Taiwan. Therefore, the main objective of the study reported herein was to estimate the lifetime health expenditure for cancer patients paid by the NHI. The estimate was made by analyzing data from national databases: the National Cancer Registry database, the National Mortality database, and the NHI's reimbursement database.

Methods

Subjects

A total of 425,294 cancer patients were recruited. The patients were grouped into 17 cancer cohorts according to the cancer sites, which were determined based on the code of the International Classification of Diseases taken from the National Cancer Registry database for the period from 1990 to 2001. Patients were followed up to the end of 2004 and the survival status for each cancer patient was obtained by linking the patients' identification (ID) and demographic information between the National Cancer Registry database and the National Mortality database. The 17 major cancer sites were as follows: oral cavity, nasopharynx, esophagus, stomach, colorectum, liver, gallbladder and extrahepatic bile duct, pancreas, lung, leukemia, skin, breast, cervix uteri, ovary, prostate, bladder, and kidney and other urinary organs.

Method for extrapolation of life expectancy

After 15 years of follow-up, the lifetime survival can be obtained for patients with cancers that yield a short life expectancy, such as liver, lung and pancreas cancers. However, there are several cancers that needed projection estimations. For these cases, we used the method proposed by Hwang and Wang[9] to extrapolate the long-term or lifetime survival curve beyond the follow-up period. The approach was to borrow the information from the age- and gender-matched reference population, of which the survival function can be obtained from the life table of the general population in Taiwan. The extrapolation process comprised three phases. First, we chose a reference person of the same age and gender with a known hazard function in the life table of the general population from the National Vital Statistics. The survival function of the reference person was then generated according to the Monte Carlo method. Thus, for the cohorts of each type of cancer, we were able to produce an age- and gender-matched reference population and their survival curves on the basis of the hazard function for the general population. Second, the survival function for the cancer cohorts was divided by that of the reference population at each time t to produce a new function, $W(t)$, which was defined as follows:

$$W(t) = \frac{S\ (t \mid \text{patient population})}{S\ (t \mid \text{reference population})}$$

Because the cancer cohort has, overall, a lower survival time than the reference population, the value of $W(t)$ initially equals 1 at time point $t = 0$, then gradually decreases, due to the cancer-associated excess mortality. Because the value of $W(t)$ is limited to the range from 0 to 1, linear regression for the temporal trend is not applicable. We therefore used the logit transformation of $W(t)$. The range of values was transformed from 0 to 1 to that of $-\infty$ to $+\infty$. Furthermore, if the cancer-associated excess hazard remains constant over time, the curve of the logit of $W(t)$ will converge to a straight line. Then, the logit transformation of the ratio of survival curves for both the cancer and the reference populations was fitted by simple linear regression up to the end of follow-up. Finally, the estimated regression line and the survival curve of the reference population were used to extrapolate the long-term survival function beyond the follow-up limit. Hence, life expectancy or the lifetime survival function (up to 600 months) after diagnosis could be estimated. In addition, the monthly survival probability could also be obtained. The above approach was demonstrated by computer simulation in 1999,[9] and was proven mathematically, provided that $W(t)$ is a fixed ratio after a certain period of time.[12] The standard error of survival estimates was obtained by using a bootstrap method. The extrapolation process was implemented by using data that were simulated by repeated sampling techniques with replacement from a real data set 300 times. In order to facilitate the above computation, the statistical package MC-QAS, written in R and S-Plus software, was used.[14]

Estimation of lifetime health expenditure paid by the NHI

The NHI's reimbursement database for 2001, which contained data for all outpatients and inpatients with diagnoses involving the 17 major cancer sites, was obtained. In general, the NHI comprehensively reimburses all medical services for each cancer patient, including various diagnostic work-ups and established treatments (e.g. surgery, radiation therapy, chemotherapy, or management for various complications). When a cancer patient visits a physician, it is the physician's responsibility to judge whether the patient's specific complaint, and hence the medical services provided, are related to the diagnosis of his or her underlying cancer. If so, then the physician can claim for reimbursement on the category of cancer diagnosed, using the International Classification of Diseases (9th revision, clinical modification [ICD9-CM]), which is automatically registered into the database. The average annual health expenditure was estimated by using records from the database, which contained data on 200,000 insured persons, by implementing the procedure of simple random sampling established by the Bureau of NHI. The calculation process was as follows. First, the annual incidence and prevalence for each cancer site for 2001 were calculated from the National Cancer Registry and the NHI's reimbursement database, respectively. Second, for each cancer site, we summed up the total medical expenses for each cancer type from the NHI database in 2001, which was then divided by the number of prevalence cases to obtain the average annual health expenditure per case. The average annual health expenditure per case was divided by 12 to obtain the average monthly health expenditure per case. This value was then multiplied by the monthly survival probability, calculated by using the Monte Carlo method, to obtain the lifetime health expenditure per case. Furthermore, the total lifetime health expenditure was estimated by multiplying the lifetime health expenditure per case by the number of new cases in 2001. To discount costs in future years, we also adjusted the lifetime health expenditure, using two annual discount rates (3% and 5%) and a medical care inflation rate (3%). The discount rates of 3% and 5% were recommended by researchers while conducting the cost-effectiveness analysis[15] and 3.625% was the coupon rate of Central Government Bonds with a maturity period of 30 years in 2001 in Taiwan.[16] Therefore, both 3% and 5% were chosen to discount. In addition, the mean of annual change rates from 1995 to 2001 was 3.07 (standard deviation, 1.98), calculated from the data of the Consumer Price Indices (CPI) for medical care services.[17] Thus, an inflation rate of 3% on the CPI for medical care services, as well as 3% and 5% for discount rates, were chosen for discounting to present values in 2001 or adjusting to the 2001 New Taiwan Dollar (TWD). The major process of the method is summarized as a flowchart in Figure 1.

For comparison, we also estimated the average annual health expenditure for the general population without major illnesses in Taiwan. We extended the estimation period from a single year (2001) to 5 years (1999–2003) to reduce a possible random effect generated by healthy people who did not use the NHI reimbursement scheme during the short period of time (i.e. 2001). The database we used contained data on 200,000 insured persons, selected by using the procedure of simple random sampling established by the Bureau of NHI. Using the criteria for major illnesses that were provided by the NHI, we identified 8651 patients with the codes of major illness

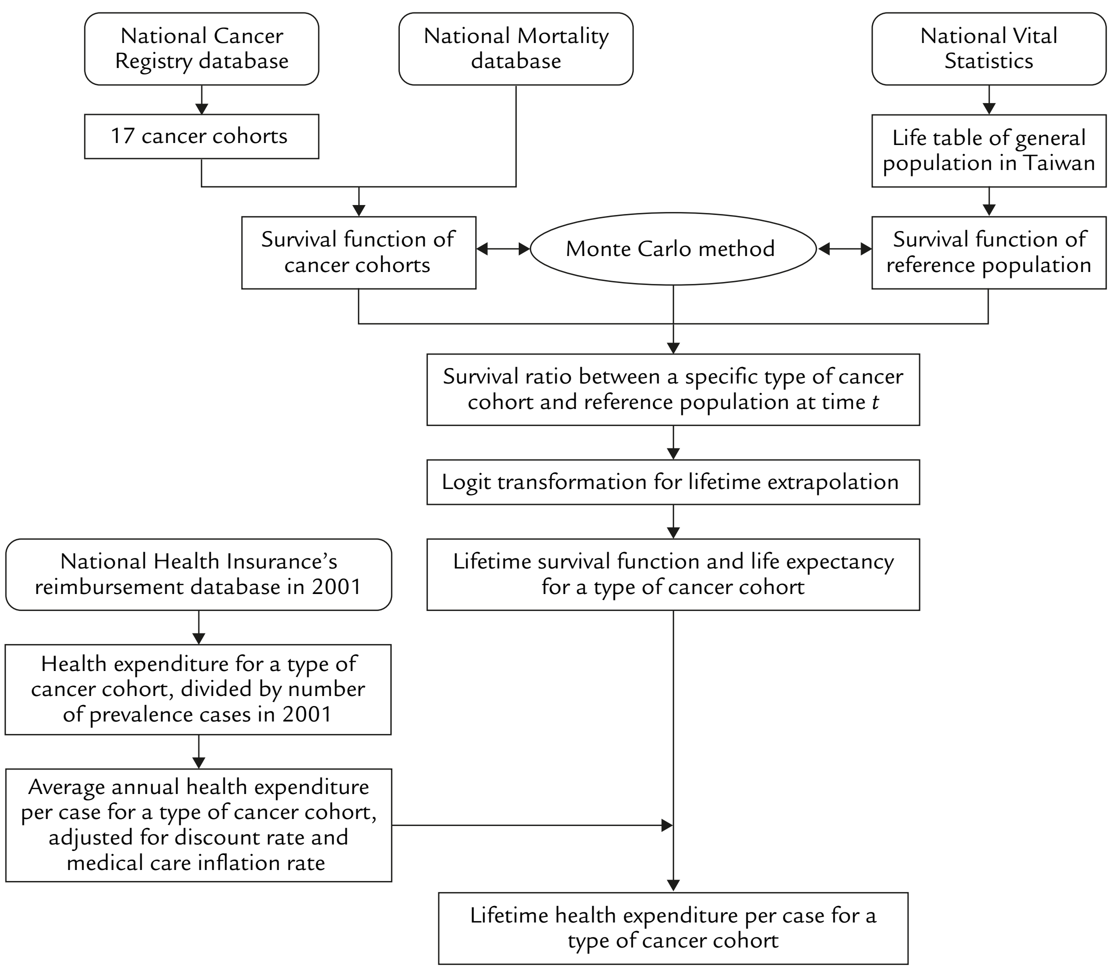

Figure 1. Flowchart of estimation method for lifetime health expenditure per case of a specific type of cancer. Data were obtained from the National Cancer Registry and National Mortality Registry to calculate the survival function and extrapolate to lifetime by the Monte Carlo method, which were integrated with the annual (or monthly) average health expenditure obtained from the reimbursement file of the National Health Insurance to estimate lifetime health expenditure.

Table. Estimations of the health expenditure paid by the National Health Insurance for 17 cancer sites, adjusted for two discount rates and a medical care inflation rate

Cancer site	Censoring rate (%)	Life expectancy, yr (SE)	Annual number of incidence cases	Annual number of prevalence cases	Average annual health expenditure per case ($\times 10^3$ TWD)	Lifetime health expenditure per case ($\times 10^3$ TWD)		Total lifetime health expenditure ($\times 10^6$ TWD)	
						Medical care inflation rate (3%)		Medical care inflation rate (3%)	
						Discount rates		Discount rates	
						3%	5%	3%	5%
Oral cavity	35.94	9.58 (0.61)	3549	15,677	95	910	725	3230	2574
Nasopharynx	43.06	12.59 (0.74)	1371	13,908	53	632	496	867	680
Esophagus	11.28	3.54 (0.20)	1229	6055	93	330	273	405	335
Stomach	26.80	7.51 (0.14)	3501	13,310	81	609	487	2133	1704
Colorectum	41.94	10.86 (0.11)	7215	40,902	64	692	555	4995	4002
Liver	13.28	3.45 (0.08)	8541	31,368	69	238	203	2030	1731
Gallbladder & extrahepatic bile duct	17.72	4.98 (0.20)	609	2359	90	446	365	272	223
Pancreas	8.28	2.81 (0.17)	992	3231	94	263	211	261	209
Lung	9.97	3.09 (0.07)	6752	22,304	111	342	286	2313	1932
Leukemia	28.49	11.61 (0.94)	962	5236	207	2404	1706	2312	1641
Skin	62.18	16.16 (0.22)	1806	4368	22	354	276	640	499
Breast	66.94	20.01 (0.80)	4667	35,082	54	1081	817	5046	3812
Cervix uteri	63.92	19.77 (0.30)	2423	22,225	41	808	608	1958	1474
Ovary	52.59	17.71 (0.80)	737	5366	72	1277	939	941	692
Prostate	44.65	8.17 (0.13)	1991	10,348	65	527	463	1050	922
Bladder	46.93	10.99 (0.20)	1756	9748	47	519	426	911	748
Kidney & other urinary organs	43.68	10.97 (0.85)	1502	7353	48	528	423	794	635

SE = standard error.

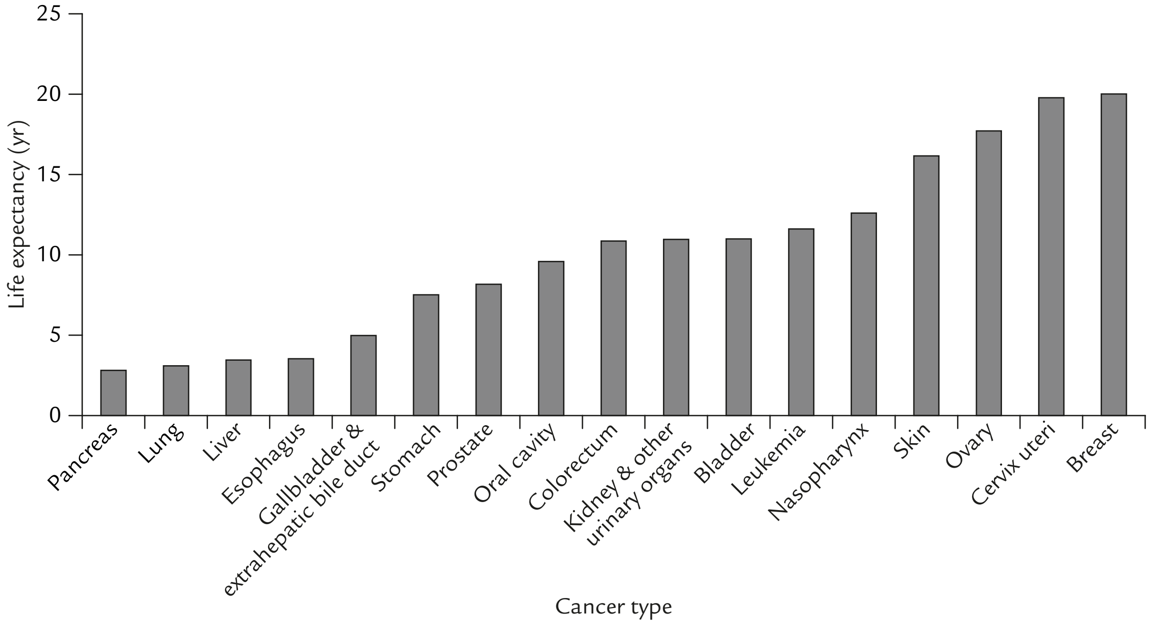

Figure 2. Life expectancy for the 17 different types of cancer.

who had visited a healthcare facility during the period 1999–2003. We removed the 8651 patients from the 200,000-person database, and totaled the health expenditure for that portion of the general population that was free from major illness for the period 1999–2003. The total remaining health expenditure was 9,819,674,747 TWD, which was divided by 5 (years) and 191,349 (=200,000 – 8651 persons) to obtain the average annual health expenditure per case, or 10,264 TWD.

Results

The percentage of patients who survived to the end of the 15-year follow-up (the censoring rate), i.e. to the end of 2004, according to cancer type, ranged from 8% to 67% (mean, 36%). The life expectancy after diagnosis for the 17 major cancer sites is summarized in the Table and Figure 2. The Table also shows the average annual health expenditure and the lifetime health expenditure for the 17 major cancer sites, which were adjusted by two annual discount rates and one medical care inflation rate, and expressed in TWD. Cancers of the liver and the gallbladder and extrahepatic bile duct had, respectively, the largest (8541) and smallest (609) number of new or incidence cases in 2001. Cases of cancers of the breast and colorectum were more prevalent in the year than cases of liver cancer, because patients with these cancers generally survive longer. Figure 3 shows that cancers with a longer survival time place a higher lifetime financial burden per case on the NHI. For example, although the average annual health expenditure per case for cancer of the ovary, breast, and cervix uteri were lower than that for many other types of cancer, the lifetime health expenditure per case for these cancers was generally higher than for others. Leukemia had the highest average annual health expenditure per case (207,000 TWD) as well as the highest lifetime health expenditure per case (2,404,000 TWD). Breast cancer had the highest total lifetime health expenditure (5046 million TWD) because of the long life expectancy. Furthermore, colorectal cancer had the second highest total lifetime health expenditure (4995 million TWD) due to its high incidence. In addition, when the chosen discount rate and medical care inflation rate were the same (3%), the estimated costs were the same as those without adjustment for both rates.

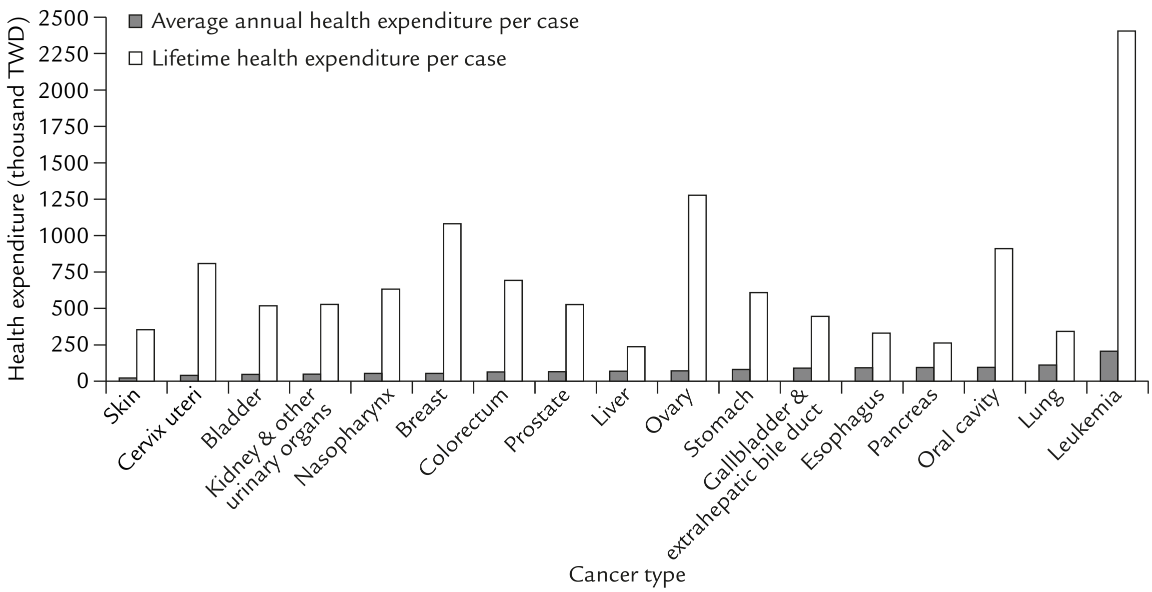

Figure 3. Annual and lifetime health expenditure per case for 17 different types of cancer.

Discussion

Although we have estimated the lifetime health expenditure to the NHI for major cancers, the validity and limitation of the estimations must be addressed before conclusions can be drawn. Extrapolation using the Monte Carlo method requires assumptions about premature mortality[9] and a stable survival ratio between the cancer cohort and the reference population.[12] Should these assumptions be unwarranted, the validity of the study would be threatened. However, the Monte Carlo method has been confirmed, in previously published studies with validity tests, to possess good validity for extrapolating the lifetime survival of patients with serious conditions and diseases, such as permanent occupational disabilities,[10] serious occupational injuries,[18] and acute myelogenous leukemia.[19] Moreover, because the lifetime extrapolation is based on previous and current clinical experiences, such as the life table of the general population, the actual survival (and hence, the health expenditure) is usually underestimated. This is because the active development and adoption of newer technology for cancer treatments extends the survival time. For example, currently, integrated cancer screening is being implemented more extensively in Taiwan; hence, more patients with early cancers can be detected and may survive longer as a result.[20] Thus, our estimate of the financial burdens of cancer patients on the NHI may even be conservative. Given the use of new technologies that may prolong survival, the estimates should be revised periodically to obtain figures on life expectancy and health expenditure that are more accurate. In order to improve the accuracy of estimates of life expectancy and health expenditure, future work should focus on the following two factors. First, some prognostic factors, such as tumor staging and performance status[21,22] of the cancer cohort, could be considered. The cancer cohort could then be stratified to a sub-cohort according to these factors. Second, although for comparison we calculated the average annual health expenditure per case (10,264 TWD) for people of the general population who did not have major illnesses, our estimates based on the NHI reimbursement data could not be considered as purely cancer-attributable medical costs. In order to overcome the challenge, details of some potential confounders (for example, underlying or concomitant diseases) could be considered to facilitate better comparability of the cancer cohort and the reference population[23] as well as to improve the accuracy of the estimates.

The method employed in our study used the average annual costs for the estimation, which counts the total number of prevalence cases in a particular year as the denominator and assumed that a patient suffering from a major cancer generally comes back to a clinic or hospital at least once a year for cancer management or follow-up checks, even after treatment has been completed. There is probably no need to worry about this assumption for cancers with a short life expectancy (say, less than 5 years) such as cancers of the liver, lung and pancreas. However, the assumption may not be valid for cancers with long life expectancy. Nonetheless, since all types of cancer are considered to fall into the category of *catastrophic illnesses* and all clinic or hospital visits related to cancer are covered comprehensively by the NHI, the potential overestimation of annual medical costs from under-counting the number of prevalence cases might be low.

Because the financial burden on the NHI depends not only on the survival function, but also on the chosen discount and medical care inflation rates, the estimation of the health expenditure for cancers that have longer survivals, e.g. breast, cervix uteri and ovary, is affected more sensitively by the chosen rates than the estimation of the health expenditure for other cancers. Technologic advancements regarding the diagnosis and treatment of cancer develop more quickly than for other products; hence, there are uncertainties associated with the use of the annual change rate of the CPI, which is based on average costs.[17] Thus, the policymaker could conduct a sensitivity analysis to determine how various discount rates and medical care inflation rates may affect financial planning.

In accordance with welfare economics, the ideal approach for estimating the value of health improvements, such as the prevention of a specific type of cancer, may be to consider how much people are willing to pay.[24,25] Although quantifying the value of willingness to pay (WTP) is more acceptable for resource allocation, it is difficult to measure, especially if one is asked to respond to a state behind a veil of ignorance.[26] An alternative approach is to measure the cost of illness by counting the combination of indirect costs (loss of earnings) and direct costs (medical expenses), which is considered to be the lower bound of WTP.[24] This study only estimated the health expenditure paid by the NHI. This underestimates even the direct costs, because at least out-of-pocket expenses, such as those for transportation to and from the hospital and the hiring of additional persons for supportive care, are not included. Nonetheless, our estimations of the health expenditure paid by the NHI could be helpful for the NHI's policy planning, especially for prevention programs for different types of cancer.[27]

The total cost of cancer includes not only the suffering of patients from premature mortality and morbidity, but also the financial burdens on the NHI of diagnosing and treating cancer. In the study reported herein, we successfully estimated the lifetime costs for 17 different types of cancer. Our estimates will be useful for the future assessment of cost-effectiveness for the comparison of different policies on cancer control. For example, hepatitis B virus (HBV) is a causal factor for hepatocellular carcinoma. The costs of immunization (say, HBV vaccine) and/or treatment of HBV infection could therefore be compared with the periodic sonographic and/or serum tumor maker (say, α-fetoprotein) for hepatocellular carcinoma. In addition, since effective prevention measures may eliminate completely both the patient's premature mortality and morbidity and the financial burdens on the NHI, future research should also focus on preventive medicine, rather than only on the development and adoption of new technology for diagnosis and treatment. Cancers with chronic morbidity should have higher priority with respect to the development of preventive medicine. For example, cancers of the oral cavity and breast, which have longer periods of morbidity and larger average annual health expenditure per case, should have a higher priority for prevention research and action than other types of cancer. Furthermore, our estimates can also be used by the NHI directly, as an overview of the potential financial benefit if a specific type of cancer (e.g. hepatocellular carcinoma) can be prevented by implementing a prevention measure such as immunization (say, HBV vaccine).

In conclusion, we have proposed and implemented a feasible method of measuring the lifetime health expenditure or the financial burden for cancer on the NHI, even with high censoring rates (for example, the mean of 36% that we found in our study). The results may be helpful to public health researchers and policymakers. The estimation of the financial burdens of cancer patients, as well as other traditional measures of the burden of cancer, e.g. incidence, prevalence, mortality, and years of life lost, could be used to establish public health goals, to assess the allocation of healthcare resources across disease categories, and to evaluate the potential costs and benefits of public health interventions.[3]

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