An Evaluation of Tuberculosis Detection By Chest X-ray Surveys

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EACH YEAR over 13 million Americans receive chest X-ray examinations in a search for undetected tuberculosis. Implicit in the conduct of chest X-ray programs is the assumption that if tuberculosis were not so detected many cases would go on to a symptomatic and more advanced stage and diagnosis would be made at a time when a cure would be more difficult. No one has ever been able actually to test this assumption since no one knows what would have happened to a case if it had not been discovered by a survey.

In other words, there have been no controls. In this instance, controls would be a group of randomly selected persons participating in an X-ray program whose X-rays are positive for tuberculosis but who are not advised of the results of their X-rays and are allowed to go on their way, to be discovered by some other device—or possibly never to be detected. Since an intentional experiment of this nature is not acceptable within the framework of a tuberculosis control operation, we must seek other methods for evaluating the detection of tuberculosis by X-ray programs.

Although we cannot know with certainty what would have happened to survey-discovered tuberculosis cases if they had not been so discovered, we can readily study the outcome of cases detected by other means. A comparison of the course of disease in the two groups of cases is probably the most practical method of estimating the extent to which tuberculosis cases are benefited by discovery through chest X-ray surveys.

The present study is a report on the findings in a 4-year followup of cases of active tuberculosis discovered by a communitywide X-ray survey in Minneapolis, Minn., in 1947 (May 5–August 25) compared with the findings in a 4-year followup of active cases found in the same area by other means. Each case in both groups was followed for 4 years, or until death, or until lost to the study. In this study, an "active" case was defined as one having positive bacterial findings or X-ray changes characteristic of active tuberculosis. The data used were obtained from the files of the Minneapolis City Health Department.

The Minneapolis survey was one of the first communitywide chest X-ray surveys conducted

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in this country in a city of more than 100,000 population. Some of the results have already been reported (*1–3*). A total of 301,513 satisfactory examinations were made during a 3½-month period, 261,000 (estimated on the basis of a 10-percent sample of the survey records) on residents of the city of Minneapolis.

The Survey Group

Within a year after the close of the survey, 233 resident cases of active pulmonary tuberculosis had been identified as a result of the followup of patients with suspicious X-rays. However, 98 of these were excluded from the study for the following reasons: known as tuberculosis cases prior to the study, 34; initially diagnosed as having inactive tuberculosis, 59 (although later diagnosed as active, it was felt that followup results on these cases should not be compared with results on the nonsurvey cases, all of which were initially reported as active); identified as suspects by the X-ray program but not diagnosed until they died of tuberculosis, 2; eventually diagnosed as not having tuberculosis, 3. There were, then, 135 resident cases of pulmonary tuberculosis discovered in an active stage as a direct result of the communitywide chest X-ray survey.

The Nonsurvey Group

Cases discovered by means other than X-ray surveys included all resident active cases of tuberculosis reported to the Minneapolis City Health Department during the first 6 months of 1947. It would have been desirable for both groups of cases to have been reported during the same period, so that each group would have had the same advantages in terms of current techniques of treatment and followup procedures. However, it was felt that nonsurvey cases reported during the time of the survey might not be typical of nonsurvey cases usually reported, because a number of the survey cases would have been reported as the result of other case-finding procedures during or shortly after the survey had the survey not been conducted. A study of cases reported during the first 6 months of 1947 appeared to be the best compromise.

A total of 188 resident cases of active pulmonary tuberculosis was reported to the Minneapolis City Health Department during this 6-month period. In selecting a group from among these cases from which implications might be drawn as to what might have happened to survey cases had they not been detected in the survey, a number of eliminations had to be made.

Ideally, this group should consist of cases of tuberculosis that could have been discovered by a communitywide X-ray survey but were not because there was no survey activity, and thus they progressed to the point where they were found by other methods. Fifty-four cases were excluded from the study. Four were under 15 years of age, and the X-ray survey was restricted to persons 15 years of age and over; 5 were inmates of the State mental institution,

Table 1. Age and sex distribution of survey and nonsurvey cases

Age at time of report (in years)	Survey						Nonsurvey					
	Total		Male		Female		Total		Male		Female	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total	135	100.0	90	100.0	45	100.0	134	100.0	87	100.0	47	100.0
15–34	31	23.0	16	17.8	15	33.3	43	32.1	19	21.8	24	51.1
35–54	50	37.0	36	40.0	14	31.1	37	27.6	27	31.0	10	21.3
55–74	50	37.0	34	37.8	16	35.6	42	31.4	32	36.8	10	21.3
75 and over	4	3.0	4	4.4	0	------	9	6.7	7	8.1	2	4.2
Unknown age	0	------	0	------	0	------	3	2.2	2	2.3	1	2.1

and the survey was not directed toward that group; 6 were eventually diagnosed as nontuberculous; 22 had been previously known as tuberculosis cases; and 17 were not reported until death. Although many of these 17 cases probably could have been discovered by an X-ray survey, they did not lend themselves to the type of analysis which follows. Their exclusion tends to minimize differences in the outcome of tuberculosis between the survey and the nonsurvey cases.

There remained, then, 134 resident active pulmonary cases of tuberculosis discovered by procedures other than the communitywide chest X-ray survey for comparison with 135 resident active pulmonary cases of tuberculosis discovered as a result of the survey.

Age and Sex Distribution

The age and sex distributions of the two groups of cases are shown in table 1. Males made up about two-thirds of each group. More nonsurvey than survey cases fell into the 15 to 34 and the 75-and-over age groups. The mean ages of males and females in the two groups were similar, however. In the survey group, the mean age of males was 50.9 years and in the nonsurvey group, 50.6 years, whereas the mean age for females was 44.4 years for the survey group and 39.5 years for the nonsurvey group. If there are large differences in the outcome of tuberculosis in these two groups of cases, they are probably not due to differences in age and sex composition.

Bacteriological Status

Ninety-two (68 percent) of the 135 survey cases had a positive bacteriological examination reported to the health department within 3 months of the case report compared with only 72 (54 percent) of the 134 nonsurvey cases. Apparently, the search for tubercle bacilli among survey cases was somewhat more thorough than among nonsurvey cases since 19 of the positive reports for survey cases were based upon examination of gastric contents compared with only 9 of the positive reports among nonsurvey cases. This may partly account for the fewer positive reports among the nonsurvey group, and it seems likely that the two groups of cases were comparable in terms of their clinical significance.

Stage of Disease

Shown in table 2 is the stage of disease of these two groups of cases at the time they were first reported. Of the survey cases, 37.0 percent were reported as minimal; only 21.7 percent of the nonsurvey cases were so reported. Conversely, only 15.6 percent of the survey cases were reported in the far advanced stage compared with 32.8 percent of the nonsurvey cases. This suggests that survey cases were discovered in a considerably earlier stage than they would have been had the chest X-ray survey not been conducted.

Table 2. Stage of disease at time of report

Stage of disease	Survey cases		Nonsurvey cases	
	Number	Percent	Number	Percent
Total	135	100.0	134	100.0
Minimal	50	37.0	29	21.7
Moderately advanced	64	47.4	61	45.5
Far advanced	21	15.6	44	32.8

Status at End of Followup

There was little apparent difference between the survey and nonsurvey cases in terms of the proportion discharged from health department supervision during the followup period and the reasons for discharge. Some of the cases in both groups were actively followed by the health department for the entire 4-year period or until death; others were discharged during the followup period because they became arrested, moved, were lost, or were considered uncooperative. Of the 135 survey cases, 11 were discharged because they became arrested compared with 9 of the 134 nonsurvey cases; 27 survey cases were discharged because they moved, were lost, or were considered uncooperative; 33 nonsurvey cases were so discharged.

Shown in table 3 is the status, according to health department records, of the 97 survey and

Table 3. Status of cases followed by health department on the fourth anniversary of the first report

Status	Survey		Nonsurvey	
	Number	Percent	Number	Percent
Total cases followed	97	100.0	92	100.0
Dead	13	13.4	42	45.7
In sanatoriums	16	16.5	11	11.9
At home with active tuberculosis	11	11.3	9	9.8
At home with inactive tuberculosis	57	58.7	30	32.6

92 nonsurvey cases actively followed by the health department during the entire 4-year period or until death, on the fourth anniversary of their being reported. Forty-five percent of the nonsurvey cases were dead, compared with only 13 percent of the survey cases. On the other hand, a larger proportion of survey than of nonsurvey cases were at home with inactive tuberculosis at the end of the study period, and a slightly larger proportion were in sanatoriums or at home with active tuberculosis at that time.

Probability of Death

The most completely recorded events in the files of the Minneapolis City Health Department during the 4-year followup period were deaths and periods of hospitalization. A life-table method has been used in analyzing mortality data, with the results shown in table 4. Cases withdrawn from observation are those who died or were discharged from health department supervision. Deaths refer to deaths from all causes. The cumulative probability of death for survey and nonsurvey cases is computed for the eight 6-month followup periods (probabilities are shown as percentages), showing total cases, and, separately, cases moderately advanced and far advanced at the time of discovery. (There were too few deaths among minimal cases for the computation of rates.)

Figure 1. Probability of death for total survey and nonsurvey cases, cumulated in successive 6-month intervals.

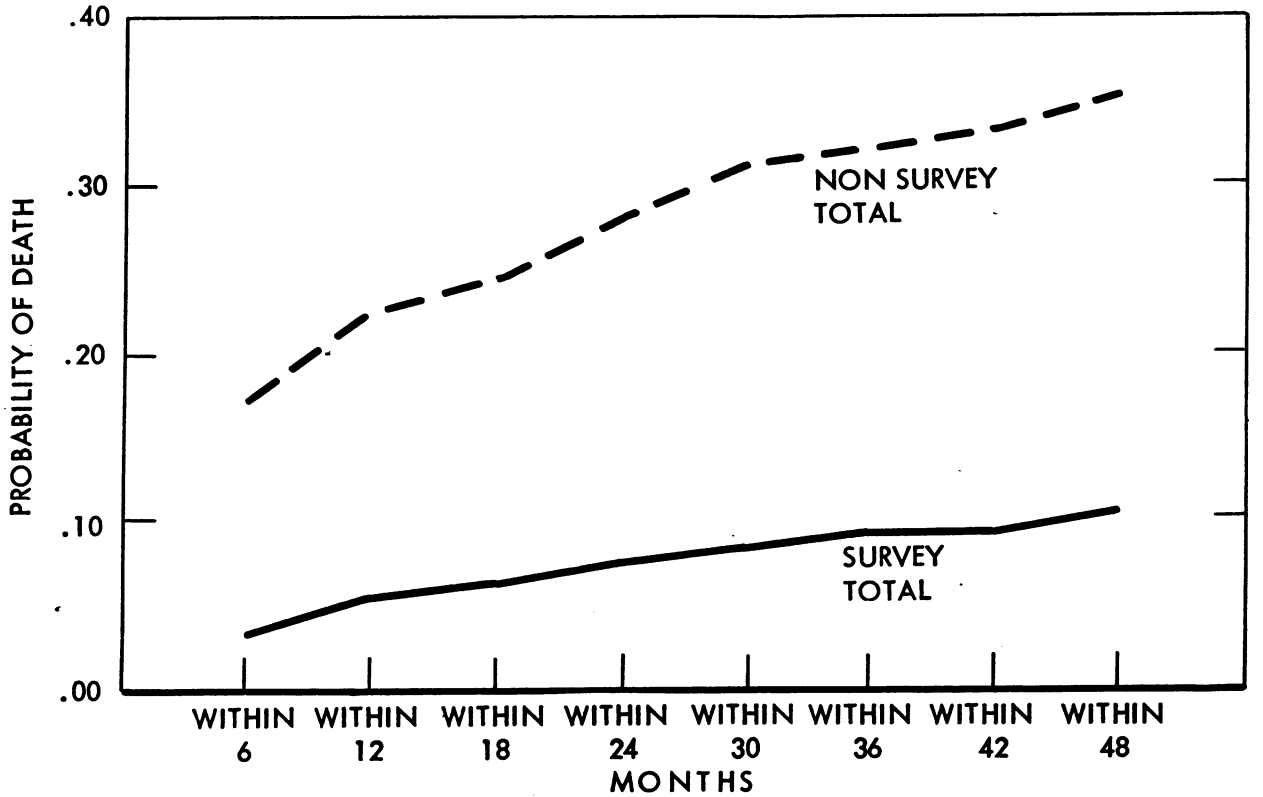
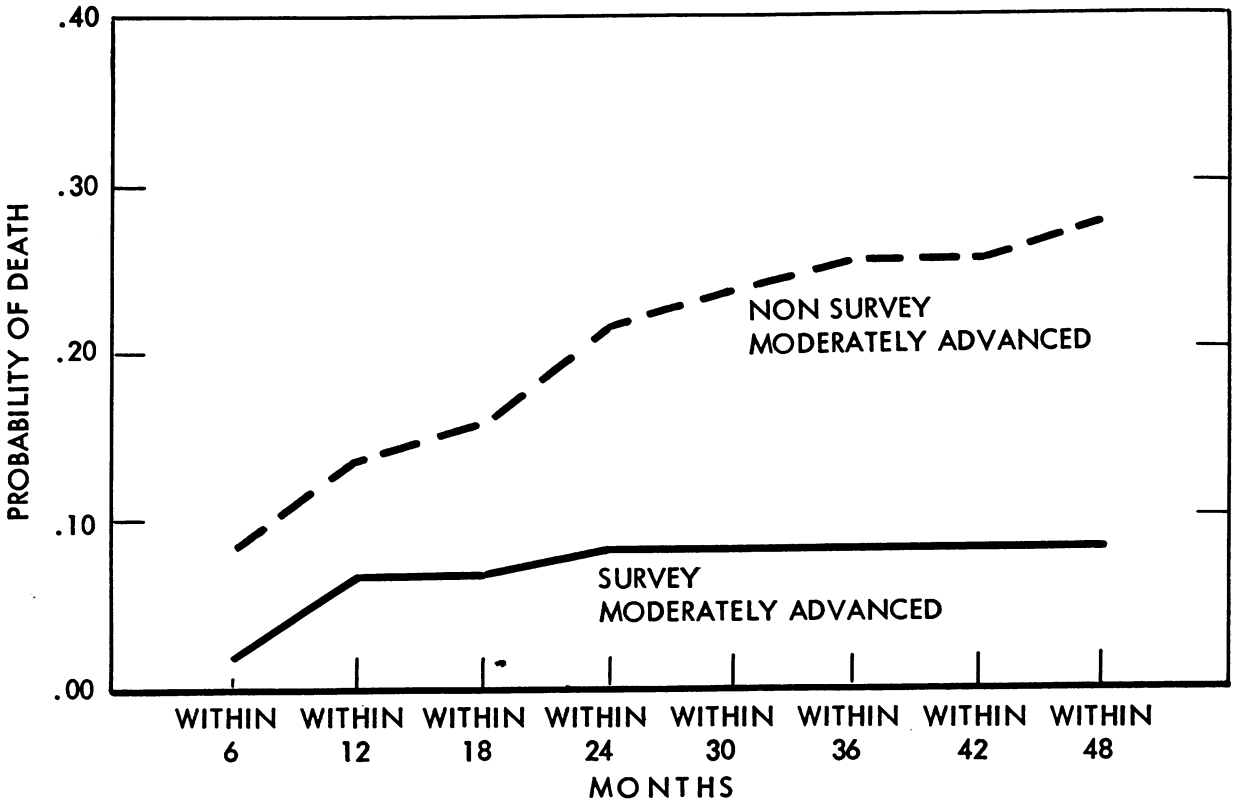


Table 4. Probability of surviving and of dying for patients with active tuberculosis, by stage of disease at time of first report and by method of discovery, for 8 consecutive 6-month periods of observation

Stage of disease	6-month period	Number at beginning of period l_x		Number withdrawn living during period W_x		Number dying during period d_x		Average number at risk $l_x - \frac{1}{2}W_x$	
		Survey	Nonsurvey	Survey	Nonsurvey	Survey	Nonsurvey	Survey	Nonsurvey
All stages (including minimal)	1	135	134	2	10	4	22	134.0	129.0
	2	129	102	4	1	3	7	126.0	101.5
	3	122	94	1	6	1	2	121.5	91.0
	4	120	86	2	7	2	4	119.0	82.5
	5	116	75	3	4	1	3	114.5	73.0
	6	112	68	7	1	1	1	108.5	67.5
	7	104	66	3	3	-------	1	102.5	64.5
	8	101	62	16	10	1	2	93.0	57.0
Moderately advanced	1	64	61	1	5	1	5	63.5	58.5
	2	62	51	2	1	3	3	61.0	50.5
	3	57	47	-------	1	-------	1	57.0	46.5
	4	57	45	1	3	1	3	56.5	43.5
	5	55	39	1	1	-------	1	54.5	38.5
	6	54	37	2	1	-------	1	53.0	36.5
	7	52	35	-------	----------	-------	----------	52.0	35.0
	8	52	35	6	6	-------	1	49.0	32.0
Far advanced	1	21	44	-------	1	2	16	21.0	43.5
	2	19	27	-------	----------	-------	4	19.0	27.0
	3	19	23	-------	3	1	1	19.0	21.5
	4	18	19	-------	----------	1	1	18.0	19.0
	5	17	18	1	2	1	2	16.5	17.0
	6	15	14	-------	----------	1	----------	15.0	14.0
	7	14	14	-------	2	-------	----------	14.0	13.0
	8	14	12	-------	----------	1	1	14.0	12.0

Stage of disease	6-month period	Percentage dying in given period $100\,q_x$		Percentage surviving in given period $100\,p_x$		Percentage surviving through preceding and current period $100\,hp_x$		Percentage dying in preceding and current period $100\,hq_x$	
		Survey	Nonsurvey	Survey	Nonsurvey	Survey	Nonsurvey	Survey	Nonsurvey
All stages (including minimal)	1	3.0	17.1	97.0	82.9	97.0	82.9	3.0	17.1
	2	2.4	6.9	97.6	93.1	94.7	77.2	5.3	22.8
	3	.8	2.2	99.2	97.8	93.9	75.5	6.1	24.5
	4	1.7	4.8	98.3	95.2	92.3	71.9	7.7	28.1
	5	.9	4.1	99.1	95.9	91.5	69.0	8.5	31.0
	6	.9	1.5	99.1	98.5	90.7	68.0	9.3	32.0
	7	-------	1.6	100.0	98.4	90.7	66.9	9.3	33.1
	8	1.1	3.5	98.9	96.5	89.7	64.6	10.3	35.4
Moderately advanced	1	1.6	8.5	98.4	91.5	98.4	91.5	1.6	8.5
	2	4.9	5.9	95.1	94.1	93.6	86.1	6.5	13.9
	3	-------	2.2	100.0	97.8	93.6	84.2	6.5	15.8
	4	1.8	6.9	98.2	93.1	91.9	78.4	8.2	21.6
	5	-------	2.6	100.0	97.4	91.9	76.4	8.2	23.6
	6	-------	2.7	100.0	97.3	91.9	74.3	8.2	25.7
	7	-------	----------	100.0	100.0	91.9	74.3	8.2	25.7
	8	-------	3.1	100.0	96.9	91.9	72.0	8.2	28.0
Far advanced	1	9.5	36.8	90.5	63.2	90.5	63.2	9.5	36.8
	2	-------	14.8	100.0	85.2	90.5	53.8	9.5	46.2
	3	5.3	4.7	94.7	95.3	85.7	51.3	14.3	48.7
	4	5.6	5.3	94.4	94.7	80.9	48.6	19.1	51.4
	5	6.1	11.8	93.9	88.2	76.0	42.9	24.0	57.1
	6	6.7	----------	93.3	100.0	70.9	42.9	29.1	57.1
	7	-------	----------	100.0	100.0	70.9	42.9	29.1	57.1
	8	7.1	8.3	92.9	91.7	65.9	39.3	34.1	60.7

Figure 2. Probability of death for survey and nonsurvey cases, moderately advanced at time of report, cumulated in successive 6-month intervals.



These probabilities of deaths are also shown in figures 1 to 3.

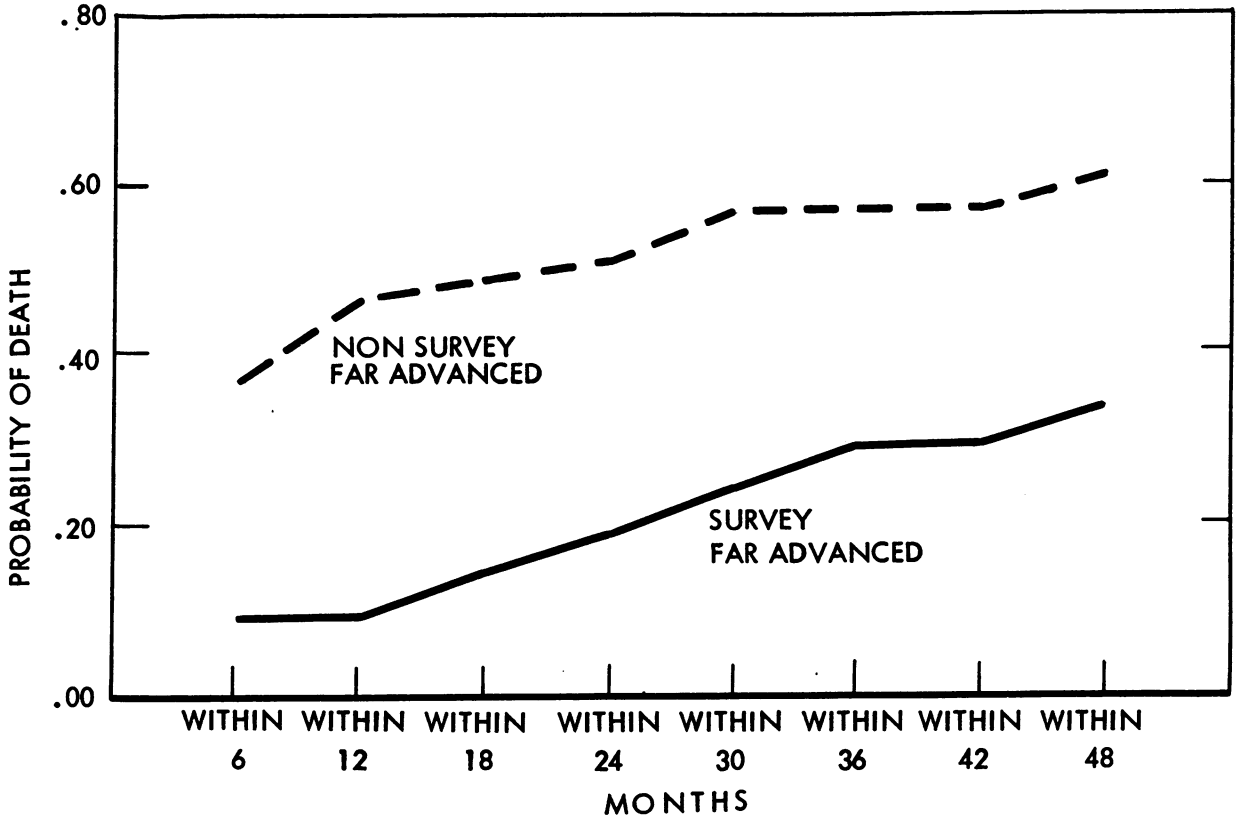
As shown in table 4 and figure 1, the chance of survey cases dying within the 4-year period was .103, or about 1 out of 10, whereas the chance of death in the nonsurvey group was .354, or about 1 out of 3. A large proportion of the deaths in the nonsurvey group occurred in the first 6-month followup period, when 17 percent of the nonsurvey cases died compared with only 3 percent of the survey cases. Even in subsequent periods, however, a somewhat higher death rate prevailed in the nonsurvey group.

Only part of the advantage survey cases apparently had over nonsurvey cases was due to the earlier stage of disease in which survey cases were first reported. Cases reported as moderately advanced showed probabilities of death within the 4-year period of .082 and .280 for survey and nonsurvey cases, respectively (table 4 and fig. 2); for far advanced cases, these probabilities were .341 and .607 (fig. 3). For moderately advanced cases, deaths occurred in the nonsurvey group at a slightly decreasing rate during the entire followup period; in the survey group, no deaths were observed after the second year. For far advanced cases, however, after a high initial mortality, the nonsurvey group appeared to have about the same mortality experience as the survey group.

Hospitalization

The amount of hospitalization required by tuberculosis cases is of considerable interest, particularly as it relates to savings in hospital care that might result from early discovery. Of the 135 survey cases, 109 (81 percent) were hospitalized during the 4-year followup period; of the 134 nonsurvey cases, 113 (84 percent) were hospitalized. Ten percent of the hospitalized survey cases were hospitalized more than once, whereas only 5 percent of

Figure 3. Probability of death for survey and nonsurvey cases, far advanced at time of report, cumulated in successive 6-month intervals.



the hospitalized nonsurvey cases had more than one hospitalization.

In all, survey cases received a total of 2,088.6 months of hospitalization during the 4-year followup period; nonsurvey cases, 1,785.9 months. Thus, although about the same proportion of both groups were hospitalized, survey cases had a tendency to be readmitted more frequently than nonsurvey cases and to require more total months of hospitalization.

Discussion

It has been shown that within a 4-year period the probability of death among active cases of tuberculosis discovered as the result of usual case-finding methods greatly exceeds the probability of death among comparable cases discovered by communitywide X-ray surveys.

In view of the significance of survey-discovered tuberculosis as revealed by the results of bacteriological examination and by the amount of hospitalization received, there is good reason to believe that, if a survey had not been conducted, many of the survey-discovered cases would have gone on to a more symptomatic and more advanced stage, to be finally discovered by some other case-finding procedure.

Because the 4-year followup of survey cases roughly covers the years 1948 to 1952, whereas the 4-year followup period for nonsurvey cases represents an earlier period—roughly, the years 1947 to 1951—the survey cases probably had some advantages in therapy not available to the nonsurvey group. This may partly account for their more favorable mortality experience. However, this advantage could not have accounted for a difference in mortality as large as that observed.

It seems probable, then, that one of the real values of tuberculosis case detection through

chest X-ray surveys is a saving in lives as the result of treatment early in the course of the disease. This value is in addition, of course, to the prevention of spread of infection to others that must have occurred as the result of the discovery and isolation of infectious tuberculosis before it ordinarily would have been brought to light.

The fact that cases of active tuberculosis discovered by the Minneapolis communitywide chest X-ray survey received about 17 percent more hospitalization during the 4-year follow-up period than did active cases discovered by other means is important in planning for hospitalization facilities in areas where intensive case-finding efforts are to be carried out. Such efforts probably do not reduce the amount of hospitalization required for each case reported but rather increase it.

The additional hospitalization given the survey-discovered cases could all be accounted for by the lower mortality in this group compared with the mortality in the nonsurvey group. This resulted in more cases being available at any given time for hospitalization. By use of a life-table technique similar to that used in table 4, it can be shown that, had the same mortality and withdrawal rates prevailed in the two groups of cases, the survey-discovered cases would actually have received somewhat less hospitalization than the nonsurvey cases.

From the foregoing it would appear that the underlying assumption in the conduct of chest X-ray programs—that tuberculosis cases benefit by discovery through chest X-ray surveys—is correct and that the chances of an unfavorable outcome for cases of tuberculosis are reduced as the result of their discovery in these programs. There is little doubt as to the importance of aggressive case-finding efforts in our attack on this disease.

Summary

1. In order to estimate the value of tuberculosis case discovery through chest X-ray surveys, a group of active cases of pulmonary tuberculosis discovered by a communitywide chest X-ray survey conducted in Minneapolis, Minn., in 1947 was compared with a group of active pulmonary cases reported to the city health department just prior to the survey.

2. The two groups of cases were found to be similar in terms of age and sex and of bacteriological significance. However, 37 percent of the survey cases were discovered in the minimal stage, compared with 22 percent of the nonsurvey cases. Conversely, only 16 percent of the survey cases were in a far advanced stage, compared with 33 percent of the nonsurvey cases.

3. Using a life-table method to study the survival of these two groups of cases over a 4-year period, it was estimated that the chance of a survey case dying within 4 years was 1 out of 10, whereas the chance of a nonsurvey case dying was 1 out of 3.

4. It was concluded that the differences observed in the outcome of tuberculosis in the two groups of cases studied are to some extent a reflection of the value of early case discovery through intensive tuberculosis case-finding efforts.

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