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Current and Future Costs of Cancer

Marc A. Koopmanschap, Leona van Roijen, Luc Bonneux and Jan J. Barendregt

Cancer costs in the Netherlands amounted to 4.8% of health care costs in 1988. For five cancer types, and a sixth group covering all other malignancies, costs were broken down by age, sex and disease phase. They showed a remarkably similar pattern of medical consumption. Costs were linked to observed incidence, mortality and estimated prevalence, together allowing for prediction of future costs of cancer. In 2020, as a result of ageing, cancer costs will have increased much more rapidly than total health care costs, in particular for cancer of the lung and prostate. Colorectal cancer costs were predicted for epidemiological scenarios. Our model shows that an increase in future prevalence may bear quite different cost implications. If it is due to higher incidence, the costs will increase substantially. If due to survival improvement, the increase will be less prominent. Simply extrapolating costs based on future prevalence or mortality may produce serious errors.
Eur J Cancer, Vol. 30A, No. 1, pp. 60–65, 1994

INTRODUCTION

AN OPTIMAL allocation of health care resources requires insight into the epidemiology and costs of diseases. Regarding cancer, we need to know both the absolute costs and the relative costs as compared to other diseases and total health care. Furthermore, the impact of demography, changes in medical practice and epidemiology on future health care costs should be analysed.

In this article, we estimate the costs for five cancer categories: cancer of the lung, breast, colorectum, prostate, stomach and all other malignancies in a sixth category. These cancer categories were selected based on their importance for mortality, morbidity and medical consumption.

First, we calculated the total costs per type of cancer, age group and sex for 1988. Next, these costs were assigned to three disease phases: the year following incidence, the year preceding death and the period in between. The estimated costs per patient by disease phase were combined with incidence, mortality and prevalence, as calculated by our cancer disease model. This allows for prediction of future cancer costs for several possible scenarios: a demographic scenario and scenarios concerning expected trends in incidence and survival. The costs predicted by the 'three phase model' were compared with outcomes using simple extrapolations of average costs per patient.

MATERIALS AND METHODS

Total costs of cancer

In a recent study, we estimated total health care costs for the Netherlands in 1988, for the six aforementioned cancer types,

Correspondence to M. A. Koopmanschap.
The authors are at the Department of Public Health, Erasmus University, P. O. Box 1738, 3000 DR Rotterdam, The Netherlands.
They are members of the Technology Assessment Methods Project Team.
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together with 42 other disease categories, covering the entire ICD 9-CM classification [1–3]. Total health care costs were allocated to diseases, age groups and sex, using utilisation of services or the number of patients. Data on in-hospital and nursing home care were extracted from national registers with (nearly) complete coverage. For general practitioner's care, physical therapy and district nursing, we used data from recent, large surveys. These results were used to calculate the costs of inpatient hospital care and non-hospital care for cancer.

Costs of outpatient hospital care consist of radiotherapy, chemotherapy and follow-up. Costs of Dutch radiotherapy centres were assigned to the six cancer types, using the number of new patients receiving radiotherapy by type of cancer [4]. The costs of cytostatics administered in hospitals [5] were assigned to the six cancer types, in proportion to the distribution of in-hospital costs. The costs for monitoring patients without symptoms after diagnosis and primary treatment were calculated in detail for breast cancer [6] and were extrapolated to other cancers (see below).

Costs by disease phase

Several studies [7, 8] indicated that over the course of cancer, the costs show two peaks. The first peak due to diagnosis and primary treatment and the second peak due to palliation of often severe symptoms in advanced disease. In between, medical consumption is modest. Hence, we discerned three disease phases, inspired by Baker [7]:

— the first year following incidence, as a result of diagnosis and primary treatment;

— the last year of life for people dying of cancer (only for people who survive the first year, who develop recurrent or metastatic disease and do not die from other causes);

— the period in between: 'the intermediate phase', during which people are disease-free or have already diagnosed metastases (in these terms disease-free is a mixture of cured patients and patients who currently have no disease symptoms, but who will later get recurrent or metastatic disease).

Costs for patients dying within 1 year after incidence were assigned to the incidence phase.

The average costs per patient by type of cancer, age, sex and phase were estimated as follows. For the intermediate phase we used detailed estimates for the Netherlands of annual follow-up costs per patient for breast cancer [6]. For the other types of cancer the relative follow-up costs compared to breast cancer, calculated for 87 000 patients in the U.S.A. [7], were combined with the costs for breast cancer, yielding the annual follow-up costs per patient.

The hospital costs in the incidence phase were primarily based on the length of stay in 1988, by type of cancer, age and sex, according to the nationwide Dutch hospital register [9]. The length of stay for patients with metastases as primary cause for hospital admission determined the in-hospital cost during the last year of life. Although the last year of life and the period of metastases are not equivalent, hospital stays concerning metastases are often concentrated in the last year of life [7, 10–12]. This length of stay is assumed to be age- and sex-specific, but not cancer-specific, because if metastases are coded as the primary cause of admission, the site of the primary tumour is seldomly known.

The average hospital admission rate was derived by comparing the number of model-based incident cases and deaths for 1988 (correcting for patients dying within the first year after diagnosis) to the number of hospital stays registered in 1988, for each combination of cancer, age and sex. The ratio of hospital stays versus incidence plus deceased served as the average admission rate. The admission rate was assumed to be equal for the incidence phase and the last year of life, because the data did not allow for separate estimates (see Discussion). Combination of the model-based incidence and mortality with length of stay and admission rate yielded the number of 'model-based hospital days', which corresponds closely to the number of registered hospital days per cancer type, age and sex. Combining the number of hospital days with costs per day and adding other hospital costs (for surgery, radiotherapy, chemotherapy, etc.) and non-hospital costs generated the average costs per patient.

Disease model

Our cancer model calculated the number of patients in each disease phase, per cancer type, age and sex [13]. The model is a deterministic state transition model: it divides the population into subpopulations, defined by states. Every model year, the population 'ages' 1 year and the states are updated. Transitions from one state to another are governed by probabilities, extracted from registries and literature. Transition probabilities depend only on the current state defined by age, sex, cancer type and disease phase.

A demographic module reproduces the population forecasts for the Netherlands [14] and generates first incidents of cancer by age and sex, similar to the 1989 national cancer incidence rates for the Netherlands [15].

After incidence, patients first run a risk of immediate death as a consequence of primary treatment. The survivors are divided into two groups: the fraction which is cured and the fraction which is not. The not-cured will enter the intermediate ('disease-free') phase of the disease, and subsequently will die of the disease, provided they do not die from other causes first. In practice, of course, cured and disease-free patients cannot be distinguished, and both will incur follow-up costs.

The cancer-specific mortality of the non-cured is modelled by applying a log normal survival to the relative survival rate. Relative survival rates correct the observed mortality in the diseased population for the expected mortality in the reference population with the same age and sex [16, 17]. Together, this implies that survival after diagnosis can be characterised by four parameters: a fraction dead after treatment, a fraction cured and the geometrical mean (equalling the median survival time) and variance of the log normal distribution. A mathematical description of the survival is shown in the Appendix.

The demographic module takes care of all other causes of death, corrected for the studied diseases, by using cause elimination life table methodology. This other causes mortality probability is applied to all states in the model, under the assumption that it is independent. Prevalences are calculated from incidence, disease-specific mortality and all other causes mortality. Surviving patients run a higher risk of a second cancer episode. Therefore, they are again subjected to the cancer incidence of the reference population, multiplied by the relative risks observed in the Connecticut cancer register [18].

The model was calibrated on aggregate data of cancer survival from Dutch and Scandinavian cancer registries, corrected for other causes of death. The fraction dead after treatment is from the Dutch hospital register [19], the other three survival parameters were estimated by an iterative non-linear least squares regression, weighed for the number of deaths. Residual errors were small.

Scenarios

We have illustrated the relevance of epidemiology for future cost estimates with four scenarios for colorectal cancer. Scenario 1 only incorporates the expected demographic development. In scenario 2 we have added an improving prognosis after diagnosis. In the Norwegian and Finnish registries, a very significant improvement over time of 5-year relative survival rates has occurred between 1954 and 1985 of 2% per year [20–23]. We have extrapolated an average relative decrease of cancer-specific mortality of 2% per year to 2005. Five-year survival rates thus increased from 44% (1985) to 55% (1995) to 66% (2005).

Scenario 3 involves, in addition to demography, a 2% annual relative increase in the incidence of all stages for men, and 1% for women. The trend in incidence is assumed to be 2% higher than the observed mortality trend in most western countries, and is primarily caused by earlier diagnosis and increased detection of slower growing tumours [24].

Scenario 4, in our opinion the most realistic one, incorporates demography, increasing incidence (2.5% per year for men, 1.4% for women) and improved survival. As a consequence, mortality rates for men decrease by 0.4% annually and by 1.1% for women, as has been observed in the Netherlands over the period 1978–1989 [19].

All costs are given in millions of Dutch guilders. In 1988, the exchange rate of one Dutch guilder (dfl) was approximately 0.3 British Pounds and 0.5 U.S. Dollar.

RESULTS

Total costs

Total costs of malignant cancer in the Netherlands amounted to 1894 million Dutch guilders in 1988 (Table 1), representing 4.8% of total health care costs. West Germany and Sweden have a comparable share: 4 and 5.1%, respectively [25–26]. For the U.S.A., it is somewhat higher: 6.2% [27]. In-hospital care takes approximately 60% of total costs. Outpatient hospital costs consist of radiotherapy (200 million), chemotherapy (200 million) and follow-up costs (143 million).

About dfl 1000 million was assigned to the five specific cancers, leaving almost 900 million for the other cancers (Table 2). Lung cancer is in first place: it is responsible for 16% of the costs of cancer (300 million), and is mainly caused by men. Colorectal and breast cancer each represent about 13% of the total cancer costs, whereas stomach cancer and prostate cancer cause about 5–6% of the total costs. This ranking corresponds to recent estimates for Texas [28]. Hospital costs predominate and costs are fairly equal for both sexes.

Length of stay and admission rate

Figure 1 shows the average length of hospital stay by age and sex for colorectal cancer for the incidence phase and the last year of life. Only the results for colorectal cancer are shown, but the general pattern applies to all types of cancer.

Until age 55, the length of stay (per stay) is stable and fairly equal for both sexes. With increasing age, hospital stays become longer for both sexes, but at a quicker rate for women. For each type of cancer, older women in the Netherlands stay in hospital significantly longer than men of the same age, irrespective of the disease phase. Subsequent analyses have shown that this holds for the majority of diseases in the Netherlands [9]. Older women are more often single than older men (41 versus 15% in 1987 [29]), limiting the opportunities for home care, which may cause longer hospital stays.

The average admission rate for colorectal cancer patients is relatively high (1.8) until age 45, but diminishes considerably with increasing age (Fig. 2). For people of age 80 and older it becomes smaller than 1, implying that a substantial number of these patients are not hospitalised. Consequently, they consume relatively more nursing home care, district nursing care and general practitioner's services, which we took into account. The admission rate is hardly sex-specific.

Costs per disease phase

Figure 3 shows the average costs per patient having colorectal cancer during the incidence phase and the last year of life, respectively. Until age 55 the costs are stable, amounting to dfl

Table 1. Health care costs for cancer, by health care sector in millions of Dutch guilders (in parentheses as percentage of total cancer costs), the Netherlands 1988

Health care sector	Costs for 1988 in million dfl
In-patient hospital care	1148 (61%)
Out-patient hospital care	543 (29%)
Non-hospital care	203 (11%)
Total health care	1894 (100%)

Table 2. Health care costs per type of cancer, sex and health care sector, for six types of cancer in millions of Dutch guilders (in parentheses as percentage of total cancer costs), the Netherlands 1988

Type of cancer	Total costs	% for men	% in hospital
Lung cancer	300 (16%)	83*	92
Breast cancer	253 (13%)	0	82
Colorectal cancer	250 (13%)	45	88
Prostate cancer	110 (6%)	100	87
Stomach cancer	99 (5%)	59	84
Other cancers	882 (47%)	46	92
All malignant cancers	1894 (100%)	49	89

*83% of total costs are incurred for men and 17% for women.

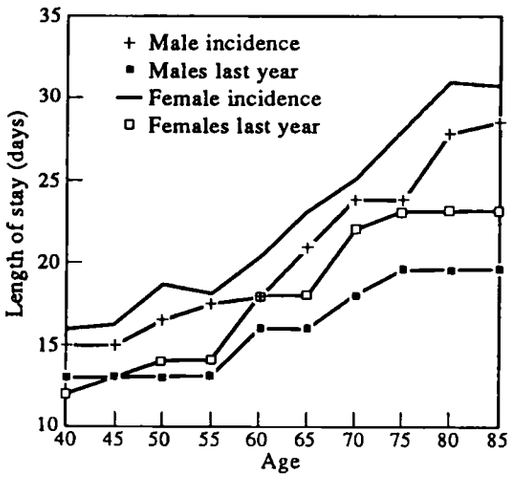

Fig. 1. Average length of hospital stay in days for colorectal cancer, by age group, sex and disease phase, the Netherlands 1988.

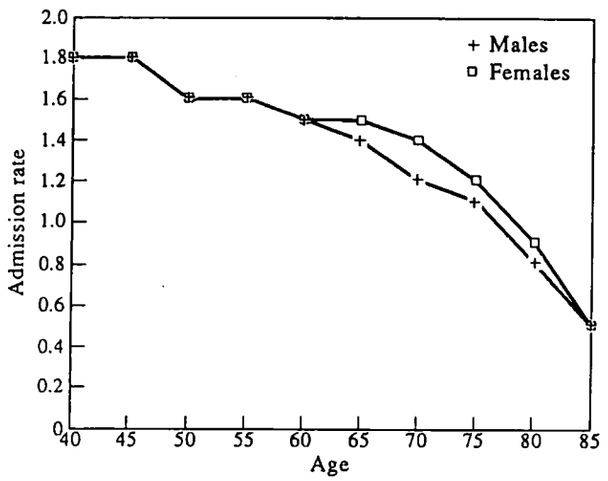

Fig. 2. Average hospital admission rate per patient having colorectal cancer, by age group and sex (model-based outcomes), the Netherlands 1988.

20–30 000 per patient. For women between ages 60 and 75 costs rise due to the increase in length of stay, which more than compensates for the falling admission rate. For people older than 80, the costs fall to 12–20 000, as the low admission rate then becomes the dominant factor. Relatively low costs for patients older than 80 years were also found by Riley [11]. During the incidence phase, costs (dfl 25–30 000) are higher than during the last year of life (dfl 20 000), irrespective of age and sex. For women over 60, the costs are about dfl 5000 higher than for men of the same age.

A considerable part of the results for colorectal cancer holds for all six cancer types, such as the lower costs for patients older than 75. The higher costs for women older than 60 apply to all four cancer types that are relevant for both sexes. Fairly stable costs until age 60 prevail for all cancers, except for 'other cancers', in which patients younger than 15 years incur considerably higher costs. This category is a mixture of very different types of cancer, both for young and for elderly patients. The high costs for people under 15 are mainly caused by leukaemia, brain cancer and non-Hodgkin's disease [30], for which therapy (immunotherapy and chemotherapy and bone marrow transplantation) is very expensive [31–33]. The notable increase in costs between ages 60 and 75 also applies to prostate cancer and lung cancer (women), but not to stomach cancer and other cancers. The incidence phase is not always more expensive than the last year of life. For breast, prostate and other cancers, the last year of life appears to be more expensive. De Koning's study [34] confirms this result for breast cancer.

During the incidence phase, the average costs per person are the highest for stomach cancer (dfl 30 000) and other cancers in younger people (dfl 30–50 000). Breast and prostate cancer are relatively 'cheap' (dfl 21 000), leaving colorectal and lung cancer in the middle range (dfl 25–30 000). The variation in costs for the last year of life is much smaller, resembling Baker's findings for U.S.A. Medicare cancer patients [7], as well as Dutch results for breast and cervical cancer [12, 34]. We estimated these costs at about dfl 25 000. The only exception is 'other cancers', causing higher costs during the last year of life.

Costs over the course of cancer

Assembling the three disease phases illustrates the costs over the entire course of cancer (Fig. 4). The costs show two peaks, the first peak just after clinical detection, the second in the last year of life. In the intermediate phase, annual costs are very modest. The total costs of the intermediate phase depend chiefly on the length of disease-free survival. The total costs related to prevalence of cancer only become important if the intermediate phase is very long, say 15 years.

Demography and costs

Table 3 shows the predicted costs regarding all six cancer types, for the years 2005 and 2020, applying the demographic scenario. In 2005, the index for total cancer costs (in 1988 it was 100) is 122: a 1.2% annual increase, comparable to total health care (index, 116). Costs increase at about the same rate for each type of cancer. In the year 2020, the burden of ageing becomes heavier, as the Dutch postwar baby boom reaches ages 60–75. By then cancer costs (index 147) will have increased considerably more rapidly than total heath care costs (index 130). The costs of lung and prostate cancer will be most seriously affected by ageing (index 158 and 157, respectively). The consequences for breast cancer and other cancers are less severe as they predominate at relatively young ages. Still, their rate of cost increase is higher than for total health care.

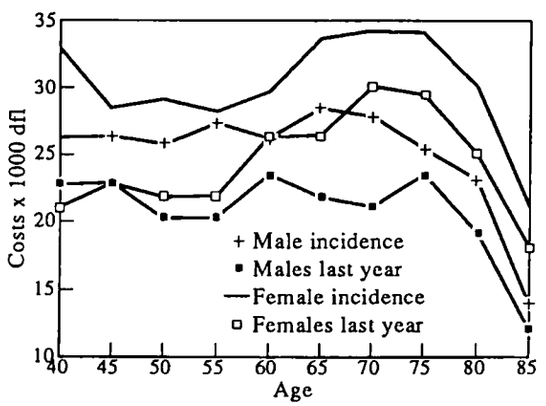

Fig. 3. Average costs per patient having colorectal cancer, by disease phase, age group and sex, in thousands of Dutch guilders (model-based outcomes), the Netherlands 1988.

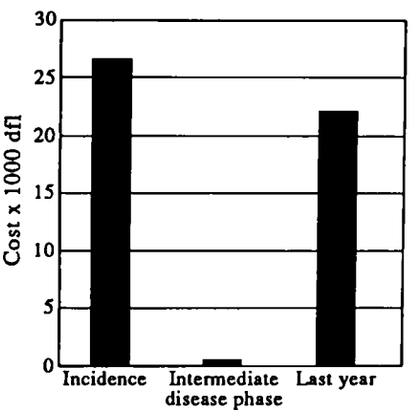

Fig. 4. Average costs per patient by disease phase for colorectal cancer, in thousands of Dutch guilders (model-based outcomes), the Netherlands 1988.

Table 3. Predicted costs per type of cancer for the Netherlands in 2005 and 2020, demographic scenario, in millions of guilders in 1988 prices and as index (in parentheses) compared to 1988 (1988 = 100)

Type of cancer	Costs in 2005	Costs in 2020
Lung cancer	377 (126)	474 (158)
Breast cancer	311 (123)	352 (139)
Colorectal cancer	308 (123)	375 (150)
Prostate cancer	134 (123)	173 (157)
Stomach cancer	122 (123)	151 (150)
Other cancers	1060 (120)	1253 (142)
All cancers	2312 (122)	2778 (147)
All diseases	46 110 (116)	51 675 (130)

Scenarios for colorectal cancer

The two-peaked cost pattern has important implications for future cancer costs. The results of four scenarios for colorectal cancer are presented for the year 2005 (Table 4). According to our model, costs of colorectal cancer in 2005 amount to 308 million gulders, if only demography is taken into account. Improving disease-free survival (scenario 2), and consequently increasing the prevalence of cancer, will result in costs of dfl 299 million, since it only raises the number of patients consuming the relatively inexpensive follow-up (incidence remains the same), and cancer-specific mortality declines, because of mortality from other causes. On the other hand, if the same increase in prevalence of disease-free persons occurs, but due to a rise in incidence (scenario 3), the costs will rise substantially to dfl 395 million. All extra patients will undergo expensive diagnosis and primary therapy. Furthermore, cancer mortality increases, causing extra costs as well. In case of the most realistic course of events (scenario 4), the costs will amount to dfl 417 million.

Table 4 also presents the predicted costs using simple extrapolations without discerning disease phases. Three variants are shown, based on constant costs per prevalent case, per death and per incident case, respectively. In case of scenario 1, incorporating only demography, the predictions are quite accurate, although the incidence method understates the costs by 6%.

The prevalence-based method predicts the same costs for scenarios 2 and 3 since either produces the same prevalence in 2005. In case of improved survival (scenario 2), this leads to overestimating the costs by 20%. If the incidence increases (scenario 3), the costs are underestimated by 9%. The mortality-based approach is quite accurate if the incidence rises (and consequently, mortality) but fails completely in predicting the costs of survival improvement. For scenarios 2 and 4, the costs are understated by 27–33%. The incidence-based method performs reasonably for scenarios 1 to 3, but for scenario 4 costs are overestimated by 10%.

Table 4. Predicted costs for colorectal cancer for the year 2005 applying four models to four scenarios, in millions of Dutch guilders.

	1988	2005 Scenario 1	2005 Scenario 2	2005 Scenario 3	2005 Scenario 4
Three-phase model	250	308	299	395	417
No phase model prevalence-based	250	309	358 (+20%)	358 (−9%)	413 (−1%)
No phase model mortality-based	250	310	218 (−27%)	401 (+2%)	279 (−33%)
No phase model incidence-based	250	290 (−6%)	290 (−3%)	380 (−4%)	460 (+10%)

In parentheses: differences in percent compared to outcomes of the three-phase model. Scenario 1: only demography; scenario 2: demography and survival improvement; scenario 3: demography and incidence increase; scenario 4: demography, incidence increase and survival improvement. For exact details on the scenarios, see Materials and Methods.

DISCUSSION

Epidemiology and medical consumption vary considerably between types of cancer as well as between individual patients. Recognising this variability, our analysis shows that the general pattern of medical consumption coincides remarkably well for the six cancer types described. The length of hospital stay increases uniformly with age, especially for women. On the other hand, the admission rate falls with age. For patients older than 75, the second factor dominates, resulting in lower costs. Over the course of cancer, medical consumption shows two peaks: during the first year after incidence and in the last year of life. In between the costs are modest.

We assumed the same admission rate for patients in the incidence phase and the last year of life. The length of hospital stay for patients with metastases was assumed to be age- and sex-specific, but equal for all cancer types, which is supported by research in the U.S.A. and the Netherlands. Both assumptions are obviously rather crude, but sufficient to demonstrate the divergent consequences of several scenarios. Sensitivity analysis, by substantially varying the most uncertain parameter—the admission rate during the incidence phase versus the last year of life—proved not to affect the basic two-peaked pattern of costs seriously. Consequently, the predictions of future costs for the scenarios described are robust.

The costs during the prevalence phase were based on Dutch calculations for breast cancer, combined with Baker's relative estimates for other types of cancer. As the costs are relatively low, errors in these estimates will not influence the results seriously. However, more precise estimates of prevalence costs would be helpful in completing the picture of medical consumption for cancer.

The assumed survival improvement for colorectal cancer (scenarios 2 and 4) seems high, but is the results of two processes: a true decrease of mortality due to more effective treatment, and a spurious increase of survival due to earlier diagnosis (lead time) and increased detection of slow growing tumours, which had passed unnoticed before (length time and pseudo-diagnosis) [24, 35].

If one is only interested in the costs of demographic scenarios, simple extrapolations of current costs are satisfactory, provided that reliable information on costs by type of cancer, age and sex is available. However, it is highly plausible that in the future, trends in incidence and survival of cancer will prevail, as they have over the past 20 years. Although our three-phase model is still somewhat crude, it takes these dynamics into account and thus provides useful predictions of the costs of epidemiological scenarios.

The demographic scenario, as described, is quite restrictive, since it does not account for future trends in risk factor exposure, like smoking for lung cancer, and the influence of screening on breast cancer. Further refinement of the disease model and the cost estimates is underway, in order to predict the influence of these trends on future morbidity, mortality and costs.

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APPENDIX

1. The survival was modelled by using the log normal distribution:

$$f(t) = \frac{1}{t\sqrt{(2\pi\sigma)}} \exp\left[\frac{-(\log t - \mu)^2}{2\sigma^2}\right]$$

Where t is the time after diagnosis, μ the median survival and σ^2 the variance. We used a discrete approximation with a time step of 1 month. The proportion of survivors at any time t_i after diagnosis t_0 is then given by:

$$P(S)_{t_i} = (1 - M_{op})\left(c + (1-c)\sum_{t_0}^{t_1}\left[\frac{1}{t_i\sqrt{2\pi\sigma}} \exp\left(\frac{-(\log t_i - \mu)^2}{2\sigma^2}\right)\right]\right)$$

where M_{op} is the proportion dying in hospital after first admission and c is the fraction cured.