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Magnitude and Time Trends of the Life-time Risk of Developing Cancer in Saarland, Germany

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The probability of developing cancer within defined age-intervals or during life-time was assessed for the population of Saarland, Germany in 1970–1972 and 1980–1985 based on life-tables and age-specific cancer incidence rates. As a result of increasing life expectancy and, for some forms of cancer, increasing age-specific incidence rates, the probability at birth of eventually developing a malignant neoplasm (ICD-9 140–208) increased from 24.12% in 1970–1972 to 32.35% in 1980–1985 in men, and from 24.76 to 29.72%, respectively, in women. Comparable calculations are presented and discussed for all of the most common malignancies in women and men. The relation to common measures of descriptive epidemiology, mainly the cumulative rate and the cumulative risk, is numerically illustrated.
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INTRODUCTION

WITH INCREASING life expectancy in the first world, the importance of cardiovascular disease and cancer is steadily increasing. Major progress in cancer prevention and therapy is so far restricted to a few cancer sites, such as the uterine cervix [1], while for many other sites age-specific or age-standardised mortality rates continue to rise [2, 3]. While the common measures of descriptive epidemiology (crude, age-specific, age-standardised and cumulative incidence rates) are well suited to characterise the cancer problem for society as a whole, they do not satisfactorily describe the threat cancer poses to individuals [4]. The cumulative rate is calculated by summation of age-specific incidence rates within a specified age-span and may be interpreted as an approximation of the probability of an individual developing cancer within this age-span. But this approximation only holds if the risk is small (in which case the "cumulative rate" approximates to the "cumulative risk") and no other causes of death are in operation [5].

Life-table methods have been developed to assess the individual risk of cancer independently of these two assumptions [4, 6–9]. We have applied life-tables methods to cancer incidence and mortality data from Saarland, Germany, to illustrate the magnitude as well as recent trends and determinants of the life-time risk of cancer in a European society with a high standard of living.

METHODS

Saarland is a small state located in south-west Germany. The total population is about 1.05 million. Population-based cancer registration was started in 1966 and achieved high levels of completeness from the early 1970s [10, 11]. Within Western Germany, Saarland is the only state for which reliable cancer incidence rates are recorded [10]. Our calculations were based on (unpublished) period life-tables of Saarland 1970–1972 and 1980–1985 which were provided by the Federal Statistical Office of Germany, and age-specific and sex-specific cancer incidence rates from the cancer registry of Saarland for the same periods. Non-melanoma skin cancer (International Classification of Diseases 9th revision [ICD-9] 173) was excluded because it is under-registered. We used a complex statistical methodology [6, 7]. Briefly, the estimated numbers of cancer cases for the "life-table population" above certain ages (or within certain age-intervals) are divided by the estimated numbers of persons alive and free of cancer at the beginning of these age-intervals.

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RESULTS

For men, life expectancy at birth increased from 66.1 years in 1970–1972 to 69.2 years in 1980–1985 (Table 1). Life expectancy of women was about 7 years higher in both periods (72.8 and 76.2 years). Given the mortality rates of 1970–1972, 34.6% of newborn males and 56.8% of newborn females would survive until age 75. These proportions rose to 41.7% (males) and 65.4% (females) according to the 1980–1985 mortality pattern.

For men, the probability of developing a malignant neoplasm (ICD-9 140–208) other than non-melanoma skin cancer during life rose from 24.12% in 1970–1972 to 32.35% in 1980–1985 (Table 2). The life-time risk rose substantially for all of the most common forms of cancer, with the exception of stomach and larynx cancer whose age-specific incidence rates declined from 1970–1972 to 1980–1985. In both periods, life-time risk was highest for lung cancer (6.67% and 8.14%).

The probability of eventually developing cancer after age 50 (for those persons alive and previously free of cancer at age 50) was slightly higher than the corresponding values at birth for most common forms of cancer in men. This is explained by the fact that the population at risk is decreased (mainly due to deaths from other causes) to some extent, while the vast majority of malignancies occur at ages above 50. There are, however, a few extreme exceptions, such as the rare childhood cancers (not shown here) or tumours of the testes, which occur most commonly in young men. The probability of developing tumours of the testes after age 50 is extremely low.

The risk of eventually developing a malignant neoplasm among men alive and free of cancer at age 65 (the normal age of retirement in Germany) is generally considerably lower than the

Table 1. Excerpts from period life-tables of Saarland 1970–1972 and 1980–1985

	Men				Women			
	1970–1972		1980–1985		1970–1972		1980–1985	
Age (x)	L_x	$\mathring{e}_x$	L_x	$\mathring{e}_x$	L_x	$\mathring{e}_x$	L_x	$\mathring{e}_x$
0	100 000	66.1	100 000	69.2	100 000	72.8	100 000	76.2
25	94 331	44.6	96 943	46.1	96 564	50.3	98 078	52.6
50	86 756	22.1	90 017	23.4	92 338	26.8	94 544	28.9
75	34 612	6.9	41 719	7.1	56 785	8.2	65 353	9.4

L_x = survivors at age x (per 100 000 births).
$\mathring{e}_x$ = mean life expectancy at age x (years).

corresponding risk at birth or at age 50. The only exception is cancer of the prostate which is mainly a disease of the elderly.

For women, the rise in the probability of developing any form of cancer during life was lower than that in men [from 24.76% in 1970–1972 to 29.72% in 1980–1985 (Table 2)]. There was a substantial increase in life-time risk of breast cancer (from 5.64 to 7.15%) and colon cancer (from 1.99 to 3.02%), which were the most commonly observed malignancies in women in 1980–1985. However, the life-time risk of stomach cancer moderately decreased (from 2.62 to 2.20%), and the life-time risk of cervical cancer was impressively reduced (from 2.97 to 1.33%). The risk of eventually developing cancer after age 50 was similar to the corresponding risk at birth for most of the common malignancies in females. There are, however, some important exceptions, such as breast cancer, cervical cancer, ovarian cancer and malignant melanoma, a substantial proportion of which occurs

Table 2. Probability (%) of eventually developing cancer for cancer-free persons at various ages

		At birth		At age 50		At age 65	
Site	ICD-9	1970–1972	1980–1985	1970–1972	1980–1985	1970–1972	1980–1985
Men							
Stomach	151	2.94	2.59	3.21	2.65	2.84	2.40
Colon	153	1.60	2.49	1.71	2.59	1.67	2.37
Rectum	154	1.69	2.19	1.79	2.26	1.54	2.10
Pancreas	157	0.54	0.90	0.57	0.95	0.38	0.78
Larynx	161	0.78	0.72	0.80	0.68	0.55	0.41
Lung	162	6.67	8.14	7.19	8.52	5.61	6.90
Skin							
Melanoma	172	0.21	0.40	0.16	0.30	0.10	0.20
Prostate	185	2.42	3.57	2.76	3.95	2.91	4.21
Testis	186	0.24	0.39	0.05	0.03	0.05	0.00
Urinary bladder	188	0.98	2.58	1.10	2.72	0.98	2.37
Kidney	189	0.55	1.13	0.48	1.08	0.24	0.73
Total	140–208 (except 173)	24.12	32.35	25.13	32.72	21.87	29.14
Women							
Stomach	151	2.62	2.20	2.70	2.21	2.51	2.07
Colon	153	1.99	3.02	1.98	3.01	1.71	2.63
Rectum	154	1.40	1.92	1.41	1.91	1.14	1.60
Gall bladder	156	0.99	1.04	1.03	1.09	0.88	0.98
Lung	162	0.76	1.02	0.76	0.98	0.57	0.69
Skin							
Melanoma	172	0.26	0.53	0.16	0.36	0.11	0.22
Breast	174	5.64	7.15	4.68	5.97	2.85	3.91
Cervix uteri	180	2.97	1.33	2.11	0.95	0.79	0.57
Corpus uteri	182	1.61	2.03	1.59	2.05	0.95	1.39
Ovary	183	1.08	1.25	0.88	1.09	0.42	0.74
Urinary bladder	188	0.26	0.78	0.27	0.80	0.24	0.70
Kidney	189	0.43	0.72	0.40	0.67	0.25	0.47
Total	140–208 (except 173)	24.76	29.72	22.95	27.87	17.08	22.55

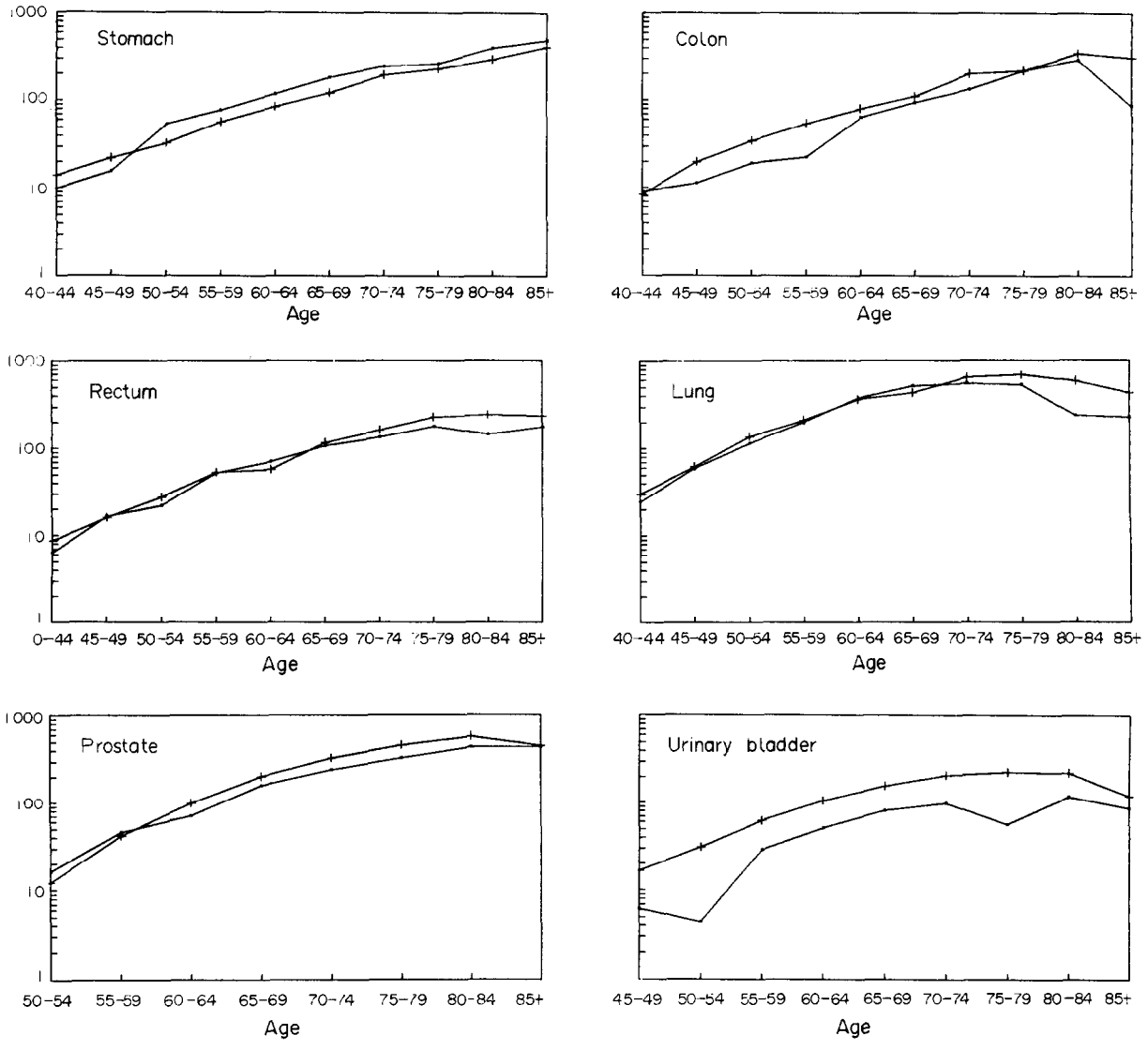

Fig. 1. Men—age-specific cancer incidence per 100 000 person-years in Saarland. ·—· = 1970–1972 and +—+ = 1980–1985.

before age 50. The risk of developing these tumours after age 50 is therefore considerably lower than the corresponding risk at birth. Women alive and previously free of cancer at age 65 generally have a clearly reduced probability of eventually developing cancer.

DISCUSSION

The concept of the life-time risk should be used as a supplement, not a substitute, for the common epidemiological measures of cancer occurrence: crude, age-specific and age-standardized incidence are the measures of choice in cancer surveillance on the population level. The risk of developing cancer within a specified age-range (or during life) is, on the other hand, more suited to characterizing the threat cancer poses to individuals at various ages. The cumulative rate, which is calculated as the sum of age-specific incidence rates within a defined age-span, can be interpreted on both levels: it represents a special case of direct age-adjustment (where all considered age-groups are equally weighted) and it approximates to the cumulative risk of developing cancer during the age-span, provided that the risk is small [5]. A further implicit assumption in this interpretation is that there are no competing causes of death.

Table 3 shows, for various age-intervals, a comparison of the cumulative rate, the cumulative risk and the probability of developing any form of cancer calculated by the life-table method we used, which takes competing causes of death into account. Until about age 50, the three measures differ only slightly, as both cancer risk and risk of dying from other causes are small. For higher age-groups, the discrepancy between cumulative rate and risk as well as the discrepancy between cumulative risk and the probability of developing any form of cancer increases rapidly, the latter discrepancy increasing especially in men (who have substantially higher age-specific rates of competing causes of death) than in women.

As a result of increasing age-specific cancer incidence rates, cumulative rate and risk increased substantially in men and to some degree also in women from 1970–1972 to 1980–1985. Due to a simultaneous decrease in competing causes of death, the rise in the probability of developing any form of cancer was even more pronounced, as seen from the higher probability/risk ratios in 1980–1985.

The probabilities we present are the best available estimates of the chances of developing cancer for persons born in 1980–1985 based on current mortality and cancer incidence rates. Similar to the commonly used measure of life expectancy, they may

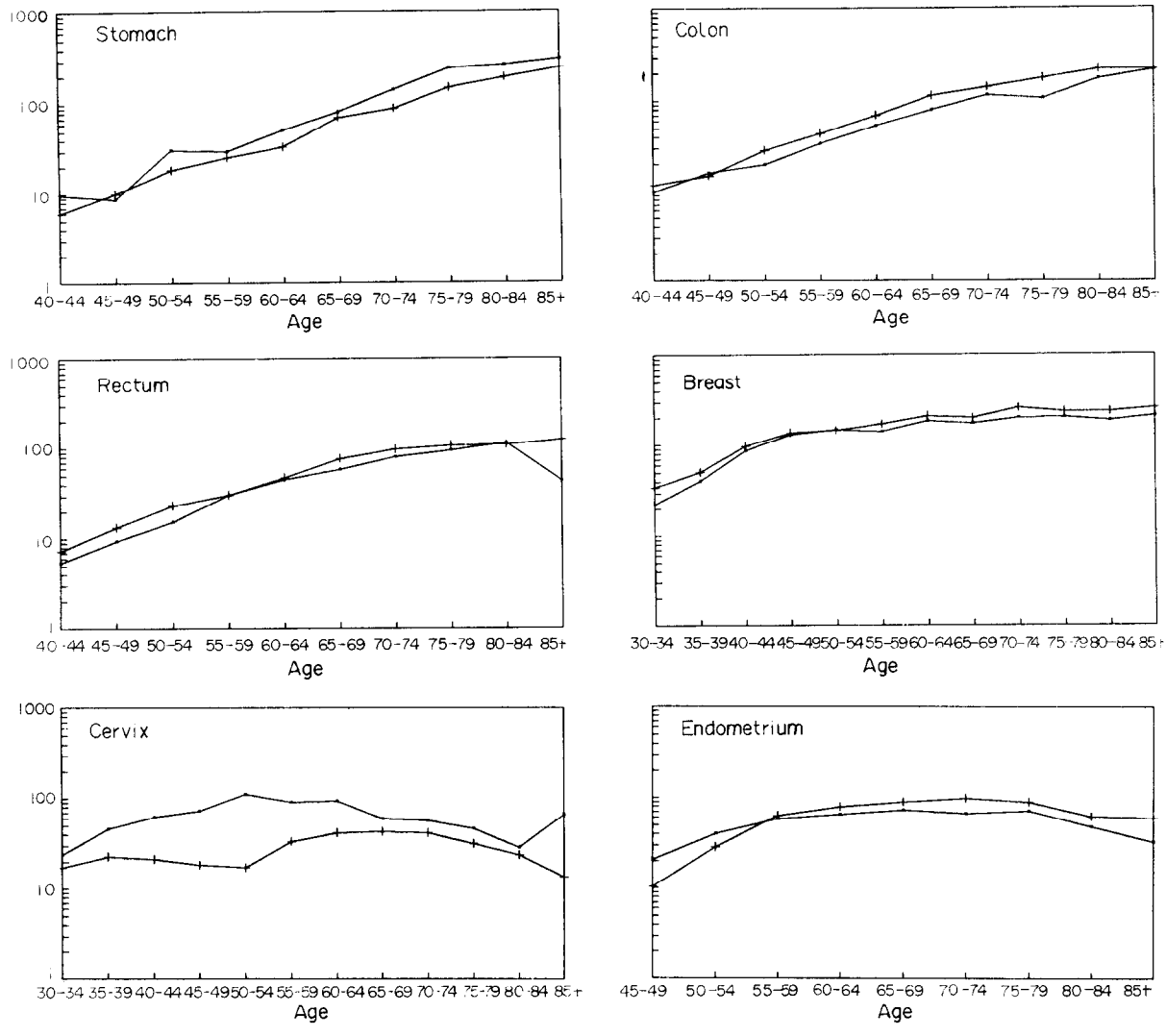

Fig. 2. Women—age-specific cancer incidence per 100 000 person-years in Saarland. ·—· = 1970–1972 and +—+ = 1980–1985.

obviously be altered by future changes in mortality or incidence rates.

In the interpretation of magnitude and time trends of the life-time risks the following factors have to be taken into account: (1) Incidence rates of malignant and semi-malignant non-melanoma skin tumours are likely to be severely under-estimated, mainly in 1970–1972, and therefore have not been considered. (2) Calculated life-time risks apply to clinically manifest and diagnosed tumours only. For example, detection rates of prostate cancer are heavily dependent on the extent of screening, which may be a major determinant of observed trends. (3) Classification criteria change over time, which may, for example, explain part of the rise in incidence of cancer of the urinary bladder (which was more often classified as "papilloma" in the past).

For other forms of malignancies, the observed changes in incidence from 1970–1972 to 1980–1985 are unlikely to be due to changes in coverage or registration rates. If so, we would have expected consistent proportionate changes in various site-specific incidence rates over a wide range of ages, which were not observed in the most common forms of cancer (Figs 1 and 2). Also, the "death certificate only" index, which indicates the proportion of total registered cases for whom the death certificate was the only notification to the registry and which is a commonly used indirect indicator for completeness of registration, was similar and low (under 10%) for both periods. The high rate of completeness of registration in both periods was achieved by excellent cooperation of all pathological institutes in Saarland, which at the same time ensured a high rate of histologically verified cancers.

Although the detection rates registered are therefore generally to be regarded as complete, they can nevertheless only be interpreted as the lower limit of the actual incidence rates of clinically manifest cancer.

Mortality statistics suggest that cancer incidence in Saarland is not necessarily representative of other parts of West Germany [12] or other countries in Central Europe. The proportion of malignant neoplasms among causes of death was slightly lower in Saarland than in West Germany for both men and women, but the increase of this proportion from 1970–1972 to 1980–1985 was in the same order of magnitude (Table 4). Life expectancy was about 1.0 to 1.5 years lower than the average values for West Germany in both periods, but again the increase from 1970–1972 to 1980–1985 was similar (3.1 vs. 3.5 years). Therefore, an even higher life-time risk of cancer can be assumed for West Germany, with time trends similar to those observed in Saarland.

We therefore conclude that more than 30% of men and women born in West Germany in 1980–1985 are expected to develop

Table 3. Comparison of the cumulative rate (CRA), the cumulative risk (CRI) and the probability (P) of developing any form of malignant neoplasm other than non-melanoma skin cancer from birth to various age limits (numbers are given as percentages)—Saarland 1970–1972 and 1980–1985

	1970–72				1980–85			
Age	CRA	CRI	*P*	*P*/CRI	CRA	CRI	*P*	*P*/CRI
Men								
0–40	1.16	1.15	1.09	0.94	1.38	1.37	1.33	0.97
0–50	2.88	2.84	2.62	0.92	3.76	3.69	3.52	0.95
0–60	8.19	7.87	6.94	0.88	9.99	9.50	8.82	0.93
0–70	21.14	19.06	15.14	0.79	23.76	21.15	18.35	0.87
0–75	30.52	26.31	19.16	0.73	35.15	29.64	24.06	0.81
0–80	40.71	33.44	21.92	0.66	48.72	38.57	28.56	0.74
0–90+	—	—	24.12	—	—	—	32.35	—
Women								
0–40	1.51	1.50	1.45	0.97	1.68	1.67	1.64	0.98
0–50	4.45	4.35	4.20	0.97	4.26	4.17	4.11	0.99
0–60	9.81	9.34	9.00	0.96	9.25	8.83	8.70	0.99
0–70	17.72	16.24	15.27	0.94	17.93	16.41	15.97	0.97
0–75	23.12	20.64	18.74	0.91	24.06	21.38	20.37	0.95
0–80	29.45	25.51	21.77	0.85	30.83	26.53	24.25	0.91
0–90+	—	—	24.76	—	—	—	29.72	—

Table 4. Life expectancy at birth and proportion of cancers (ICD-9 140–208) among causes of death in Saarland and West Germany

	Saarland		West Germany	
	1970–1972	1980–1985	1970–1972	1980–1985
Life expectancy (yr)				
Men	66.1	69.2	67.4	70.6
Women	72.8	76.2	73.8	77.3
Proportion of cancer deaths				
Men	18.2%	23.0%	19.5%	23.3%
Women	17.8%	20.6%	19.8%	21.7%

clinically manifest cancer (other than non-melanoma skin cancer) during life if mortality and cancer incidence rates remain on the level observed in 1980–1985. If death rates from competing causes continue to decline at the pace currently observed in many European societies, the life-time risk of cancer will further increase rapidly, even if age-specific cancer rates remain constant.

More than ever before, a shift of health policy efforts, medical care and research funds towards cancer prevention is therefore required. This particularly applies to Germany, where the public health and preventive medicine have been severely neglected in the past, and epidemiological research is continuing to be embarrassed by overly restrictive data protection laws.

1. Hakama M, Miller AB, Day NE, eds. Screening for cancer of the uterine cervix. IARC Scientific Publications No. 76, Lyon, International Agency for Research on Cancer, 1986.
2. Bailar JC, Smith EM. Progress against cancer? *N Engl J Med* 1986, **314**, 1226–1232.
3. Becker N, Smith EM, Wahrendorf J. Time trends in cancer mortality in the Federal Republic of Germany: Progress against cancer? *Int J Cancer* 1989, **43**, 245–249.
4. Cutler SJ, Haenszel WM. The magnitude of the cancer problem. *Pub Health Rep* 1954, **69**, 333–339.
5. Day NE. A new measure of age standardized incidence, the cumulative rate. In: Waterhouse J, Muir CS, Correa P, Powell J, eds. *Cancer Incidence in Five Continents*. IARC Scientific Publications No. 15, Lyon, International Agency for Research on Cancer, Vol. III, 443–452.
6. Goldberg ID, Levin ML, Gerhardt PR, Handy VH, Cashman RE. The probability of developing cancer. *J Natl Cancer Inst* 1956, **17**, 155–173.
7. Zdeb MS. The probability of developing cancer. *Am J Epidemiol* 1977, **106**, 6–16.
8. Seidman H, Silverberg E, Bodden A. Probabilities of eventually developing and dying of cancer (risk among persons previously undiagnosed with the cancer). *CA* 1978, **28**, 33–46.
9. Seidman H, Mushinsky MH, Gelb SK, Silverberg E. Probabilities of eventually developing or dying of cancer—United States, 1985. *CA* 1985, **35**, 36–56.
10. Schön D, Bertz J, Hoffmeister H, eds. Bevölkerungsbezogene Krebsregister in der Bundesrepublik Deutschland. München, MMV Medizin Verlag, 1989, Vol. 2.
11. Muir CS, Waterhouse J, Mack T, Powell J, Whelan S, eds. *Cancer Incidence in Five Continents*. IARC Scientific Publications No. 88, Lyon, International Agency for Research on Cancer, 1987, Vol. V.
12. Becker N, Frentzel-Beyme R, Wagner G. Atlas of cancer mortality in the Federal Republic of Germany. Berlin, Springer, 1984.