PRINCIPLES OF MEDICAL STATISTICS

XI—LIFE TABLES AND SURVIVAL AFTER TREATMENT

In the assessment of the degree of success attending a particular treatment given to patients over a series of years the life table method is sometimes an effective procedure. Before illustrating its application to such data, consideration of the national life tables and the information they contain will be of value. A life table, it must be realised, is only a particular way of expressing the death-rates experienced by some particular population during a chosen period of time. For instance, the last English Life Table, No. 10, is based upon the mortality of the population of England and Wales in the three years 1930–32. It contains six columns as follows :—

English Life Table. No. 10. Males

Age x	l_x	d_x	p_x	q_x	$\mathring{e}_x$
0	100,000	7186	·92814	·07186	58·74
1	92,814	1420	·98470	·01530	62·25
2	91,394	600	·99343	·00657	62·21
3	90,794	400	·99559	·00441	61·62
4	90,394	..	..	..	..
..	..	..	..	..	..
..	..	..	..	..	..
..	..	..	..	..	..
..	..	..	..	..	..
102	3·9	2·1	·46960	·53040	1·32
103	1·8	1·0	·44553	·55447	1·25
104	0·8	0·5	·42115	·57885	1·18

The essence of the table is this: suppose we observed 100,000 infants all born on the same day and dying as they passed through each year of life at the same rate as was experienced at each of those ages by the population of England and Wales in 1930–32, in what gradation would that population disappear ? How many would be still left alive at age 25, at age 56, &c. ? How many would die between age 20 and age 30 ? What would be the chance of an individual surviving from age 40 to age 45 ? What would be the average length of life enjoyed by the 100,000 infants ? Such information can be obtained from these different columns. The basis of the table is the value known as q_x, which is the probability, or chance, of dying between age x and age $x+1$, where x can have any value between 0 and the longest observed duration of life. For instance q_{25} is the chance that a person who has reached his twenty-fifth birthday will die before reaching his twenty-sixth birthday. These probabilities, one for each year of age, are calculated from the mortality-rates experienced by the population in 1930–32 (for details of method see Woods and Russell, Medical Statistics). This probability of dying is the ratio of those who fail to survive a particular year of life to those who started that year of life (to take an analogy, if 20 horses start in the Grand National and 5 fail to survive the first round of the course the probability of "dying" on that round is 5/20 ; 15 horses are left to start on the second round and if 3 fail to survive, the probability of "dying" on the second round is 3/15).

The National Life Table

In Life Table No. 10 the probability of dying in the first year of life is 0·07186, or in other words, according to the infant mortality-rate of 1930–32, 7·186 per cent. of our 100,000 infants will die before they reach their first birthday. The actual number of deaths between age 0 and age 1 will therefore be 7·186 per cent. of 100,000, or 7186. Those who *survive* to age 1 must be 100,000 less 7186=92,814. According to this table, the probability of dying between age 1 and age 2 is 0·01530, or in other words 1·530 per cent. of these 92,814 children aged 1 year old will die before reaching their second birthday. The actual number of deaths between age 1 and age 2 will therefore be 1·530 per cent. of 92,814=1420 ; those who survive to age 2 must therefore be 92,814 less 1420=91,394. From these q_x values the l_x and d_x columns can thus be easily constructed, l_x showing the number of individuals out of the original 100,000 who are still alive at each age, and d_x giving the number of deaths that take place between each two adjacent ages. p_x is the probability of living from one age to the next. p_x+q_x must equal 1, since the individuals must either live or die in that year of life (to return to our analogy if 5 out of 20 horses do not complete the round, clearly 15 out of 20 do survive the round). p_x, therefore, equals $1-q_x$; for example, of the 91,394 children aged 2, 0·657 per cent. die before reaching age 3, and it follows that 99·343 per cent. must live to be 3 years old. Finally, we have the column headed $\mathring{e}_x$ which is the "expectation of life" at each age. This value is not really an "expectation" at all but is the *average* duration of life lived beyond each age. For example, if we added up all the ages at death of the 100,000 infants and took the average of these durations of life we should reach the figure 58·74 years. If, alternatively, we took the 92,814 infants who had lived to be 1 year old, calculated the *further* duration of life that they enjoyed, and then found the average of those durations, we should reach the figure 62·25 years. At age 102 there are only 3·9 "persons" still surviving, and the average duration of life that they will enjoy after that age is only 1·32 years. The so-called expectation of life is thus only the average length of life experienced after each age. We thus have the complete life table.

To reiterate, it shows how a population would die out if it experienced as it passed through life the same death-rates as were prevailing in England and Wales in 1930–32. It does not follow, therefore, that of 100,000 children born this year in reality only 90,794 will be alive at age 3 ; if the death-rate is in fact declining below its 1930–32 level, then more than that number will survive, if it is rising less than that number will survive. The life table can show only what would happen under *current conditions of mortality*, but it puts those current conditions in a useful form for various comparative purposes and for estimating such things as life insurance risks (inherent in the questions that were propounded above).

The Measurement of Survival-rates after Treatment

We turn now to the application of the method to groups of patients treated over a period of calendar years whose subsequent after-history is known. Let us suppose that treatment was started in 1931, that patients have been treated in each subsequent calendar year and have been followed up to the end of 1936 on each yearly anniversary after their treatment was started (none being lost sight of). Of those treated in 1931 we shall know how many died during the first year after treatment, how many died during the second year after treatment, and so on to the fifth year after treatment. Of those treated in 1932 we shall know the subsequent history up to only the fourth year of treatment, in 1933 up to only the third year of treatment, and so on. Our tabulated results will be, let us suppose, as in Table XI.

TABLE XI

Results of Treatment. (Hypothetical Figures)

Year of treat-ment.	No. of patients treated.	Number alive on anniversary of treatment in—				
		1932.	1933.	1934.	1935.	1936.
1931 ..	62	58	51	46	45	42
1932 ..	39	..	36	33	31	28
1933 ..	47	..	..	45	41	38
1934 ..	58	..	..	..	53	48
1935 ..	42	..	..	..	..	40

Calculation of the survival-rates of patients treated in each calendar year becomes somewhat laborious if the number of years is extensive and has also to be based upon rather small numbers. If the fatality-rate is not changing with the passage of time there is no reason why the data should not be amalgamated in life table form. For clarity we can write Table XI in the form given in Table XII.

TABLE XII

Results of Treatment. (Hypothetical Figures)

Year of treat-ment.	No. of patients treated.	Number alive on each anniversary (none lost sight of).				
		1st.	2nd.	3rd.	4th.	5th.
1931 ..	62	58	51	46	45	42
1932 ..	39	36	33	31	28	..
1933 ..	47	45	41	38	..	..
1934 ..	58	53	48	..	..	..
1935 ..	42	40	..	..	..	..

All the patients have been observed for at least one year and their number is 42+58+47+39+62=248. Of these there were alive at the end of that first year of observation 58+36+45+53+40=232. The probability of surviving the first year after treatment is, therefore, 232/248=0·94, or in other words 94 per cent. of these patients survived the first year after treatment. Of the 40 patients who were treated in 1935 and were still surviving a year later, no further history is yet known. (If the year's history is known for some of them these must not be added in, for the history would tend to be complete more often for the dead than for the living, and thus give a bias to the results.) As the exposed to risk of dying during the second year we therefore have the 232 survivors at the end of the first year minus these 40 of whom we know no more—viz., 192. Of these there were alive at the end of the second year of observation 51+33+41+48=173. The probability of surviving throughout the second year is, therefore, 173/192=0·90. Of the 48 patients who were treated in 1934 and were still surviving in 1936, no later history is yet known. As the exposed to risk of dying in the third year we, therefore, have the 173 survivors at the end of the second year minus these 48 of whom we know no more—viz., 125. Of these there were alive at the end of the third year of observation 46+31+38=115. The probability of surviving the third year is, therefore, 115/125=0·92. We know no further history of the 38 patients first treated in 1933 and still surviving on the third anniversary. The number exposed to risk in the fourth year becomes 46+31=77, and of these 45+28=73 are alive at the end of it. The probability of surviving the fourth year is, therefore, 73/77=0·95. Finally during the fifth year we know the history only of those patients who were treated in 1931 and still survived at the end of the fourth year—namely, 45 persons. Of these 42 were alive on the fifth anniversary, so that the probability of surviving the fifth year is 42/45, or 0·93.

CONSTRUCTION OF THE SURVIVORSHIP TABLE

Tabulating these probabilities of surviving each successive year we have the values denoted by p_x in column (2) of Table XIII. The probability of not surviving in each year after treatment, q_x, is immediately obtained by subtracting p_x from 1. The number of patients with which we start the l_x column is immaterial, but 100 or 1000, or some such number is convenient. Starting with 1000 our observed fatality-rate shows that 94 per cent. would survive the first year and 6 per cent. would die during that year. The number alive, l_x, at the end of the first year must, therefore, be 940 and the number of deaths, d_x, during that year must be 60. For these 940 alive on the first anniversary the probability of living another year is 0·90, or in other words there will be 90 per cent. alive at the end of the second year—i.e., 846—while 10 per cent. will die during the second year—i.e., 94. Subsequent entries are derived in the same way. (The order of the columns in the table is immaterial. The order given in Table XIII is the most logical while the table is being constructed because p_x is the value first calculated and the others are built up from it. In the final form the order given in the English Life Table No. 10, of which an extract was previously given, is more usual.)

TABLE XIII

Results of Treatment in Life Table Form

Year after treat-ment.	Probability of surviving each year.	Probability of dying in each year.	Number alive on each anniversary out of 1000 patients.	Number dying during each year.
x (1)	p_x (2)	q_x (3)	l_x (4)	d_x (5)
0	·94	·06	1000	60
1	·90	·10	940	94
2	·92	·08	846	68
3	·95	·05	778	39
4	·93	·07	739	52
5	..	..	687	..

By this means we have combined all the material we possess for calculating the fatality in each year of observation after treatment, and have found that according to those fatality-rates approximately 69 per cent. of treated patients would be alive at the end of 5 years. If we want the average duration of life so far lived by the patients, it is easily obtained.

687 patients of our imaginary 1000 live the whole 5 years. If we presume that those who died actually lived half a year in the year in which they died (some will have lived less, some more, and we can take, usually without serious error, the average as a half), then 60 lived only half a year after treatment, 94 lived a year and a half, 68 lived two years and a half, 39 lived three years and a half, and 52 lived four years and a half. The average length of after-life is, therefore (so far as the experience extends) $(687 \times 5 + 60 \times 0{\cdot}5 + 94 \times 1{\cdot}5 + 68 \times 2{\cdot}5 + 39 \times 3{\cdot}5 + 52 \times 4{\cdot}5) \div 1000 = 4{\cdot}15$ years.

The percentage alive at different points of time makes a useful form of comparison. For instance of patients with cancer of the cervix treated between 1925 and 1934 we find by summarising some published figures in life table form, roughly the following number of survivors out of 100 in each stage of disease :—

	Stage			
	1	2	3	4
At end of 5 years	86	70	33	11
„ 9 „	78	57	27	0

EXCLUSION OF PATIENTS

If some of the patients have been lost sight of, or have died from causes which we do not wish to include in the calculation (accidents for example), these must be taken out of the exposed to risk at the appropriate time—e.g., an individual lost sight of in the fourth year is included in the exposed to risk for the first three years but must be removed for the fourth year. If he is taken out of the observations from the very beginning the fatality in the first three years is rather overstated, for we have ignored an individual who was exposed to risk in those years and did not, in fact, die. If patients are being lost sight of at different times during the year or dying of excluded causes during the year, it is usual to count each of them as a half in the exposed to risk for that year. In other words they were, on the average, exposed to risk of dying of the treated disease for half a year in that particular year of observation. Clearly if a relatively large number of patients is lost sight of we may be making a serious error in calculating the fatality-rates from the remainder, since those lost sight of may be more, or less, likely to be dead than those who continue under observation. Complete follow-up histories are the desiderata. An excellent example of the application of life table methods to the survival-rates of patients will be found in an analysis of 8766 cases treated at the Brompton Hospital Sanatorium, Frimley, made by Sir Percival Horton Smith-Hartley, R. C. Wingfield, and V. A. Burrows (1935, *Brompton Hosp. Rep.* vol. **4**).

Summary

Life tables are convenient methods of comparing the mortality-rates experienced at different times and places. The same methods may be usefully applied to the statistics of patients treated in a particular way and followed up over subsequent years. A. B. H.

SPECIAL ARTICLES

SOME PRACTICAL ASPECTS OF MEDICINE IN U.S.S.R.

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MUCH has been written, in books and in medical journals, on the State medical service of Soviet Russia. These have made it possible to understand not only the organisation as it exists now, but also the immense difficulties that faced the Government fifteen years ago when there was nothing but an inadequate and primitive medical service disorganised by war and revolution. Our object here is to supplement existing publications by recording observations, mainly on maternity and child welfare, made whilst visiting clinics, institutions, and hospitals in Moscow and Leningrad.

The primary concern of the medical service in the U.S.S.R. is not with hospitals or with diseases and their cures but with the maintenance and improvement of the health of the community. The care of the sick and their disposal to hospital becomes a subsidiary function. In the public mind the emphasis has thus been shifted away from the idea of disease toward that of health, which in itself helps to promote a healthy society.

The medical service of the towns aims at dividing the population into groups of from 40,000 to 100,000 persons, each group in a district being centred around a polyclinic, or prophylactorium. These clinics are responsible for all matters concerning health and disease in their districts, and their functions include maternity and child welfare, health visiting, public health services, and sanitary inspection of houses, shops, and public baths, as well as the care of the sick either in the clinic, or in their homes, or by arranging for their transference to hospitals. Thus under one institution and under the control of one district director and his staff are centralised functions that in London may be divided between the general practitioner, the panel doctor, the consultant, the local medical officer of health, the voluntary hospital, and the medical services of the London County Council.

We visited two such institutions in Moscow. The first is one of eleven large new clinics opened in 1930, each of which is responsible for approximately 100,000 of the population. It is a building that would put to shame most out-patient departments in this country. The staff consists of the director and his assistant whose duties are mainly administrative, general physicians responsible for subsections of the district, specialists in all branches of medicine, and pathologists, together with a full staff of sisters, nurses, health visitors, and sanitary inspectors.

The district served by a clinic is divided into subdistricts of so many streets and housing approximately 2000 people, and each is under the charge of a district medical officer whose duty it is to attend to ambulatory cases at the clinic in the morning and to visit those confined to bed in their homes in the afternoon. A doctor is also available for visiting those needing attention between 9 P.M. and 9 A.M. The district officer has the services of the pathology department at his disposal and refers cases needing special advice or treatment to the appropriate consultant, who either sees the patient at the clinic or visits him in his home.