THE EXPECTED FREQUENCY OF BLADDER TUMOUR IN WORKS POPULATIONS

BY

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It has long been recognized that certain occupations, such as the manufacture or use of some dyestuff intermediates, have caused an increase in the frequency of either papilloma or carcinoma of the bladder. It is unnecessary here to make detailed references to papers on this topic, since an extensive review was written by Goldblatt in 1947.

There is little or no certainty, however, as to how far such an occupational risk affects other industries or occupations, and before an occupational risk of this sort can be recognized it is necessary to show that more cases are occurring amongst men employed in a particular environment than occur amongst men not so employed. This comparison makes it necessary to have an estimate of the expected frequency of the disorder that would occur among the same men if no environmental risk were affecting them.

Unfortunately, sickness records for England and Wales are not sufficiently complete to enable an estimate to be made of the frequency with which papilloma or carcinoma of the bladder occurs in living patients, but it is possible to form a reasonably precise estimate of the number of death certificates which mention papilloma or carcinoma of the bladder for males in England and Wales. Such an estimate will give the frequency of death certificates mentioning tumour of the bladder at the average rate for males in England and Wales, a figure not quite the same as the death rate for the disorder, since some of the deaths are assigned to other causes, although the certificate also mentions bladder tumour. For the present purpose the estimate of certificates mentioning tumour of the bladder is more appropriate than the death rate.

It is also possible to obtain a copy of the death certificate of a deceased person, so that if death records are kept by a firm the number of death certificates mentioning tumour of the bladder that

actually occur can be found, and a comparison of the number expected and the number found can be made. Collecting the information about the actual number of death certificates with mention of tumour of the bladder may present some difficulty. For the future, this could partly be solved by the employing firm keeping death records, but this would not give a complete record, since it would not be practicable to complete such records for all men who had left the particular employment.

By arrangement with the Registrar General an alphabetical register of all deaths in England and Wales of males whose death certificates contained mention of bladder tumour is at present being maintained at the Chester Beatty Research Institute. This covers the years 1936–50, but will be extended from year to year as information becomes available. With adequate safeguards against misuse of the information contained in the register, it would be possible to arrange for lists of men on the nominal roll to be checked against this register with a view to full death certificates being obtained from the General Register Office where necessary. To save labour such lists should be the nominal roll used to form the estimate with the names of men known to be alive removed from it. This procedure would also ensure that any desired degree of industrial reticence could be preserved. Should a demand become apparent, the register could also be extended to cover the period 1921–35.

It thus becomes possible for medical officers or other responsible persons having access to works records to investigate whether or not there is any reason to believe that a particular industry, occupation, or process gives rise to tumours of the urinary bladder. It is of course necessary that the works records should be sufficiently complete to enable this to be done.

The purpose of this paper is to describe how the

TABLE A FACTORS

Period of Observation (X)	Age at Entry (Z)																	
	15-0	17-5	20-0	22-5	25-0	27-5	30-0	32-5	35-0	37-5	40-0	42-5	45-0	47-5	50-0	52-5	55-0	57-5
2-5	0-00	0-00	0-00	0-01	0-02	0-04	0-08	0-15	0-29	0-52	0-92	1-56	2-54	4-01	6-06	8-94	12-67	17-38
5-0	0-00	0-00	0-01	0-02	0-04	0-09	0-17	0-32	0-58	1-02	1-72	2-87	4-42	6-69	9-78	13-81	18-84	24-86
7-5	0-01	0-01	0-02	0-05	0-09	0-19	0-35	0-63	1-11	1-88	3-01	4-81	7-27	10-59	14-89	20-23	26-57	33-78
10-0	0-01	0-02	0-05	0-10	0-20	0-37	0-68	1-20	2-03	3-30	5-17	7-81	11-35	15-91	21-53	28-19	35-64	43-72
12-5	0-02	0-05	0-11	0-20	0-39	0-72	1-27	2-16	3-51	5-51	8-30	12-05	16-85	22-74	29-63	37-35	45-58	54-08
15-0	0-05	0-11	0-21	0-41	0-75	1-33	2-26	3-69	5-80	8-74	12-67	17-70	23-82	30-95	38-89	47-32	55-88	64-16
17-5	0-11	0-21	0-42	0-77	1-38	2-35	3-85	6-04	9-11	13-21	18-43	24-77	32-13	40-26	48-84	57-45	65-76	73-35
20-0	0-22	0-42	0-78	1-40	2-41	3-95	6-23	9-41	13-65	19-05	25-58	33-14	41-45	50-15	58-85	67-14	74-65	81-16
22-5	0-42	0-79	1-42	2-44	4-02	6-35	9-62	13-99	19-54	26-25	33-97	42-44	51-25	60-04	69-32	75-78	82-17	87-38
25-0	0-78	1-41	2-44	4-05	6-42	9-76	14-23	19-90	26-75	34-63	43-24	52-19	61-02	69-31	76-72	83-02	88-10	92-00
27-5	1-38	2-41	4-03	6-43	9-81	14-34	20-13	27-10	35-11	43-85	52-90	61-80	70-12	77-50	83-72	88-69	92-47	95-21
30-0	2-36	4-09	6-37	9-76	14-35	20-21	27-29	35-41	44-27	53-42	62-39	70-74	78-10	84-27	89-17	92-86	95-50	97-29
32-5	3-89	6-26	9-65	14-27	20-15	27-30	35-53	44-49	53-73	61-79	71-18	78-56	84-70	89-55	93-17	95-75	97-47	98-56
35-0	5-68	9-45	14-04	19-95	27-15	35-45	44-50	53-85	62-99	71-45	78-86	85-01	89-83	93-40	95-95	97-59	98-65	99-28
37-5	9-17	13-72	19-62	26-84	35-19	44-32	53-77	63-01	71-55	79-02	85-19	90-01	93-57	96-06	97-69	98-72	99-32	99-66
40-0	13-30	19-15	26-36	34-74	43-95	53-50	62-84	71-49	79-04	85-25	90-11	93-66	96-15	97-79	98-77	99-36	99-68	99-88
42-5	18-55	25-73	34-11	43-38	53-01	62-49	71-25	78-91	85-22	90-13	93-71	95-33	97-81	98-78	99-38	99-70	99-89	99-94
45-0	25-04	33-31	42-61	52-34	61-94	70-84	78-63	85-05	90-04	93-68	96-19	97-82	98-82	99-39	99-71	99-86	99-94	99-98
47-5	32-33	41-65	51-46	61-19	70-25	78-20	84-76	89-87	93-60	96-15	97-81	98-82	99-40	99-71	99-87	99-94	99-98	99-99
50-0	40-50	50-39	60-24	69-48	77-62	84-37	89-61	93-45	96-08	97-78	98-81	99-40	99-72	99-87	99-94	99-98	99-99	100-00
52-5	49-11	59-10	68-53	76-89	83-83	89-25	93-22	95-96	97-71	99-36	99-38	99-72	99-88	99-94	99-98	99-99	100-00	100-00
55-0	57-76	67-39	75-98	83-16	88-79	92-93	95-78	97-62	98-73	99-72	99-70	99-88	99-95	99-98	99-99	100-00	100-00	100-00
57-5	66-04	74-89	82-35	88-22	92-56	95-56	97-49	98-67	99-33	99-85	99-86	99-95	99-99	99-99	100-00	100-00	100-00	100-00
60-0	73-61	81-36	87-52	92-10	95-27	97-33	98-58	99-29	99-66	99-93	99-93	99-99	99-99	100-00	100-00	100-00	100-00	100-00
62-5	80-22	86-69	91-54	94-92	97-13	98-47	99-23	99-65	99-84	99-97	99-97	99-99	100-00	100-00	100-00	100-00	100-00	100-00
65-0	85-78	90-86	94-49	96-87	98-33	99-16	99-60	98-82	99-93	99-99	99-99	100-00	100-00	100-00	100-00	100-00	100-00	100-00
67-5	90-07	93-98	96-50	98-16	99-08	99-57	99-81	99-92	99-97	99-99	100-00	100-00	100-00	100-00	100-00	100-00	100-00	100-00
70-0	93-25	96-19	97-95	98-97	99-51	99-78	99-91	99-96	99-99	100-00	100-00	100-00	100-00	100-00	100-00	100-00	100-00	100-00

TABLE B FACTORS

Date of Mid-point of Period Observation (w)	Age at Entry (Z)																	
	15-0	17-5	20-0	22-5	25-0	27-5	30-0	32-5	35-0	37-5	40-0	42-5	45-0	47-5	50-0	52-5	55-0	57-5
1920	0-3787	0-3832	0-3877	0-3922	0-3967	0-4012	0-4057	0-4102	0-4147	0-4192	0-4237	0-4282	0-4327	0-4372	0-4417	0-4462	0-4507	0-4552
1922	0-4025	0-4070	0-4115	0-4160	0-4205	0-4250	0-4295	0-4340	0-4385	0-4430	0-4475	0-4520	0-4565	0-4610	0-4655	0-4700	0-4745	0-4790
1924	0-4263	0-4308	0-4353	0-4398	0-4443	0-4488	0-4533	0-4578	0-4623	0-4668	0-4713	0-4758	0-4803	0-4848	0-4893	0-4938	0-4983	0-5020
1926	0-4501	0-4546	0-4591	0-4636	0-4681	0-4726	0-4771	0-4816	0-4861	0-4906	0-4951	0-4996	0-5041	0-5086	0-5131	0-5176	0-5221	0-5266
1928	0-4739	0-4784	0-4829	0-4874	0-4919	0-4964	0-5009	0-5054	0-5099	0-5144	0-5189	0-5234	0-5297	0-5324	0-5369	0-5414	0-5459	0-5504
1930	0-4977	0-5022	0-5067	0-5112	0-5157	0-5202	0-5247	0-5292	0-5337	0-5382	0-5427	0-5472	0-5517	0-5562	0-5607	0-5652	0-5697	0-5742
1932	0-5215	0-5260	0-5305	0-5350	0-5395	0-5440	0-5485	0-5530	0-5575	0-5620	0-5665	0-5710	0-5755	0-5800	0-5845	0-5890	0-5935	0-5980
1934	0-5453	0-5498	0-5543	0-5588	0-5633	0-5678	0-5723	0-5768	0-5813	0-5858	0-5903	0-5948	0-5993	0-6038	0-6083	0-6128	0-6173	0-6218
1936	0-5691	0-5736	0-5781	0-5826	0-5871	0-5916	0-5961	0-6006	0-6051	0-6096	0-6141	0-6186	0-6231	0-6276	0-6321	0-6366	0-6411	0-6456
1938	0-5929	0-5974	0-6019	0-6064	0-6109	0-6154	0-6199	0-6244	0-6289	0-6334	0-6379	0-6424	0-6469	0-6514	0-6559	0-6604	0-6649	0-6694
1940	0-6167	0-6212	0-6257	0-6302	0-6347	0-6392	0-6437	0-6482	0-6527	0-6572	0-6617	0-6662	0-6707	0-6752	0-6797	0-6842	0-6887	0-6932
1942	0-6405	0-6450	0-6495	0-6540	0-6585	0-6630	0-6675	0-6720	0-6765	0-6810	0-6855	0-6900	0-6945	0-6990	0-7035	0-7080	0-7125	0-7170
1944	0-6643	0-6688	0-6733	0-6778	0-6823	0-6868	0-6913	0-6958	0-7003	0-7048	0-7093	0-7138	0-7183	0-7228	0-7273	0-7318	0-7363	0-7408
1946	0-6881	0-6926	0-6971	0-7016	0-7061	0-7106	0-7151	0-7196	0-7241	0-7286	0-7331	0-7376	0-7421	0-7466	0-7511	0-7556	0-7601	0-7646
1948	0-7119	0-7164	0-7209	0-7254	0-7299	0-7344	0-7389	0-7434	0-7479	0-7524	0-7569	0-7614	0-7659	0-7704	0-7749	0-7794	0-7839	0-7884
1950	0-7357	0-7402	0-7447	0-7492	0-7537	0-7582	0-7627	0-7672	0-7717	0-7762	0-7807	0-7852	0-7897	0-7942	0-7987	0-8032	0-8077	0-8122
1952	0-7595	0-7640	0-7685	0-7730	0-7775	0-7820	0-7865	0-7910	0-7955	0-8000	0-8045	0-8090	0-8135	0-8180	0-8225	0-8270	0-8315	0-8360
1954	0-7833	0-7878	0-7923	0-7968	0-8013	0-8058	0-8103	0-8148	0-8193	0-8238	0-8283	0-8328	0-8373	0-8418	0-8463	0-8508	0-8553	0-8598

Linear interpolation is permissible for both w and Z. The constants are 0.0119 per year for w and 0.00178 per year for Z.

estimate of the number of bladder tumours at the mean rate for males in England and Wales (referred to as the expected number) can be made. The theoretical basis of the calculation is complex, but an understanding of the full details of this basis is unnecessary for forming the estimate, and they have therefore been described elsewhere (Case, 1953).

The underlying principles of the method, which is a form of cohort analysis, are that the disease becomes progressively more common with increasing age of the individual until 80 is attained, and that the death rate from this cause at any given age has increased in a more or less regular manner between 1920 and the present day. In addition, death rates from all causes have tended to decrease at any given age during the same time.

An extensive study (Case, 1953) of the death rates from bladder tumour for the 30 years 1921-50 has made it possible to construct tables of factors (Tables A and B) which will allow these changes to be assessed with reasonable accuracy when considering a group (cohort) of men originally in a stated age group (Z) who enter a specified environment between certain dates and who are then observed for X years to the date of assessment. The men are considered as having acquired bladder tumours at the rate that would have obtained if the

whole of the X years had the risks at each age current for the date w, which is the mid-point between the date of starting and the date of assessment.

The Table A factors represent the percentage reached by the date of assessment of the final incidence of death from bladder tumour that would occur in a cohort of men originally aged Z who were observed until death from any cause had wiped out the cohort. The Table B factors show what this final incidence would be (as a percentage of the number of men in the original cohort) for men starting at different ages and different dates.

Table C gives the highest estimated value that makes it possible to assume an environmental risk.

Methods

Works Records.—It is necessary to search the works records and find what men have worked in the environment under consideration, the date at which they entered that environment, and their age when they did so. It is desirable to define a lower limit for time of employment by the firm (say six months) since people who are only employed for a week or so tend to be migrants and it would be difficult to trace their death certificates when they died. Subsequent withdrawal from the environment by change of occupation or retirement does not affect the method except insofar as it makes the proof of identity of the man and a possible death certificate more tedious. Having compiled such a list of men, which will be described as a nominal roll, it should be set out in the following manner.

The men should be grouped according to the date at which they started work in the environment under consideration; this will be called the date of entry. The dates of entry should be arranged in convenient groups, preferably of five years each, and the date of entry used for the calculation is the date of the mid-point of that group.

The men in each date of entry group should be divided further according to how old they were at that date. This age is termed the age at entry, and these ages should be arranged in groups of 10, or, preferably, five years, and the ages at entry used for the calculation are the ages at the mid-points of these groups. An example of this process is shown in Table 1. The age groups should be chosen so that the mid-points lie on a figure ending in 2.5, 5.0, 7.5, or 0.0.

It is now necessary to decide at what date the final assessment is to be made. For example, a process has records extending from 1920 to 1950, and death records have been searched up to January 1, 1950. The final assessment is therefore made at 1950, and this is called the end of the period of observation. This should be chosen in relation to the age of entry groups so that the X values lie on figures ending in 2.5, 5.0, 7.5, or 0.0.

Now for each age of entry group there is a mid-point, which is called Z, and for each date of entry group there

TABLE C

HIGHEST ESTIMATED VALUE PERMITTING THE ASSUMPTION THAT THE NUMBER OF DEATH CERTIFICATES INDICATES AN ENVIRONMENTAL RISK

No. of Bladder Tumour Death Certificates Actually Found (1)	Highest Estimated Value Making Nos. in Col. 1 Suspect (2)	Highest Estimated Value Making Nos. in Col. 1 Excessive (3)
1	0.052	0.020
2	0.356	0.215
3	0.818	0.567
4	1.367	1.016
5	1.970	1.530
6	2.613	2.089
7	3.285	2.684
8	3.981	3.307
9	4.695	3.953
10	5.426	4.619
11	6.169	5.300
12	6.920	5.996
13	7.690	6.705
14	8.854	7.424
15	9.247	8.153

TABLE I
A HYPOTHETICAL NOMINAL ROLL TO SHOW METHOD OF EVALUATING X, W, AND Z

Date of Entry	Jan. 1, 1920-Dec. 31, 1924	Jan. 1, 1925-Dec. 31, 1929	Jan. 1, 1930-Dec. 31, 1934	Jan. 1, 1935-Dec. 31, 1939	Jan. 1, 1940-Dec. 31, 1944	Jan. 1, 1945-Dec. 31, 1949	
Mid-point of date of entry group	1922-5	1927-5	1932-5	1937-5	1942-5	1947-5	
X = Date of final assessment minus date at mid-point of date of entry group	27-5	22-5	17-5	12-5	7-5	2-5	
w = Date at mid-point between mid-point of date of entry group and date of assessment	1936-25	1938-75	1941-25	1943-75	1946-25	1948-75	
Number of men in each age at entry group	10 23 27 11 2	15 28 29 12 1	23 37 39 15 3	29 44 50 17 2	94 106 110 50 5	108 127 151 70 9	Total 1,247
Z = Mid-point of age at entry group	17-5 25 35 45 55	17-5 25 35 45 55	17-5 25 35 45 55	17-5 25 35 45 55	17-5 25 35 45 55	17-5 25 35 45 55	
Code number of age at entry group	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	
Date of assessment = Jan. 1, 1950	Key to age at entry code number	(1) Between 15 and 19 years	(2) Between 20 and 29 years	(3) Between 30 and 39 years	(4) Between 40 and 49 years	(5) Between 50 and 59 years	

All that is now necessary is to multiply the number of men in each small division of Table 1 by the factor from Table A and then by the factor from Table B, the appropriate factors being identified by the value of X, Z, and w for that particular subdivision, add up all these products, and divide by 10,000. This is the estimate of the expected number of death certificates. Table 2 shows the workings of this calculation for the hypothetical population set out in Table 1. The selection of the mid-points of the age of entry groups and the values for X described above ensures that no interpolation is necessary in Table A, where the differences between successive entries are not linear. The w values may necessitate interpolation in Table B, but here the differ-

This table gives two figures for the highest estimate of deaths from bladder tumour expected in a particular population. If the calculation gives a figure higher than in column 2 there is no ground for suspicion; if it gives a figure falling between the numbers in columns 2 and 3 the chance of having obtained so large a difference between expectation and observation from random errors is less than 1 in 20 and it may be suspected that an environmental risk is operating; if it gives a figure falling below that in the third column this chance is less than 1 in 50 and it may safely be assumed that such a risk is operating.

A method is described whereby works medical officers or other interested persons with access to

[illegible]

works records can obtain an idea of whether an environmental risk of bladder tumour formation exists in industries, occupations, or processes in which they are interested, assuming that the works records show the name of the employee, his age or date of birth, and the date at which he started work in the environment to be considered. It is also necessary to find the number of deaths from bladder tumour which have in fact occurred.

The method is applicable to males in England and Wales, and is valid for employment between 1921 and 1950, but probably no great error will be

introduced by extending these limits by about a decade either way.

No expert statistical knowledge is required for using the method.

The alphabetical index has been constructed by Miss Margery E. Hosker and Miss Joan T. Pearson.

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