BMJ 1997;314:1682 (7 June)

Education and debate

Fraction of normal remaining life span: a new method for expressing survival in cancer

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Introduction

Conventionally, the time between diagnosis and date of last follow up or death is used to plot survival curves for patients with cancer. This ignores the patient's expected life span had the patient been healthy at the time of diagnosis. In human terms the impact of a projected prognosis of 10 year survival on a woman diagnosed as having breast cancer, for example, may be different depending on whether she is aged 30 or 70. Furthermore, oncologists have no answer to the question: "What is my chance of cure?" For this reason, we believe that survival is better expressed as a fraction of normal remaining life span expected at the time of diagnosis. We propose a new method which takes account of age at diagnosis in calculating survival.

The new method

To illustrate this concept we used a database of 1134 patients with breast cancer from Bombay who were operated on at Tata Memorial Hospital between 1974 and 1988. The patients were divided into three groups on the basis of the number of involved axillary lymph nodes (0, 1-4, and >4). The survival curves were plotted in two different ways: by the conventional method (fig 1) and by a new way that we call the real life expectancy method (fig 2). The difference in the two methods is not in the statistical handling of data but in the way period of survival is expressed. Both curves were plotted with the computer program SUREAL by the actuarial method.[1]

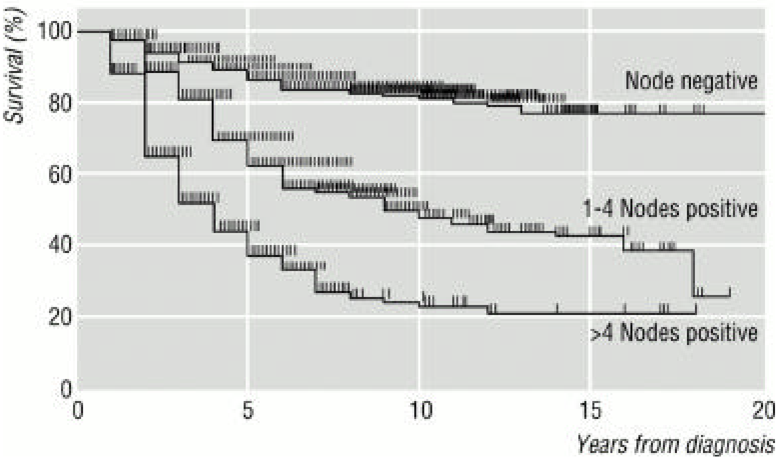

Fig 1 Conventional actuarial survival curves, with *x* axis indicating number of years from diagnosis and *y* axis indicating cumulative percentage surviving

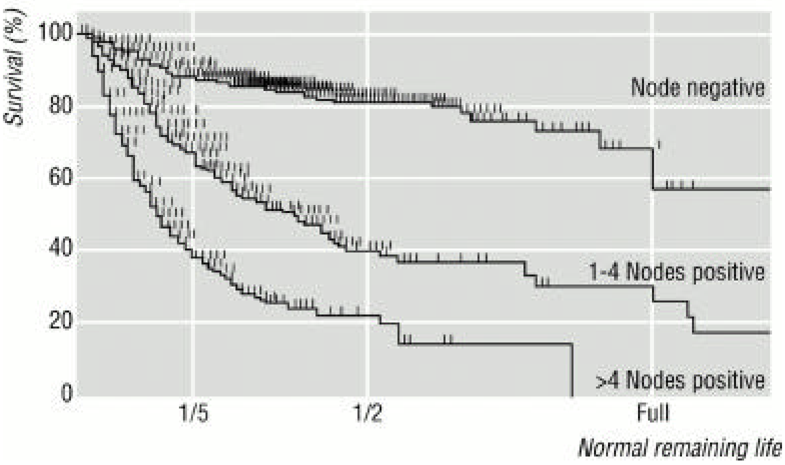

Fig 2 Real life expectancy curves, with *x* axis indicating fraction of normal remaining life and *y* axis indicating cumulative percentage surviving

To plot real life expectancy curves we used data from the Life Insurance Corporation of India to estimate the normal life expectancy of each patient at the age of diagnosis had she not had breast cancer (Life Insurance Corporation of India, personal communication). At the time of survival analysis each patient's age at diagnosis was subtracted form her normal life expectancy at that age to obtain what we call normal remaining life (NRL). The time from diagnosis to the date of last follow up or death was then calculated and divided by the normal remaining life to obtain the percentage of normal remaining life that had been lived by the patient. For example, in India, a healthy woman of 40 woman has a normal life expectancy of 72 years and a normal remaining life (NRL) of 32 years (72-40). If at 40 she were diagnosed as having breast cancer and she lived for 10 years her survival is expressed as 31% of her normal remaining life (10/32x100). On the other hand, a patient who is diagnosed as having breast cancer at 60 would have a normal life expectancy of 75 years and normal remaining life (NRL) of 15 years (75-60). If she lives for 10 years after diagnosis her survival is expressed as 67% (10/15x100) of her normal remaining life. To plot the real life expectancy curves we used these percentage figures instead of actual number of years. The mathematical procedure and statistical considerations are exactly the same as that used for plotting conventional actuarial survival curves. The difference is that survival time, instead of being expressed as years from diagnosis, is expressed as percentage of the remaining life which the woman would have lived had she been healthy. Thus, to plot real life expectancy curves we convert the years from diagnosis to percentage of normal remaining life, and to use these curves to calculate survival for an individual patient we convert the percentage figure back into number of years, calculated according to each patient's normal life expectancy (see below). The percentage figures may be used to compare different groups of patients.

Summary points

Conventional survival curves for cancer use the time between diagnosis and last follow up or death to denote survival time

This ignores a person's normally expected life span at the age of diagnosis and estimates survival in terms of a fixed number of years

Our new method proposes that each patient's age at diagnosis is subtracted from the average life expectancy for that age to obtain the patient's normal remaining life (NRL)

At analysis the percentage of normal remaining life that has been lived by the patient is calculated and used in place of survival time to plot actuarial survival curves

An estimate of survival time, which will vary with age at diagnosis, can then be calculated for each individual patient

Survival expressed as a probability of living a fraction of normal life span gives a better idea than conventional methods of the impact of a disease such as cancer on an individual patient's life

Oncologists can now answer the unanswerable: "What is the chance of my `cure'?"

Comparison between conventional and real life expectancy method

According to the conventional survival curves given in figure 1), the 5 year survival of node negative, 1-4 node positive, >4 node positive patients is 88%, 66%, and 40% respectively. According to the real life expectancy curves given in figure 2), one fifth normal remaining life survival of these three groups of patients is 89%, 65%, and 38% respectively. Just as survival estimates for any number of years can be read off from the conventional curves survival estimates for any fraction of normal remaining life can be read off from real life expectancy curves. Instead of the conventional 5 year or 10 year survival we say survival for a fifth or half of normal remaining life (1/5 NRL or ½ NRL), or even for full normal remaining life (cure). As normal remaining life changes with age, an individual patient's survival estimate (in years from diagnosis) will also change with age.

On the basis of conventional life table curves shown in figure 1), a node negative woman has an 82% chance of living for 10 years. With the real life expectancy curves (fig 2) she has a 81% chance of living half of her normal remaining life. As the normal life expectancy of a 40 year old Indian woman is 72 years and that of a 60 year old woman 75 years, this would work out to a 81% chance of living for 16 years ((72-40)/2) for a woman of 40 and an 81% chance of living for 7.5 years ((75-60)/2) for a woman of 60. With these new curves, we could even say that a node negative woman has a 68% chance of living her full normal remaining life, which is 32 years (72-40) for a 40 year old woman and 15 years (75-60) for a 60 year old woman. A similar difference in the estimates by the conventional and real life expectancy curves is seen for the two other lymph node groups (table 1).

Table 1 Comparison of survival estimates by conventional and real life expectancy methods

Conventional method	**Real life expectancy method**
Node negative;	
88% Survive 5 years	89% Survive a fifth of normal remaining life (6.4 years at age 40, 3 years at age 60)
82% Survive 10 years	81% Survive half normal remaining life (16 years at 40, 7.5 years at 60)
	68% Survive full normal remaining life (cure) (32 years at 40, 15 years at 60)
1-4 Nodes positive	
66% Survive 5 years	65% Survive a fifth normal remaining life (6.4 years at 40, 3 years at 60)
48% Survive 10 years	38% Survive half normal remaining life (16 years at 40, 7.5 years at 60)
	28% Survive full normal remaining life (cure) (32 years at 40, 15 years at 60)
>4 Nodes positive	
40% Survive 5 years	38% Survive a fifth normal remaining life (6.4 years at 40, 3 years at 60)
22% Survive 10 years	20% Survive a half normal remaining life (16 years at 40, 7.5 years at 60)
	None survive full normal remaining life (cure)

Fundamental change in perspective

Living all of normal remaining life is equivalent to cure. It could be said that node negative women have a 68% chance of being cured of breast cancer. The importance of the facility to express survival in terms of cure, especially for a disease such as cancer, is profound. This might help to resolve the controversy about whether some chronic diseases such as breast cancer are ever cured.[2]

Once adulthood is attained life expectancy does not change greatly with age. For example, for an Indian population it is 71 years for those aged 15-30, 72 years for those aged 31-45, 75 for those aged 57-60, and 80 for those aged 71-72, and so on. What does change with age, however, is the remaining life expected to be lived (normal remaining life) and, consequently, the percentage of remaining life actually lived by the patient. For a 40 year old woman normal remaining life is 32 years (72-40), whereas for a 60 year old woman it is 15 years (75-60). Since the average life expectancy changes little once adulthood is attained and since we express survival in terms of fractions of normal remaining life rather than in absolute number of years, a substantial interclass (social) or intercountry variation should not occur in our estimates of survival. Of course, the study population should be reasonably similar to the population whose normal life expectancy is used for the calculations.

Survival of patients with various diseases may be compared with that of the normal population by other methods.[3] [4] [5] [6] [7] [8] Unlike our method, these methods usually require cumbersome calculations. Typically, they compare two survival curves, one for the general and the other for the diseased population, and they may include 95% confidence limits.[2] This does not lend itself to easy translation in terms of individual estimates of life span or cure rates, especially by someone with little statistical knowledge such as a clinician or patient. The advantage of our method is that the comparison between the normal population and patients with disease is integrated in a single curve that is similar to the conventional survival curves except for the label given in the *x* axis. Our method is not intended to replace the expression of survival as a yearly probability relative to the general population[6] as this has a different purpose of elucidating the temporal biology of the disease.

There are two additional steps in our method. Firstly, the calculations use actuarial life tables for normal life expectancy. This can be easily integrated as a simple arithmetic formula in the database. Secondly, to translate the fraction of normal remaining life to actual number of years for an individual patient requires the use of life expectancy tables. This is facilitated by using a table such as table 1.

Our new method is not a new statistical procedure but introduces a subtle change in the perspective of the standard method. When survival is expressed in the manner we describe, the impact of a potentially lethal disease on an individual patient's life, especially when the disease is prevalent across a broad range of ages, is more meaningfully defined. We believe that it is kinder to a patient with breast cancer, for example, to estimate her survival in terms of the whole life span rather than to limit it to five or 10 years. We believe that by individualising survival estimates according to age and expressing survival in terms of cure rates the new method that we have proposed makes survival estimates more meaningful, relevant, and human.

Acknowledgements

We thank Dr R G Presswala, chief medical officer, Life Insurance Corporation of India, for his help in acquiring the ultimate agewise yearly death rates for the Indian population. We thank Drs J J Vyas, K A Dinshaw, and R A Badwe for supplying parts of the patient database. We also thank Professor Michael Baum, Dr Ken D MacRae, and Dr Joan Houghton for their critical comments on the manuscript.

References

1. Walter G. *Actuarial survival curves programme sureal, version 2.0.* London: Guy's Hospital, 1992.

2. Brinkley D, Haybittle JL. The curability of breast cancer. *Lancet* 1975;ii:95-7.

3. Berkson J, Gage RP. Calculation of survival rates for cancer. *Proceedings of Staff Meeting of Mayo Clinic* 1950;25:270-86.

4. Ederer F, Axtell LM, Cutler SJ. The relative survival rate: a statistical methodology. *National Cancer Institute Monographs* 1961;6:101-21.

5. Hakulinen T. On long-term relative survival rates. *J Chron Dis* 1977;30:431-43.

6. Hakama M, Hakulinen T. Estimating the expectation of life in cancer survival studies with incomplete follow-up information. *J Chron Dis* 1977;30:585-97.

7. Hakulinen T. Cancer survival corrected for heterogeneity in patient withdrawal. *Biometrics* 1982;38:933-42.

8. Berrino F, Esteve J, Coleman MP. Basic issues in estimating and comparing the survival of cancer patients. *International Agency for Research on Cancer Scientific Publications* 1995;132:1-14.

(Accepted 17 February 1997)