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TUBERCULOSIS IN THE ARMY OF THE UNITED STATES IN WORLD WAR II

An Epidemiological Study With an Evaluation of X-ray Screening

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The work reported herein is part of the program of studies of the Follow-up Agency of the National Research Council developed by the Committee on Veterans Medical Problems in cooperation with the Veterans Administration, the Army and the Navy.

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Foreword

Following World War II, The Surgeon General, U. S. Army, Major General Norman T. Kirk, suggested that a research program be organized to take advantage of the scientific potentialities of the recorded medical experience of the armed services in World War II, and the extensive observations which would subsequently be made on veterans in the hospitals and regional offices of the Veterans Administration. Research in the natural history of disease is greatly facilitated by certain characteristics of the medical experiences of the Armed Forces, both in war and in peace, and of veterans as a class of beneficiaries of the Federal Government. Since 1946, the Veterans Administration has placed great emphasis upon the encouragement of essential investigations in this area. In war especially, but also in time of peace, the military personnel comprise a large population with a great diversity of stress, trauma, and disease, in which each illness or injury generates a permanent record; all such episodes (or a fair statistical sample thereof) are indexed by means of punched cards, and there also exists a uniquely complete and centralized reservoir of pathological material. The veteran population is now in excess of 20 millions and is both more easily located and more readily motivated to participate in specific studies than any other large segment of the U. S. population. It is served by an integrated system of medical care, with emphasis upon service-connected illness or injury, administered by 172 hospitals with a rated aggregate capacity in excess of 118,000 beds, by clinics in 69 regional offices, and by many additional supplementary medical and dental services.

Several efforts had previously been made to extract scientific information on the natural history of disease from the medical experience of World War I, supplemented by the later records of what was then called the Bureau of Veterans' Affairs. This led to the publication of special reports in the History of the U. S. Army in the World War. However, no systematic program had been established and the opportunity was never fully realized.

In 1946, Major General Paul R. Hawley, then Chief Medical Director of the Veterans Administration, requested that the National Research Council advise the Veterans Administration on the organization and conduct of its developing program of medical research. For this purpose the Committee on Veterans Medical Problems of the National Research Council was established. This committee was charged with the broad responsibility for initiating and fostering a general program of medical follow-up studies based on experience with the military and veteran population. Under this committee was organized the Follow-up Agency of the National Research Council to carry out the staff functions associated with the planning and organization of research projects, arranging access to medical records, and providing statistical analysis. The Veterans Administration has provided the direct financial support for the majority of the studies in this program and the Armed Forces have provided strategic support in the form of access to necessary records and ancillary services. Many Federal, State, and private agencies have also given generous assistance to the work as required.

The program is a general one, its unity arising out of the availability of a research tool of broad applicability in clinical medicine, especially in the area of the natural history of disease. Some studies have been based entirely on existing records (military, clinical, pathological, mortality, disability, etc.) while in others the recorded information has been supplemented by intensive laboratory and clinical observations.

The Veterans Administration is deeply indebted to the members of the Committee on Veterans Medical Problems for their vision and foresight in organizing and directing this program of medical follow-up studies.

Much of the product of the program will be found in medical periodicals appropriate to the subjects of investigation. However, some of the studies are of such magnitude as to require that they be reported at greater length than would be possible even in a series of journal articles. The Veterans Administration has, therefore, inaugurated a series of monographs as the most effective means of presenting the results of these larger studies.

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Table of Contents

	Page
1. Introduction	1
2. Method and Sampling Plan	3
Tuberculosis and Control Rosters	3
Methods	3
Adequacy of Sample	6
3. Multiple Interpretation of Films	9
Comparison of X-Ray Readings	9
Agreement with respect to the presence of tuberculosis	10
Agreement with respect to extent of tuberculosis	11
Agreement with respect to activity of tuberculosis	12
Agreement with respect to location of tuberculous lesions	13
Agreement with respect to calcification	13
Agreement with respect to other pathology than tuberculosis	14
Discrepancy in interpretation in relation to type of film	15
Comparison of first two readings with final reading	18
Disagreement in Rereading Films	20
4. The Induction Screen	24
Variability of Induction Stations	24
Efficiency of Screening Levels	26
Screening in Relation to Race	32
Relation to Nontuberculous Pathology	33
5. The Separation Screen	36
Accuracy of Separation Screen	36
6. Tuberculosis in the Army	41
Types and Stages of Tuberculosis	41
Length of Service Before Medical Discharge	44
Service Connection in Discharged Men	51
Summary on Induction Screen	34
Relation of Tuberculosis to Previous Residence	52
Course of Disease During Service in Men with Tuberculosis at Induction	56
7. Background Characteristics of Men Discharged for Tuberculosis	60
Race	60
Age	62
Residence	65
Urban and Rural Background	65
Educational Status	66
Body Build	68
8. Aspects of Military Service in Relation to the Development of Tuberculosis	73
United States and Foreign Service	73
Prisoners of War	75
Place of Foreign Service	76
Military Arm and Occupation	79
9. Summary	82
References	85
Index	87

TABLES

Table		Page
1.	Number and Percent of Induction and Separation Films Found and Reviewed for Each Roster	6
2.	Percent of Induction and Separation Films Found and Reviewed for Each Roster by Selected Characteristics of Service	7
3.	Number and Percent of Induction and Separation Films Found and Reviewed for the Tuberculosis Roster by Discharge Diagnosis	7
4.	Location of Films Found	8
5.	Overall Comparison of Interpretations of Films by Two Readers	10
6.	Comparison of First and Second Readings as to Presence of Pathology	10
7.	Comparison of First and Second Readings as to Extent of Tuberculosis	11
8.	Comparison of First and Second Readings as to Activity of Tuberculosis	12
9.	Comparison of First and Second Readings as to Activity of Tuberculosis; Induction Films, Tuberculosis Roster	13
10.	Comparison of First and Second Readings as to Presence of Calcification	14
11.	Comparison of First and Second Readings in Relation to Kind of Film; Tuberculosis Roster, Induction Films	16
12.	Comparison of First and Second Readings in Relation to Kind of Film; Tuberculosis Roster, Separation Films	16
13.	Comparison of First and Second Readings in Relation to Kind of Film; Control Roster, All Films	17
14.	Comparison of First and Second Readings as to Extent of Tuberculosis in Relation to Type of Film; Roster I and Roster II, Induction and Separation Films	18
15.	Comparison of First and Second Readings With Final Reading as to Diagnosis of Tuberculosis or Suspect Tuberculosis	19
16.	Discrepancies in Film Readings Between Two Roentgenologists and Between Original Readings and Rereadings After Interval of Four Months; Tuberculosis Roster, Induction Films	21
17.	Discrepancies in Film Readings Between Two Roentgenologists and Between Original Readings and Rereadings After Interval of Four Months; Tuberculosis Roster, Separation Films	22
18.	Discrepancies in Film Readings Between Two Roentgenologists and Between Original Readings and Rereadings After Interval of Four Months; Control Roster, Induction and Separation Films	22
19.	Errors of Omission at Induction Station by Race and Service Command; Tuberculosis Roster—Induction Film Called Negative at Induction Station	25
20.	First, Second, Summary, and Final Readings of Induction Films and CDD Ratios	28
21.	Screening Efficiency of First, Second, Summary, and Final Readings	28
22.	Screening Efficiency of Combinations of First and Second Readings	28
23.	Effect of Consideration of Activity on Screening Efficiency of Four Readings	30
24.	Final Reading of Induction Films and CDD Ratios by Race	31
25.	Relation Between Pulmonary Calcification as Sole Pathology on Induction Film and Discharge for Tuberculosis	33
26.	Four Readings of Separation Films; Control Roster	36
27.	Results of Search of Veterans Administration Files, August 1953, for Men Considered To Have Suspicious Separation Films; and for Controls	37
28.	The Tuberculosis Roster by Diagnosis and Final Reading of Induction Film; Whites	42
29.	The Tuberculosis Roster by Diagnosis and Final Reading of Induction Film; Not White	43

Page
30. The Tuberculosis Roster by Diagnosis and Final Reading of Separation Film; Whites 45
31. The Tuberculosis Roster by Diagnosis and Final Reading of Separation Film; Not White 46
32. Length of Service, Excluding Time in Hospital for Tuberculosis; Roster I 47
33. Duration of Hospitalization in Army for Tuberculosis, Roster I 47
34. CDD Ratios Partitioned by Kind of Disease for All Men and for Men With Unequivocally Negative Induction Films 52
35. Tuberculosis Death Rate, White Inhabitants, 1940; Selective Service Rejections for Tuberculosis Among White Registrants and Proportions of White Enlisted Men Discharged for Tuberculosis for Groups of States 53
36. Activation and Arrest of Tuberculosis During Service Among Men Infected at Induction, by Race 56
37. Progression and Retrogression of Stage of Tuberculosis Between Minimal and Moderately or Far Advanced During Service, by Race 57
38. Progression and Retrogression of Stage of Tuberculosis Between Moderately Advanced and Far Advanced During Service, by Race 59
39. Appearance and Disappearance of Cavities During Service Among Men With Active Tuberculosis at Induction and Separation, by Race 59
40. Discharges for Tuberculosis in Relation to Race 60
41. Discharges for Tuberculosis in Relation to Race Among Men for Whom the Induction Film Was Called Negative on Final Reading 61
42. Discharge for Tuberculosis in Relation to Age at Induction, Type of Diagnosis and Race 62
43. Discharge for Tuberculosis in Relation to Age at Induction, Type of Diagnosis and Race 63
44. Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Census Division of Induction Residence and Birthplace 65
45. Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Size of City of Induction Residence and Birthplace 66
46. Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Education at Induction 68
47. Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Civilian Occupation 68
48. Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Height 70
49. Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Ratio of Weight at Induction to Median Weight for Height 70
50. Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Ratio of Weight at Induction to Median Weight for Height; White Enlisted Men, Final Reading of Induction Film Negative 71
51. Distribution of Weight at Induction in Relation to Roster and Final Reading of Induction Film for the Tuberculosis Roster, White Recruits 72
52. Development of Tuberculosis in Relation to Oversea; Service and Prisoner-of-War Status; Men With 25 Months or More of Service, Excluding Time in Hospital for Chest Disease 76
53. Development of Tuberculosis in Relation to Place of Longest Overseas Service; Men With 25 Months or More of Service, Excluding Time in Hospital for Chest Disease 77
54. Development of Tuberculosis in Relation to Venereal Disease and Theater of Overseas Service; Men With 25 Months or More of Service, Excluding Time in Hospital for Chest Disease 78

1. INTRODUCTION

As the sub-title of this work makes clear our guiding interest has been epidemiological, not clinical, and in a sense operational rather than theoretical. The clinician will find here, for example, no consideration of methods of treatment. The study was undertaken primarily to determine the effectiveness of X-ray screening of recruits at induction and discharge in the detection of disabling tuberculosis in World War II. It was hoped that the investigation would also throw light on factors of intrinsic or environmental character associated with the occurrence of tuberculosis in the Army during the war. After describing the methods of study we shall discuss in general terms the implications of our findings regarding the operation of an X-ray screen for tuberculosis at the induction station, in relation to the reliability of interpretation of films. We shall assess the quality of performance of the induction screen during World War II and attempt to characterize the individuals who developed tuberculosis insofar as this is possible in terms of routinely available recorded information.

During the years 1942–1945, about 17,500 men were admitted to Army hospitals with a diagnosis of tuberculosis and ultimately separated for disability (1). These individuals represent a staggering potential cost to the taxpayer in terms of disability pensions alone: at an average of $10,000 the cost of pensions for these men would be $175 million. On the other hand, it is estimated that 171,300 selective service registrants, or approximately ten times as many men, who were still under 38 years of age on 1 August 1945, had been rejected for tuberculosis as primary cause (2). The problem which faces the induction screen is, then, twofold: if sick men are inducted, in addition to the general hazard to the health of other men which is created, a large burden to the Government in future pensions is generated; but if well men are rejected, the military services may, in time of grave need, be deprived of the services of a very large number of potentially useful men.

During and after the war, a number of induction station roentgenologists reported rejection rates in their stations for supposedly inactive and active tuberculosis. Several of these reports dealt with a hundred thousand or more photoroentgen examinations. The literature on this and related matters has been reviewed by Long (3) in a chapter of the forthcoming official History of the Medical Department of the U. S. Army in World War II. His conclusion was that "on the average it appears that about half the men rejected for tuberculosis were considered to have active, and half potentially active or inactive lesions" (4,5).

Similarly, Temple and Crutchlow (6) on the basis of a follow-up study of recruits rejected for tuberculosis by the Canadian armed services in World War II, estimated that about 50 percent of the rejections were not justified. It therefore seems necessary, in order to assess the functioning of the induction screening process in a realistic way, to take account not only of the necessity of excluding from service men who are sick, but also to consider the need during a time of manpower shortages of avoiding unwarranted losses of manpower to the services.

2. METHOD AND SAMPLING PLAN

TUBERCULOSIS AND CONTROL ROSTERS

The individuals studied were 3,099 men discharged from the Army for disability with the diagnosis of tuberculosis during the period 1 May 1943–31 December 1946, inducted on or after 1 July 1942, but not after 1 July 1945. Names were taken from files maintained by the Tuberculosis Division of the Veterans Administration and by the Medical Statistics Division, Office of the Surgeon General, Department of the Army. The method of selection employed was to choose all men meeting the criteria of the study whose Army serial numbers terminated in the digits or combinations of digits 2, 4, 6, 78, 88, 98. This method of choice was calculated to yield a 33 percent, essentially random sample of the whole number of men eligible for study, and we shall denote it briefly as Roster I or the "tuberculosis roster." A "control" group ("contrasting" might be a better term) was also chosen, consisting of 3,000 individuals who served as enlisted men in the Army, who were inducted between 1 July 1942 and 1 July 1945, and separated to a civilian component between the same inclusive dates mentioned above for Roster I, but not discharged for tuberculosis. The particular men were chosen from the one percent punchcard file of separations maintained by the Veterans Administration, and originally prepared by the Office of the Adjutant General. This file was created by choosing men on the basis of the two terminal digits of the Army serial number, and for our purposes was further subsampled first by choice of a particular digit in the sixth place of the serial number; the numbers were further reduced by selecting six cards out of each successive group of ten on the basis of their positions, the file having been first put in serial number order. We have, then, a sample of 0.06 percent of the eligibles, which we will call Roster II, or the "control roster."

A few individuals otherwise eligible were dropped from the study because their records could not be located, usually because the Army serial number on the punchcard was incorrect. The number discarded from Roster I was 32 and from Roster II, 69, constituting 1.0 percent of Roster I and 2.3 percent of Roster II.

While the particular sampling ratios which were employed (33 percent and .06 percent), for the two rosters were chosen with the objective of obtaining rosters numbering about 3,000 each, that we were so successful in the case of Roster II was quite fortuitous.

METHODS

Data with respect to personal factors and Army service for each man were abstracted from personnel files at the Demobilized Personnel Records Branch, Department of the Army, at St. Louis. This included race, weight and height at induction, birthplace and birth date, residence at induction, number of years of schooling, civilian occupation and marital status, branch of service, military occupation, duration and places of overseas service, and imprisonment, if captured. Diagnoses and dates of Army hospital admissions were abstracted from clinical records available at St. Louis and also from records transferred to Veterans Administration claims folders. Finally, a system of multiple interpretation of induction and discharge films was set up in the X-ray film file of the Veterans Administration Records Center (then located at Philadelphia). Figure 1 illustrates the card coded by the roentgenologists in the study. This form was devised by Dr. W. Edward Chamberlain of Temple University, who served as consultant to the study.

FIGURE 1

Film Coding Form

Case No.		Film Date:		Film Type:	
Name:				Date Read:	
A	X	Not read	C	9	Minimal
	9	Negative		8	Moderately advanced
	8	Unsatisfactory		7	Far advanced
	7	Tuberculosis		6	Extent not classifiable
	6	Suspect Tbc.		5	Tumor
	5	Calcification		4	Sarcoidosis
	4	Pleurisy, dry		3	Cardiac
	3	Pleurisy, wet		2	Unclassified pathology
	2	Other pathology	D		No cavitation
B	1	Upper right		1	Believed inactive
	2	Upper left		2	Questionable activity
	3	Lower right		3	Believed active
	4	Lower left		4	Cavitation

For the multiple film reading a sequential procedure was followed. Two roentgenologists, hereinafter designated Reader 1 and Reader 2, interpreted all films independently (first and second readings). Following this reading they conferred on all films in which one or more of the following discrepancies occurred (third reading):

Discrepancies:

1—Negative or unsatisfactory vs. tuberculosis
2—Negative vs. suspected tuberculosis
3—Tuberculosis vs. suspected tuberculosis
4—Wet pleurisy vs. no wet pleurisy
5—Left vs. no left or right vs. no right
6—Minimal vs. far advanced
7—Inactive vs. questionably active
8—Inactive vs. active

9—Questionably active vs. active

10—Cavity vs. no cavity

Not Considered Discrepancies:

Calcification vs. no calcification

Dry pleurisy vs. no dry pleurisy

One half vs. two halves on same side

Minimal vs. moderately advanced

Moderately advanced vs. far advanced

Other pathology vs. no other pathology

Tumor, sarcoidosis, or cardiac vs. no tumor, no sarcoidosis, and no cardiac

Following the conference the senior author reread all films on which the two first readers had been unable to reach agreement (fourth reading). For subsequent purposes we designated as the "summary reading": (a) the common reading of those films on which there had been initial agreement and (b) the conference reading if there was initial disagreement followed by agreement in conference; or (c) the referee reading of the senior author if it was required.

As a final check a fifth reading was made by an experienced roentgenologist, who was a tuberculosis specialist and former Army Medical Corps officer with a current large experience in the diagnosis of tuberculosis. His reading was limited to those cases in which Army medical officers at induction or discharge of men had apparently made an error. An "error" was considered to be any one of the following:

1. An induction film, whether Roster I or Roster II, read as tuberculosis or suspect tuberculosis.

2. A discharge film from Roster I *not* read as tuberculosis or suspect tuberculosis.

3. A discharge film from Roster II read as tuberculosis or suspect tuberculosis.

In the fifth reading every effort was made to establish a definitive diagnosis, and eliminate insofar as possible the category "suspect tuberculosis." The fifth reading was made in consultation with the senior author to this extent: All films with respect to which the roentgenologist selected for this purpose disagreed conspicuously with the first two readers or in which for any reason the fifth reading as first made appeared to be questionable were reread by the senior author. The number thus reread was relatively small and in all cases a final agreement was reached by the roentgenologist making the fifth reading and the senior author, so that in effect the fifth reading was a final joint reading by these two interpreters.

The fifth reading did not cover all films included in the summary reading, but did include some films from the initial uncontested readings and the conference and subsequent referee readings. In case of discrepancy with any of the latter the fifth reading was considered to take precedence as a definitive interpretation. From a combination of the fifth reading and all films from the summary reading in which no Army error was involved, a so-called final reading was tabulated, which was considered to be as close to a theoretically perfect reading as it was possible to obtain with the organization set up for the study.

Finally, the data were brought together at the Follow-up Agency of the National Research Council, where the information was coded and transferred to punchcards and tabulations prepared.

ADEQUACY OF SAMPLE

While the sampling plan insures that the two rosters are truly representative of all enlisted men who meet the criteria for study, it was not possible to obtain induction and separation X-rays for all men on the rosters. Table 1 shows the success we had in finding films.

TABLE 1

Number and Percent of Induction and Separation Films Found and Reviewed for Each Roster

	Roster I		Roster II	
	Number	Percent	Number	Percent
Total	3,099	100.0	3,000	100.0
Induction films reviewed	2,759	89.0	2,872	95.7
Separation films reviewed	2,462	79.4	2,733	91.1

Inasmuch as films labeled "induction film" might be taken many months before the man in question actually entered upon active duty in the Army, and a parallel situation held with respect to separation films, for the purposes of this study an induction or separation film was considered to be any film taken within 90 days of the actual date of entry into service or discharge. For 88 men on the tuberculosis roster with very short service it was necessary, using this criterion, to search for only a single film; 62 of these films were obtained while 26 could not be found. Thus, although we have 10,826 readings, only 10,764 films are involved.

The question, of course, arises as to whether the men for whom films were found and reviewed for each roster are representative of the whole roster. We have, therefore, compared the individuals on each roster for whom films were or were not found with respect to the various items of information available. Factors not significantly related to the chance of recovering films are race, place of induction, educational level, and branch of service. Factors which were found to be related have to do with the year of separation and the length of service and, in Roster I, the discharge diagnosis. Table 2 shows that in the control roster (Roster II) the chance of obtaining the induction film seemed to be constant for all groups, but the chance of finding the separation film was relatively poor for men who were separated in 1944 or earlier, or who served 18 months or less. This reflects the fact that separation films were not made routinely until mid-1944.

Table 3 shows the proportions of films reviewed for men on the tuberculosis roster according to the discharge diagnosis.

TABLE 2

Percent of Induction and Separation Films Found and Reviewed for Each Roster by Selected Characteristics of Service

	Roster I			Roster II		
	Number of Men	Percent of Films Reviewed		Number of Men	Percent of Films Reviewed	
		Induction	Separation		Induction	Separation
All men	3,099	89.0	79.4	3,000	95.7	91.1
Inducted in 1942	1,295	90.4	81.0	1,061	94.9	88.7
Inducted 1943 or later	1,804	88.0	78.3	1,939	96.2	92.4
Separated in 1943	741	87.3	74.2	153	94.1	47.7
Separated in 1944	661	91.1	76.9	107	92.5	73.8
Separated in 1945–1946	1,697	89.0	82.7	2,740	95.9	94.2
18 months or less of service	1,419	88.7	74.8	450	94.9	72.0
19 months or more of service	1,680	89.3	83.3	2,550	95.9	94.5
Age at induction 35 or less	2,876	88.8	79.5	2,857	95.8	91.3
Age at induction 36 or more	218	91.3	78.9	132	94.7	87.1

TABLE 3

Number and Percent of Induction and Separation Films Found and Reviewed for the Tuberculosis Roster by Discharge Diagnosis

Diagnosis at Discharge	Number of Men	Induction Films Reviewed		Separation Films Reviewed	
		Number	Percent	Number	Percent
All men	3,099	2,759	89.0	2,462	79.4
Active pulmonary tuberculosis	2,006	1,791	89.3	1,612	80.4
Inactive pulmonary tuberculosis	626	539	86.1	480	76.7
Pulmonary tuberculosis, activity not stated	31	28	90.3	22	71.0
Tuberculosis of trachea, bronchi, or pleura	174	159	91.4	158	90.8
Other nonpulmonary tuberculosis	262	242	92.4	190	72.5

As might be expected, the proportions of induction films reviewed vary but little, but there are differences of some magnitude among the proportions of separation films found. Proportionate recovery of the latter group is about the same for men called active or inactive pulmonary tuberculosis at discharge, but is higher for men with tuberculosis of the trachea, bronchi, or pleura, and lower for men with other nonpulmonary tuberculosis and for men with pulmonary tuberculosis of unstated activity. That we lack separation films for men with nonpulmonary tuberculosis is not particularly damaging. Moreover, the fact that recovery of induction films is independent of the discharge diagnosis implies that the group of films found and reviewed can probably serve as a fair basis for a review of the operation of the induction screen as it was applied to men destined to be discharged for tuberculosis.

The fact that the return of films for Roster I is lower than for Roster II must be ascribed to the fact that films for men on the tuberculosis roster were much more frequently called out of file for review and hence subject to much greater risk of loss. This is inferred from table 4, which shows the location of those films which were found: more than a quarter of the separation films for Roster I were found in Veterans Administration hospital files.

TABLE 4

Location of Films Found

Location of Film	Roster I				Roster II			
	Induction Films		Separation Films		Induction Films		Separation Films	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Total	3,099	100.1	3,099	100.1	3,000	100.0	3,000	99.9
VA Records Center	2,702	87.2	1,261	40.7	2,872	95.7	2,719	90.6
VA Hospital	34	1.1	841	27.1	0	0	4	.1
Army Hospital	14	.5	321	10.4	0	0	10	.3
VA Claims Folder	9	.3	39	1.3	0	0	0	0
Not Found	340	11.0	637	20.6	128	4.3	267	8.9

3. MULTIPLE INTERPRETATION OF FILMS

A series of investigations since the war has revealed a previously unsuspected variability in the interpretation of the same films by different experienced roentgenologists, and similar discrepancy in interpretation by one roentgenologist when examining the same films after a short interval of time. These studies were an outgrowth of an investigation organized in 1945 at the request of the Administrator of Veterans Affairs, in which a group of roentgenologists and chest specialists made a comparative study of the value of chest X-ray films of several types. After intensive study (7) these investigators concluded that all survey films should be read independently by at least two investigators and that persons whose films were read as positive or suggestive for tuberculosis should be recalled for further study.

A recent account (8) in which preceding pertinent literature is reviewed, describes a specific study in which three roentgenologists, all of them recognized leaders in their profession, interpreted a series of films independently of each other on two occasions separated by a short interval of time, endeavoring to classify all films as tuberculous or not, and defining diagnosed tuberculosis in terms of extent and activity. The results disclosed "some disagreement concerning the presence of a possibly tuberculous lesion and more serious disagreement concerning the state of activity of those lesions agreed upon as tuberculous." The authors summarized their results in the latter respect by the statement that "only approximately one-half of the time did two readers agree definitely on *active* or *inactive*. Self confirmation was only a little better."

The investigation described in the present paper was set up in part to study variability in X-ray film interpretation with special reference to military X-ray screening. W. E. Chamberlain, who had been chairman of the board appointed by the Administrator of Veterans Affairs in 1945, acted as consultant to our study and furnished valuable advice based on the numerous similar investigations in which he had participated.

COMPARISON OF X-RAY READINGS

In our study two roentgenologists, hereinafter designated Reader 1 and Reader 2, were employed. Both had had extensive experience in mass X-ray surveys. One had read many thousands of films in New York City and Philadelphia surveys as a roentgenologist for the city department of health and the local tuberculosis association, and the other had read films in continuing Washington, D. C., surveys and particularly in the examination of civilian employees in the Department of the Army in World War II.

The original film interpretations by the two roentgenologists were made independently on different days without knowledge of the roster from which the films came. Discrepancies in reading by the two roentgenologists, as defined above, were noted by the clerical staff, and conferences were held in which the two roentgenologists studied films on which they had disagreed. These conferences in a large proportion of cases resulted in an agreement, which might be agreement with the interpretation of one or the other roentgenologist, or a different interpretation from the original reading of either. In a substantial number of cases, however, agreement was not reached, and a referee reading was made by the senior author, who had the advantage of knowledge of the roster from which the film emanated.

Comparison of the extent of agreement was made with special relation to (1) the presence or absence of tuberculosis, and its location, stage, and degree of activity, (2) the presence and character of other pathology, and (3) the type of film interpreted.

Agreement With Respect to the Presence of Tuberculosis

Table 5 furnishes a gross breakdown of the interpretations of the two readers with respect to the diagnosis of tuberculosis, the suspicion of tuber-

TABLE 5

Overall Comparison of Interpretations of Films by Two Readers

	Total Films		Negative		Tbc.		Suspect Tbc.		Unsat.		Other Pathology	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Reader 1	10,764	100.0	6,555	60.9	2,712	25.2	774	7.2	15	.1	708	6.6
Reader 2	10,764	99.9	6,073	56.4	2,621	24.3	1,316	12.2	13	.1	741	6.9

TABLE 6

Comparison of First and Second Readings as to Presence of Pathology [1]

Reader No. 1	Reader No. 2: Total	Negative	Tbc.	Suspect Tbc.	Pathology Other than Tbc. Only
Total	10,741	6,068	2,619	1,314	740
Negative	6,552	5,497	182	589	284
Tbc.	2,711	68	2,199	353	91
Suspect Tbc.	771	254	177	263	77
Path. other than Tbc. only	707	249	61	109	288
Negative	100.0	83.9	2.8	9.0	4.3
Tbc.	100.0	2.5	81.1	13.0	3.4
Suspect Tbc.	100.0	32.9	23.0	34.1	10.0
Path. other than Tbc. only	99.9	35.2	8.6	15.4	40.7
Total		100.0	100.0	100.0	100.0
Negative		90.6	6.9	44.8	38.4
Tbc.		1.1	84.0	26.9	12.3
Suspect Tbc.		4.2	6.8	20.0	10.4
Path. other than Tbc. only		4.1	2.3	8.3	38.9

[1] This table omits 23 films considered unsatisfactory by one or the other reader.

TABLE 7

Comparison of First and Second Readings as to Extent of Tuberculosis [1]

First Reading	Second Reading					
	Total	Non-Tbc.	Minimal	Mod. Advanced	Far Advanced	Not Classifiable
Total	10,741	6,811	2,308	1,040	476	106
Nontuberculous	7,255	6,317	872	57	5	4
Minimal	2,130	451	1,284	370	8	17
Mod. advanced	865	32	147	514	112	60
Far advanced	471	8	4	95	346	18
Not classifiable	20	3	1	4	5	7

[1] This table omits 23 films considered unsatisfactory by one or the other reader.

culosis, and the diagnosis of nontuberculous lesions. It will be noted that the two roentgenologists agreed fairly well on the percentages of definite tuberculosis and other pathology, but that Reader 2 read about 5 percent less films as negative and 5 percent more films as suspect tuberculosis than Reader 1. In other words, in gross aspect, Reader 1 appeared to make a definite decision in a substantially larger number of equivocal cases than did Reader 2. Table 6 shows that the discrepancy was largely with respect to films considered negative by Reader 1. Of the films read as negative by Reader 2, Reader 1 read as negative 90.6 percent and as suspect tuberculosis 4.2 percent. On the other hand, Reader 2 read as negative only 83.9 percent of the films so read by Reader 1, but read as suspect tuberculosis 9.0 percent of the films read as negative by Reader 1. Their agreements with respect to each other's readings of tuberculosis were respectively 84.0 and 81.1 percent.

The effect of consultation between the two readers with respect to these discrepancies will be discussed later.

Agreement With Respect to Extent of Tuberculosis

Table 7 compares the readings of the two first readers with respect to agreement on extent of tuberculous lesions. Considerable disagreement is evident. There were 2,992 films which both readers called tuberculosis or suspect tuberculosis; within this number there were 112 in which one reader or the other found the extent of the disease unclassifiable, most frequently because of the presence of pneumothorax. Thus 2,880 films were available in which both readers diagnosed tuberculosis and classified it by extent. They agreed in 2,144 instances, or 74.4 percent, and disagreed in 736 instances, or 25.6 percent. Most of the disagreements (98.4 percent) were between minimal and moderately advanced or moderately advanced tuberculosis and far advanced tuberculosis. There were 12 films in which the respective readings were minimal and far advanced, i. e., 1.6 percent of the disagreements and 0.4 percent of the films diagnosed by both readers as tuberculous. It will be noted that in 13 cases one reader read a film as far advanced tuberculosis which the other reader interpreted as nontuberculous.

Agreement With Respect to Activity of Tuberculosis

Table 8 compares the two readers with respect to their diagnoses of activity of tuberculosis. Again, there are 2,992 films which both the readers considered to show tuberculosis; in 1,906 instances, or 63.7 percent of these films, both diagnosed active disease. In 417 instances both readers thought that activity was questionable, while in only 15 films was there agreement on inactive tuberculosis. If, therefore, we ignore for the moment the question of cavitation, we find agreement with respect to activity in 2,338 films, or 78.1 percent. Actually, the agreement is even better than this figure would indicate, for the majority of the 654 disagreements, if they may be called that, were with respect to films which one reader or the other considered questionable and in which there was no mention of cavitation: 621, or 95.1 percent, of the disagreements were of this relatively trivial nature. In only 33 cases, or 4.9 percent, were the disagreements substantial, i. e., inactive vs. active or cavitation vs. inactive or questionable activity.

TABLE 8

Comparison of First and Second Readings as to Activity of Tuberculosis [1]

First Reading	Second Reading					
	Total	Tuberculosis				Non-Tbc.
		Inactive	Questionable Activity	Active		
				No Cavitation	Cavitation	
Total	10,741	102	1,456	1,809	566	6,808
Tuberculosis:						
Inactive	68	15	23	6	1	23
Questionable activity	1,071	27	417	269	13	345
Active:						
No cavitation	1,869	7	302	1,252	191	117
Cavitation	474	0	6	106	357	5
Nontuberculous	7,259	53	708	176	4	6,318

[1] This table omits 23 films considered unsatisfactory by one or the other reader.

Table 9 is similar to table 8 except that now we restrict ourselves to the induction films for the tuberculosis roster: these films, as a group, should represent the most difficult problems. We find somewhat poorer agreement here than in table 8. Of the 980 films which both readers call tuberculous, agreement as to activity (without reference to the presence of cavitation in active disease) is found in 666 films, or 68.0 percent. This is considerably lower than the 78.1 percent agreement found in table 8. On the other hand, of the 314 films in which there was disagreement, 299, or 95.2 percent, were of relatively minor nature, i. e., inactive vs. questionable activity, or questionable activity vs. activity without cavitation.

TABLE 9

Comparison of First and Second Readings as to Activity of Tuberculosis; Induction Films, Tuberculosis Roster [1]

First Reading	Second Reading					
	Total	Tuberculosis				Non-Tbc.
		Inactive	Questionable Activity	Active		
				No Cavitation	Cavitation	
Total	2,752	29	729	572	54	1,368
Tuberculosis:						
Inactive	23	5	4	4	0	10
Questionable activity	565	11	255	126	7	166
Active:						
No cavitation	594	3	158	350	26	57
Cavitation	33	0	1	12	18	2
Nontuberculous	1,537	10	311	80	3	1,133

[1] This table omits 7 films considered unsatisfactory by one or the other reader.

Agreement With Respect to Location of Tuberculous Lesions

The analysis showed that the readers agreed well on location of lesions within the limits set for conference, i. e., not counting as disagreement those cases in which one reader read only one-half of a lung as involved where the other read both halves. However, there were 65 instances in 2,992 films in which both readers diagnosed tuberculosis in which one reader located the disease entirely on one side and the other reader entirely on the opposite side, thus necessitating a conference to resolve the disagreement. This represents a discrepancy of 2.2 percent, not large but not insignificant.

Agreement With Respect to Calcification

Mobilization Regulations for World War II (MR 1–9) laid considerable stress on calcified lesions as a cause for rejection. Disqualification was based on the size and number of supposedly tuberculous calcified lesions, and many induction stations interpreted the regulations with absolute rigidity. Since the distinction between a spot of calcification and a blood vessel on end is not always easy, and other factors interfere with definitive diagnosis, it is not surprising that discrepancy between the two readings in this study was frequent.

For our purposes, calcification was divided as follows:

Code No.

5............. Single spot.
6............. Multiple, single system, unilateral.
7............. Multiple, single system, bilateral.
8............. Disseminated widely.
V............ Unclassified.

Table 10 compares the first and second readings as to presence of calcification. Of the 1,206 films in which one reader or the other diagnosed calcification, only 418, or about 35 percent, were so diagnosed by both readers. The correlation between the readers is, therefore, not high. The two readers disagreed on the presence of calcification in a total of 788 films, i. e., 7.3 percent of the total number of films examined.

In the films in which both readers agreed on the presence of calification, agreement as to its type and extent was low. Out of 400 such films in which the extent of the calcification was stated by both readers, there was agreement as to extent in only 223, or 55.8 percent. In view of the stress on calcified lesions in mobilization regulations this discrepancy in the readings of two experienced roentgenologists is striking.

TABLE 10

Comparison of First and Second Readings as to Presence of Calcification

First Reading	Total	Second Reading	
		No calcification	Calcification
Total	10,741	9,948	793
No calcification	9,910	9,535	375
Calcification	831	413	418

Agreement With Respect to Other Pathology Than Tuberculosis

In order to save space the tabulations are omitted. Like all other omitted tabulations they are available on request to the authors.

For present purposes wet pleurisy is included with other pathology. Although the readers were encouraged to note all pathology seen, of every kind, actually, combinations were infrequent; in the entire group of films only 27 times did one reader or the other diagnose two distinct pathological findings other than tuberculosis or calcification.

Disagreement was great regarding the presence of "other pathology," particularly in the heterogeneous group of nontuberculous lesions tabulated simply as "unclassified" other pathology. Out of 292 films in which one or the other reader made this diagnosis there was agreement in only 31, or 10.6 percent.

Agreement was better in the case of wet pleurisy. Out of 590 films in which either reader made this diagnosis, agreement occurred in 317, or 53.7 percent. In 219, or 37.1 percent, of the 590 cases one reader diagnosed wet pleurisy while the other saw no lesion at all. Apparently, in many of these cases the discrepancy rested on a film defect. In not a few films the diaphragmatic region was clouded; the obscuring cloud was frequently interpreted as effusion by one reader and considered a defect in film technic by the other. In the remaining 54 cases, or 9.2 percent, shadows interpreted as wet pleurisy by one reader were called something else by the other reader. Reader 1 diagnosed "dry pleurisy" in 44 cases in which Reader 2 had diagnosed "wet pleurisy." This is not surprising, as distinction in many cases was equivocal. The senior author in refereeing the conference readings frequently saw cases of resolving pleural effusion in which either diagnosis would have been correct.

In general, agreement as to "dry pleurisy" was poor. Each reader diagnosed the lesion in approximately 100 cases, but in only 18 instances did both readers diagnose dry pleurisy in the same film. Although the original instructions with respect to apical pleural thickening and small diaphragmatic adhesions seemed clear at the time of the organization of the study, actually, agreement on separation of the significant from the insignificant, as the figures show, proved impractical.

Similar results prevailed in the case of cardiac abnormalities. In the two groups of readings cardiac lesions were read 65 times. They were diagnosed by both readers in the same film only 8 times. In general, what was called cardiac by one reader was read as negative or other pathology by the other.

There were 24 instances of diagnosis of tumor by one or the other reader. There were joint readings in only 2 cases, or 8.3 percent. In 17 instances, or 70.8 percent, where one reader diagnosed tumor, the other saw no pathology. In the remaining 5 cases, or 20.8 percent, the other reader saw a lesion, but interpreted it differently.

There were only 2 instances of diagnosis of sarcoidosis, and agreement in neither of them.

Discrepancy in Interpretation in Relation to Type of Film

In order to study the relation between the film size and discrepancies in interpretation, comparisons were made of the interpretations of the two readers in three groups: (1) the induction films of the tuberculosis roster, which actually contained numerous cases of tuberculosis; (2) the discharge films of the tuberculosis roster, which on every basis of reading were predominantly tuberculous; and, (3) the total control roster, including both induction and discharge films, most of which on every basis of reading were predominantly negative. Tables 11, 12 and 13 show the results of the comparison.

No differences worthy of note between different film sizes were detected in the comparison (as negative or not negative) of the readings of the induction films of the tuberculosis roster (table 11). This group, if we may accept the final reading as representing actuality, was made up to the extent of about 40 percent of cases of tuberculosis and 60 percent of nontuberculous cases. The proportion of films for which there was agreement was not high for any film size in this group.

The comparison of the readings of discharge films for the tuberculosis roster was quite different (table 12). Here the agreement, measured as before, was much higher for all film sizes. The overwhelming majority of these films exhibited frank pulmonary tuberculosis, frequently in an advanced stage. The disagreement, as subsequent study showed, was largely in the case of men discharged with nonpulmonary tuberculosis, who might

TABLE 11

Comparison of First and Second Readings in Relation to Kind of Film; Tuberculosis Roster, Induction Films

First Reading	Second Reading			Percent Agreement
	Total	Negative	Not Negative	
4 by 5 film				
Total	111	51	60	77.5
Negative	52	39	13	
Not negative	59	12	47	
4 by 10 film				
Total	2,218	1,005	1,213	76.4
Negative	1,138	810	328	
Not negative	1,080	195	885	
14 by 17 film				
Total	171	27	144	77.8
Negative	49	19	30	
Not negative	122	8	114	
14 by 17 paper				
Total	242	90	152	77.7
Negative	104	70	34	
Not negative	138	20	118	

TABLE 12

Comparison of First and Second Readings in Relation to Kind of Film; Tuberculosis Roster, Separation Films

First Reading	Second Reading			Percent Agreement
	Total	Negative	Not Negative	
4 by 5 film				
Total	57	3	54	96.5
Negative	5	3	2	
Not negative	52	0	52	
4 by 10 film				
Total	41	3	38	90.2
Negative	3	1	2	
Not negative	38	2	36	
14 by 17 film				
Total	2,244	121	2,123	93.1
Negative	179	73	106	
Not negative	2,065	48	2,019	
14 by 17 film stereo				
Total	54	0	54	98.1
Negative	1	0	1	
Not negative	53	0	53	

or might not have pulmonary tuberculosis in addition. Most of the films of this group were flat 14- x 17-inch celluloid films; in them agreement reached 93.1 percent. The numbers of films in the other groups were small and the recorded percentages of agreement correspondingly less significant, but it is interesting to note that agreement was poorest in the case of the type of film most widely used at induction, viz, the 4- by 10-inch stereophotofluorogram.

Finally, the comparison of readings in the control roster (table 13) shows that agreement in interpretation of the large films was not so good as that with small films. This is perhaps explained by the fact that the large films showed so much detail in pulmonary markings, normal or abnormal, that the chance for discrepancy was increased.

TABLE 13

Comparison of First and Second Readings in Relation to Kind of Film; Control Roster, All Films

First Reading	Second Reading: Total	Second Reading: Negative	Second Reading: Not Negative	Percent Agreement
4 by 5 film				
Total	1,870	1,694	176	88.1
Negative	1,679	1,575	104	
Not negative	191	119	72	
4 by 10 film				
Total	2,952	2,608	344	87.6
Negative	2,717	2,479	238	
Not negative	235	129	106	
14 by 17 film				
Total	502	303	199	67.1
Negative	414	276	138	
Not negative	88	27	61	
14 by 17 paper				
Total	264	160	104	74.2
Negative	206	149	57	
Not negative	58	11	47	

In tables 11, 12 and 13, agreement between readers was considered only in relation to whether or not the film was called negative. It seemed interesting to inquire whether, if one limited oneself to those films in which the readers had both independently read either tuberculosis or suspect tuberculosis, one would find in large films better agreement as to the stage of disease than in small films. Table 14 shows the numbers of readings of various kinds which were found. Summary measurements of the correlations between the two readings were: [1]

4 by 5 film	0.66
4 by 10 film	.55
14 by 17 film	.61
14 by 17 paper	.47

[1] Tschuprow's coefficient of correlation, T, in contingency tables is given by:

$$T^2 = \frac{\chi^2}{N\sqrt{(p-1)(q-1)}}$$

where N is the number classified, and p and q are the numbers of rows and columns.

See Kendall, M. G., The Advanced Theory of Statistics, Vol. 1, London, 1947, p. 320.

These measures may be interpreted as being correlation coefficients, i. e., unity would represent perfect agreement, while zero would denote complete lack of relationship between readings. In this instance, the correlations are not very different except for 14 by 17 paper plates, which seem somewhat poorer. On the other hand, the differences in the sizes of the coefficients are not large compared with their sampling variability. A further complication arises out of the fact that the 14 by 17 films, being largely separation films, contained much more pathology than the 4 by 10 films, which were largely induction films. It is not at all clear what effect this difference has on the agreement comparisons. This point would be best elucidated by a suitably designed experiment.

TABLE 14

Comparison of First and Second Readings as to Extent of Tuberculosis in Relation to Type of Film; Roster I and Roster II, Induction and Separation Films

First Reading	Second Reading			
	Total	Minimal	Moderately Advanced	Far Advanced
4 by 5 film				
Total	107	66	36	5
Minimal	66	58	8	0
Moderately advanced	31	8	23	0
Far advanced	10	0	5	5
4 by 10 film				
Total	825	652	162	11
Minimal	661	595	66	0
Moderately advanced	143	56	85	2
Far advanced	21	1	11	9
14 by 17 film				
Total	1,795	622	729	444
Minimal	810	542	261	7
Moderately advanced	576	77	391	108
Far advanced	409	3	77	329
14 by 17 paper				
Total	97	69	25	3
Minimal	79	63	15	1
Moderately advanced	15	6	9	0
Far advanced	3	0	1	2

Comparison of First Two Readings With Final Reading

It will be recalled that the final reading represented the best judgment that could be made on each film. The final readers had available not only the opinions of the first two readers, but also had both induction and discharge films together, an advantage furnishing information on the outcome of a case in which the induction film was equivocal. They were also informed of the roster from which films emanated, and made a determined effort to reach a definitive diagnosis of tuberculosis or no tuberculosis, eliminating insofar as possible the interpretation "suspect tuberculosis." An instructive view of the results of this forced choice may be obtained from table 15, wherein, in order to obtain an overall view of the situation, we group all diagnoses of tuberculosis or suspect tuberculosis together, without regard to stage or activity, and call "negative" all films on which no diagnosis of tuberculosis or suspect tuberculosis was made. Induction and discharge films have been combined for each roster, but the rosters are kept distinct. So-called "errors" (discrepancies would be a better term) have been placed in parentheses, and each kind of error is shown as a percent, the denominator of which is the maximum number of times the error could have been committed. Thus, on Roster I, of 3,194 positive films (as judged by the final reading), Reader 1 read 261 negative, which we call an error rate of "omission" of 8.2 percent. Errors of "commission" are similarly defined, being positive diagnoses by the readers of films judged in the final reading to be negative. The total numbers of films vary slightly because of differences of opinion as to whether certain films were unsatisfactory.

TABLE 15

Comparison of First and Second Readings With Final Reading as to Diagnosis of Tuberculosis or Suspect Tuberculosis

	Final Reading			Errors of—	
	Total	Negative for Tbc.	Positive for Tbc.	Commission	Omission
				(Percent)	
First Reading					
Roster I	5,151	1,957	3,194		
Negative for Tbc.	1,887	1,626	(261)		8.2
Positive for Tbc.	3,264	(331)	2,933	16.9	
Roster II	5,596	5,543	53		
Negative for Tbc.	5,374	5,358	(16)		30.2
Positive for Tbc.	222	(185)	37	3.3	
Second Reading					
Roster I	5,150	1,957	3,193		
Negative for Tbc.	1,679	1,444	(235)		7.4
Positive for Tbc.	3,471	(513)	2,958	26.3	
Roster II	5,596	5,543	53		
Negative for Tbc.	5,132	5,116	(16)		30.2
Positive for Tbc.	464	(427)	37	7.7	

The most significant feature of table 15 is that for each reader "errors" of commission are much higher for Roster I than for Roster II, while the reverse is true for "errors" of omission. This fact inclines us strongly to the view that the so-called errors of *commission* for Roster I were for the most part not errors at all; on the contrary, in all probability, the fifth reading, which entered into the final reading, erred in calling the films negative. The errors of omission for Roster II similarly, are in reality probably mistakes in the fifth reading, since the films for the most part probably were really negative. In other words, it seems likely that most films called suspect tuberculosis, on which an attempt was made to reach a decision in the fifth reading, actually were positive films when they came from Roster I and really negative when they came from Roster II.

It may be asked, at this point, what is meant by a film being "really negative" since there is not always agreement by roentgenologists on particular films. By negative films (from the standpoint of tuberculosis) we mean, ordinarily, films which do not show certain markings found characteristically in roentgenograms of persons proved by other means to have pulmonary tuberculosis. In other words, if characteristic markings appear frequently in the chest films of persons known to have tuberculosis, or proved subsequently to have developed the disease, and infrequently in films of persons without tuberculosis, then we call films with such characteristics positive. That is exactly the situation we have here, illustrated in table 15. Restricting our analysis for the moment to films called negative in the final reading, Readers 1 and 2 were each three to four times as likely to designate films from the tuberculosis roster as "positive" as to so designate films from the control roster. A corresponding situation holds for the films called positive by the final readers. We must conclude that the original readings contain useful information regarding the true character of films over and above what is present in the final readings. We shall return to this point.

DISAGREEMENT IN REREADING FILMS

As noted in a previous section of this paper, a number of investigators have studied the personal variability of individual roentgenologists as shown in the rereading of films read several months previously. These investigators found a surprising extent of self-disagreement, even among distinguished radiologists of wide experience. In order to make a similar appraisal, and so that we might be better able to evaluate the differences in interpretations *between* readers, we asked our readers to interpret the induction and separation films from 128 randomly selected cases from Roster I (the tuberculosis roster) and 122 from Roster II (the control roster) on two occasions approximately 4 months apart. In the meantime, each had read thousands of films, and the films resubmitted to them were not in the same order as before. To all intents and purposes they were new films.

The data are presented separately for the induction and separation films for men on the tuberculosis roster in tables 16 and 17 and for all films for men on the control roster in table 18. As we have seen, the chance that there will be a discrepancy in two readings on the same film depends in part on whether or not the film exhibits pathology; therefore, we examined separately the situation in a group of films about half of which showed pathology, as decided in the final reading (table 16), a group in which almost all films showed pathology (table 17), and a group in which almost all were unequivocally negative (table 18).

It will be seen from the tables that a marked self-disagreement in interpretation was found, comparable in character and extent to the variation observed between the two readers. In the case of the induction films of Roster I, in every comparison, i. e., the separate interpretations of the two readers, and the repeat readings of each, the most frequent type of disagreement was between "negative" and "suspect tuberculosis." The next most frequent disagreements were the diagnosis of "tuberculosis" in one reading, contrasting with a diagnosis of "suspect tuberculosis" in the other, and a diagnosis of "active tuberculosis" in one reading and "questionably active" disease in the other. Disagreement represented by the extremes of diagnosis of unequivocal "tuberculosis" in one reading and "negative" in the other was infrequent, nor were there any cases of so serious a discrepancy as diagnosis of "active" tuberculosis in one reading and "inactive" disease in the other.

Disagreement in interpretations of the two readers in comparison with each other and in their own first and second readings was even more frequent in the case of the separation films of this roster. Here, since virtually all films showed some type of lesion, and the lesions were of varying character and extent as indicated by the final reading, the chance for discrepancy in reading was great. It will be noted, perhaps with surprise, that the most frequent cause of disagreement in all comparative readings was with respect to the unilaterality or bilaterality of the tuberculosis process. This is perhaps not the most serious of types of disagreement, but it clearly demonstrates the fallibility of judgment in a single reading. The second and third most frequent types of discrepancy were variable, but much like the discrepancies noted in the case of the induction films of this roster. Again the major discrepancy between unequivocal "tuberculosis" and "negative" was relatively infrequent, as was the discrepancy of "active" and "inactive." It should be pointed out that the provision of a category of "questionable activity" made it possible for the roentgenologists to avoid an outright decision of activity or inactivity in equivocal cases.

TABLE 16

Discrepancies in Film Readings Between Two Roentgenologists and Between Original Readings and Rereadings After Interval of Four Months; Tuberculosis Roster, Induction Films

	Original Reading		Rereading		Reader No. 1		Reader No. 2	
	Reader 1 vs. Reader 2		Reader 1 vs. Reader 2		Original vs. Rereading		Original vs. Rereading	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
All Films	128	100.0	128	100.0	128	100.0	128	100.0
Films without discrepancy	91	71.1	79	61.7	70	54.7	85	66.4
Films with discrepancy [1]	37	28.9	49	38.3	58	45.3	43	33.6
Negative or unsatisfactory vs. tuberculosis	3	2.3	0	-------	8	6.3	1	.8
Negative vs. suspected tuberculosis	19	14.8	25	19.5	29	22.7	23	18.0
Tuberculosis vs. suspected tuberculosis	7	5.5	14	10.9	12	9.4	12	9.4
Wet pleurisy vs. no wet pleurisy	1	.8	1	.8	0	-------	0	-------
Left vs. no left or right vs. no right	5	3.9	7	5.5	5	3.9	5	3.9
Minimal vs. far advanced tuberculosis	0	-------	0	-------	0	-------	0	-------
Inactive vs. questionably active	0	-------	1	.8	1	.8	1	.8
Inactive vs. active	0	-------	0	-------	0	-------	0	-------
Questionably active vs. active	9	7.0	17	13.3	9	7.0	12	9.4
Cavity vs. no cavity	0	-------	2	1.6	2	1.6	2	1.6

[1] Since readings for some films exhibited more than a single discrepancy, the sums of the numbers of films showing the different specific discrepancies exceed the total number of films on which there was disagreement.

TABLE 17

Discrepancies in Film Readings Between Two Roentgenologists and Between Original Readings and Rereadings After Interval of Four Months; Tuberculosis Roster, Separation Films

	Original Reading		Rereading		Reader No. 1		Reader No. 2	
	Reader 1 vs. Reader 2		Reader 1 vs. Reader 2		Original vs. Rereading		Original vs. Rereading	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
All Films	128	100.0	128	100.0	128	100.0	128	100.0
Films without discrepancy	54	42.2	58	45.3	73	57.0	67	52.3
Films with discrepancy [1]	74	57.8	70	54.7	55	43.0	61	47.7
Negative or unsatisfactory vs. tuberculosis	10	7.8	5	3.9	4	3.1	5	3.9
Negative vs. suspected tuberculosis	15	11.7	14	10.9	8	6.2	9	7.0
Tuberculosis vs. suspected tuberculosis	14	10.9	9	7.0	8	6.2	10	7.8
Wet pleurisy vs. no wet pleurisy	7	5.5	8	6.3	7	5.5	4	3.1
Left vs. no left or right vs. no right	24	18.8	21	16.4	19	14.8	27	21.1
Minimal vs. far advanced tuberculosis	0	------	1	.8	0	------	0	------
Inactive vs. questionably active	2	1.6	2	1.6	3	2.3	1	.8
Inactive vs. active	1	.8	0	------	1	.8	1	.8
Questionably active vs. active	14	10.9	11	8.6	13	10.2	7	5.5
Cavity vs. no cavity	11	8.6	13	10.2	7	5.5	11	8.6
Minimal, moderately advanced or far advanced tuberculosis vs. tuberculosis with no stage given	1	.8	1	.8	1	.8	2	1.6

[1] Since readings for some films exhibited more than a single discrepancy, the sums of the numbers of films showing the different specific discrepancies exceed the total number of films on which there was disagreement.

TABLE 18

Discrepancies in Film Readings Between Two Roentgenologists and Between Original Readings and Rereadings After Interval of Four Months; Control Roster, Induction and Separation Films

	Original Reading		Rereading		Reader No. 1		Reader No. 2	
	Reader 1 vs. Reader 2		Reader 1 vs. Reader 2		Original vs. Rereading		Original vs. Rereading	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
All Films	244	100.0	244	100.0	244	100.0	244	100.0
Films without discrepancy	227	93.0	212	86.9	229	93.9	214	87.7
Films with discrepancy [1]	17	7.0	32	13.1	15	6.1	30	12.3
Negative or unsatisfactory vs. tuberculosis	2	.8	2	.8	1	.4	2	.8
Negative vs. suspected tuberculosis	14	5.7	26	10.7	13	5.3	26	10.7
Tuberculosis vs. suspected tuberculosis	0	------	0	------	0	------	2	.8
Wet pleurisy vs. no wet pleurisy	1	.4	1	.4	1	.4	0	------
Left vs. no left or right vs. no right	0	------	3	1.2	0	------	0	------
Minimal vs. far advanced tuberculosis	0	------	0	------	0	------	0	------
Inactive vs. questionably active	0	------	0	------	0	------	0	------
Inactive vs. active	0	------	0	------	0	------	0	------
Questionably active vs. active	0	------	0	------	0	------	2	.8
Cavity vs. no cavity	0	------	0	------	0	------	0	------
Minimal, moderately advanced or far advanced tuberculosis vs. tuberculosis with no stage given	0	------	0	------	0	------	0	------

[1] Since readings for some films exhibited more than a single discrepancy, the sums of the numbers of films showing the different specific discrepancies exceed the total number of films on which there was disagreement.

In the case of the films of the control roster (table 18) discrepancies in reading were relatively infrequent. As might be expected in this group, in which few films showed lesions, the chief cause of discrepancy in the reading of both induction and separation films was the same as that in the case of the induction films of Roster I, viz, the reading of "suspect tuberculosis" in the one and of "negative" in the other reading. The second most frequent type of disagreement, somewhat surprisingly, was between a diagnosis of unequivocal "tuberculosis" and "negative," but the figures concerned are very small.

In summary, it may be said that self-disagreement was great in the case of films of the tuberculosis roster and minor in the case of films of the control roster, and that the chief cause of disagreement was in the borderline range, as exemplified in the diagnoses of "negative" and "suspect tuberculosis," and in the distinction between unilateral and bilateral lesions. Two other borderline categories, "tuberculosis" vs. "suspect tuberculosis" and "questionably active" vs. "active," were not infrequent causes of discrepancy. Further, the discrepancies in film readings which arose from the comparison of the interpretations of two different roentgenologists were no more frequent than those arising out of a comparison of readings at different times by a single roentgenologist. On the whole, the discrepancies chiefly involved levels of precision attainable only with difficulty. Indeed, we may conclude that we have demanded a degree of specificity of diagnosis which cannot be consistently achieved by means of a single film reading.

4. THE INDUCTION SCREEN

VARIABILITY OF INDUCTION STATIONS

It may be supposed that the quality of work done by radiologists at the different induction stations during World War II was not identical at the different stations, nor indeed even at given stations from time to time. Besides such factors as the different training and skill of different readers, the quality of reading might be affected by variation in the workload caused by changing rates of induction. There would be little point, at this date, in attempting to assess the efficiency of particular stations 10 years ago; however, it does seem of some interest to inquire to what extent the variation in quality of work which impressed the observer at the time actually affected the efficiency of the screening. The senior author, while serving in the Office of The Surgeon General during World War II, had occasion to review the work of all of the induction stations, and at that time formed definite impressions as to which stations were good, fair and poor. We have, therefore, tabulated the final reading of the induction film for those men on Roster I who were inducted at the stations for which the senior author was willing to hazard an opinion:

Opinion of Induction Station	Tuberculosis Roster		
	Number of Induction Films Reviewed	Number Read as Tuberculosis on Final Reading	Percent Read as Tuberculosis on Final Reading
Total	1,882	759	40.3
Good	628	219	34.9
Fair	716	289	40.4
Poor	538	251	46.7

The judgments regarding the stations were, of course, made without knowledge of the results of the tabulations. It will be seen that at the fair and poor stations significantly higher proportions of men are considered to show tuberculosis on final reading than at the good stations. We can calculate what proportions of the tuberculosis roster could have been excluded from service had the fair and poor stations operated as well as did the good ones: we need only find the number which, when subtracted from both the number of films reviewed and the number read as tuberculosis, yields numbers such that the percent read as tuberculosis is 34.9. These numbers turn out to be 60, or 8.4 percent, for the fair stations, and 97, or 18.0 percent, for the poor stations. We conclude, then, that had the fair stations done as well as the good, the number of men destined for future discharge for tuberculosis inducted through those stations could have been reduced by about 8 percent, while the corresponding figure for the poor stations is 18 percent. Finally, had all induction stations operated as efficiently as did those we call good, the total number of tuberculosis discharges would have been reduced by about 8 percent. Unfortunately, we have no information regarding the number of men erroneously rejected at any of the stations; so it may be that the poorer stations compensated to a degree by erroneously rejecting fewer men than did the good stations.

Table 19 shows errors in terms of race and service command of induction. We measured error in terms of the proportion of induction films (considered negative by the induction station) for men on Roster I which, on final reading, we called tuberculosis or suspect tuberculosis. This is not the best measure of error rate conceivable, but since we had no information regarding men rejected by the induction stations we could do no better. These proportions may legitimately be compared for different groups of men and differences may be taken to represent differences in screening efficiency at different induction stations if we make the assumption that the absolute probability of becoming infected while in service is independent of the grouping being studied. Since there is no reason to suppose that white inductees from different service commands who were not infected at the time of induction had different probabilities of becoming infected while in service, we may legitimately, for each racial group separately, use our proportions to compare the service commands. We find that for each racial group the variability by service command in the error proportions far exceeded that which we might expect the forces of chance alone to have produced: the chi-square tests for homogeneity both give probabilities less than one in a thousand. The Third and Sixth Service Commands in particular seem to have done very well, while the Eighth and Ninth Service Commands seem somewhat worse than the average.

TABLE 19

Errors of Omission at Induction Station by Race and Service Command; Tuberculosis Roster—Induction Film Called Negative at Induction Station

Service Command	White			Nonwhite		
	Number Read	Final Reading of Induction Film Tuberculosis		Number Read	Final Reading of Induction Film Tuberculosis	
		Number	Percent		Number	Percent
Total	1,843	758	41.1	628	247	39.3
First	133	51	38.3	9	3	33.3
Second	257	105	40.9	63	20	31.7
Third (including Military District of Washington)	172	57	33.1	80	20	25.0
Fourth	228	96	42.1	180	62	34.4
Fifth	247	111	44.9	58	24	41.4
Sixth	219	68	31.1	34	10	29.4
Seventh	156	62	39.7	21	8	38.1
Eighth	202	101	50.0	116	63	54.3
Ninth	229	107	46.7	67	37	55.2

The differences between whites and nonwhites certainly were not remarkable; however, some caution is indicated in the interpretation of this finding. We cannot assume that the probability of infection while in service was equal for whites and nonwhites, nor do we have any reliable information regarding the prevalence of infections in men of the two races at the time they presented themselves at the induction stations. We can say no more than that for each racial group about the same proportion of the men discharged for tuberculosis represented erroneous inductions.

EFFICIENCY OF SCREENING LEVELS

This leads naturally to the question: How good an X-ray screen could one create had one the will to do it? We are possessed of several careful reviews of the induction films of the men on our two rosters and, moreover, we are in the fortunate position of knowing what happened to these men in the end. We are, therefore, in a position to examine the efficiency of various degrees of stringency in reviewing films and to assess both the gains and losses which would have been achieved during World War II by more intensive screening.

The problem which faces the military services in the construction of a screen is to devise a method capable of distinguishing those individuals able to perform satisfactory service, if inducted, from those who are not. In the case of tuberculosis, a second and no less important consideration is to safeguard the health of the troops by inducting only those men who will not constitute potential sources of infection for their companions. It is clear from this second consideration that one would wish to avoid the induction of any case of active tuberculosis, but there may be differences of opinion regarding the capacity for service of men with old inactive tuberculosis. We shall avoid the necessity of considering this rather large problem by accepting, in this retrospective study, the fact of discharge for tuberculosis as decisive. That is, we shall consider that if an individual was, in fact, discharged for tuberculosis, one would like to have rejected that individual at the induction station had it been possible to have distinguished him from his fellows. On the other hand, we accept as a desirable recruit that man who was accepted, served and was not discharged for tuberculosis. In these terms our two rosters, then, are composed entirely in one instance of men whom it would be desirable to reject and in the other instance of men whom one would want to accept.

While it is undoubtedly true that of the men on our tuberculosis roster, some were already infected at the time of induction while others were not, and that it would be a hopeless task to attempt to single out at the induction station those men not yet infected who are destined to be separated for tuberculosis, we shall, nevertheless, ignore this distinction in discussing the screen; we choose, for simplicity, to regard every individual on Roster I as mistakenly inducted in the sense that had the induction examiners the gift of prescience, all of these men would have been rejected. The reason for this attitude is that it is not possible, even now, to say with any degree of assurance, in many cases, which men were in fact already infected at the time of induction and which were not. We set up as an ideal, then, a screen which would eliminate at the induction station the whole of Roster I while accepting the whole of Roster II; while this ideal is, of course, unachievable, it makes a simple and useful yardstick by which we can measure the efficacy of any particular screening procedure.

The problem we set ourselves, then, is: Given an X-ray film for an individual to attempt to decide whether or not he will, if inducted into service, be discharged for tuberculosis within the subsequent period of 1 to 3 years. Tables 20 and 21 show how well each of the readings would serve the purpose. We use the code letters A through D to designate readings as follows:

A: Negative.
B: Pathology other than tuberculosis only.
C: Suspect tuberculosis.
D: Tuberculosis.

Table 20 shows not only how each of the readings classified the induction films in each roster but also the CDD ratio for each classification. We use this last term to mean the number discharged for tuberculosis per 100,000 discharges in the given classification. The CDD ratios are calculated after inflating the control roster counts by a suitable multiplier which is determined by the different sampling ratios used to obtain the two rosters. It will be recalled that Rosters I and II constitute, respectively, 33 percent and .06 percent samples of the eligible populations. Since the quotient of these two sampling ratios is 550, we should, ordinarily, multiply any Roster II count by 550 in order to compare it with the corresponding Roster I count. However, this multiplying factor must be modified for certain tables to take account of the fact that different proportions of the films were found (and read) for the two rosters. Thus, for first reading of the induction film we use the multiplying factor

$$550 \times \frac{2756}{3099} \times \frac{3000}{2871} = 511.1$$

where 2756 and 2871 are the numbers of films read in Rosters I and II and 3099 and 3000 are the respective roster sizes. The overall CDD ratio is then calculated as:

$$\frac{2756 \times 10^5}{2756 + (511.1) \cdot (2871)} = 187$$

and similarly for any specific category of film.

TABLE 20

First, Second, Summary, and Final Readings of Induction Films and CDD Ratios

	Total	Film Reading			
		A	B	C	D
First Reading					
Roster I	2,756	1,344	193	468	751
Roster II	2,871	2,603	164	86	18
CDD ratio	187	101	230	1,054	7,547
Second Reading					
Roster I	2,755	1,175	194	653	733
Roster II	2,871	2,429	180	218	44
CDD ratio	187	95	210	583	3,157
Summary Reading					
Roster I	2,770	1,101	234	535	900
Roster II	2,872	2,554	258	49	11
CDD ratio	187	84	176	2,081	13,739
Final Reading					
Roster I	2,772	1,266	323	10	1,173
Roster II	2,872	2,573	275	0	24
CDD ratio	187	96	228	0	8,682

TABLE 21

Screening Efficiency of First, Second, Summary, and Final Readings

	Reading of Induction Film			
	D	C+D	B+C+D	A+B+C+D
First Reading				
Percent of Roster I	27.2	44.2	51.2	100.0
Percent of Roster II	.6	3.6	9.3	100.0
Second Reading				
Percent of Roster I	26.6	50.3	57.4	100.0
Percent of Roster II	1.5	9.1	15.4	100.0
Summary Reading				
Percent of Roster I	32.5	51.8	60.3	100.0
Percent of Roster II	.4	2.1	11.9	100.0
Final Reading				
Percent of Roster I	42.3	42.7	54.3	100.0
Percent of Roster II	.8	.8	10.4	100.0

TABLE 22

Screening Efficiency of Combinations of First and Second Readings

	First and Second Reading of Induction Film (Figures are cumulative to the left)						
	D;D	D;C	C;C	D;A or B	C;A or B	B;A or B	A;A
	1.	2.	3.	4.	5.	6.	
Number of Films:							
Roster I	496	794	980	1,172	1,619	1,813	2,752
Roster II	5	17	44	84	322	559	2,870
Percent of Films:							
Roster I	18.0	28.9	35.6	42.6	58.8	65.9	100.0
Roster II	2	.6	1.5	2.9	11.2	19.5	100.0

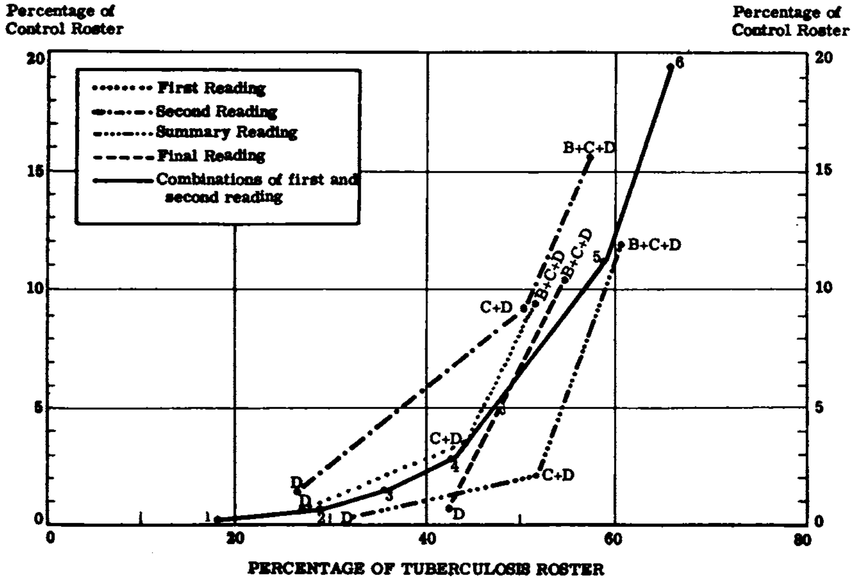
Several rather interesting features are to be noted in table 20. First, for all readings, the CDD ratio among men whose films were read as B (pathology other than tuberculosis only) was about twice the rate in men whose films were called A (negative). This would appear to force the inference that about half of the Roster I cases read as B really had tuberculosis at the time of induction, but that the reoentgenographic signs were atypical if we may assume that they were correctly discharged as tuberculous. Put in another way, about one hundred men per one hundred thousand whose X-rays were read as B may really have had tuberculosis rather than non-tuberculous pulmonary disease.

A second point of some interest is that while the summary reading was evidently much more discriminating in its choice of men for categories C and D than either the first or second reading, it is not clear that the final reading improved on the summary. In fact, the CDD ratio for category B is somewhat higher for the final reading than for the summary reading. We may better compare the relative efficiency of these readings for screening purposes by viewing the results in the form shown by table 21, wherein we see the proportions of Roster I and Roster II films in which at least certain degrees of pathology were read. Table 22 shows similar data for a screen constructed from combinations of the first and second readings. The numbers at the top of each column of table 22 are for reference to figure 2, wherein the data of tables 21 and 22 are plotted.

From figure 2 or table 21 we see that were one to have rejected all men whose induction films were called D (tuberculosis) on first reading one would have rejected 27.2 percent of all men destined to be discharged for

FIGURE 2

Screening Efficiency of Different Readings: Percentages of Controls Who Would Have Been Simultaneously Rejected by Screens Which Rejected Specified Percentages of Men Subsequently Discharged for Tuberculosis



tuberculosis, at a cost of simultaneously rejecting 0.6 percent of men *not* destined to be so discharged. Alternatively, had one rejected men called C or D on first reading, 44.2 percent of the tuberculosis cases would have been saved, but at a cost now of 3.6 percent of men whom we would not have wished to reject by reason of tuberculosis. Finally, the rightmost point on the curve for first reading, labeled "B+C+D," shows that 51.2 percent of Roster I could have been screened out at a cost of 9.3 percent of Roster II. In general, each point on a curve represents a possible way of screening; the abscissa of the point represents the gains to be achieved as measured by the proportion of the tuberculosis roster rejected, while the ordinate represents the manpower cost measured by the proportion of the control roster rejected. It is clear, then, that if one curve lies entirely below another (as the curve for summary reading lies entirely below both first reading and second reading), then the lower curve represents a better screening device at any level of operation. If we decide we want a screen which eliminates, say, 50 percent of the tuberculosis group, we can achieve this by any of the readings, but the manpower cost of the screen which utilizes the summary reading is less than half of the cost of the corresponding screens employing any of the other readings. From this point of view the summary reading seems to be the most efficient.

TABLE 23

Effect of Consideration of Activity on Screening Efficiency of Four Readings

	Induction Film Read as Tuberculosis or Suspect Tuberculosis					
	Roster I			Roster II		
	Total	Inactive		Total	Inactive	
		Number	Percent		Number	Percent
First Reading	1,219	23	1.9	104	6	5.8
Second Reading	1,386	29	2.1	262	16	6.1
Summary Reading	1,435	36	2.0	60	5	8.3
Final Reading	1,183	210	17.8	24	19	79.2

It is of interest to note that despite the very obvious differences between the first and second readings, the point C+D on the curve for second reading is very near to the point B+C+D on the first reading curve. In other words, the numbers of films read by Reader 1 as other pathology, suspect tuberculosis, and tuberculosis were about the same for each roster as the numbers read by Reader 2 as suspect tuberculosis or tuberculosis.

Since the classifications employed do not take account of whether the tuberculosis diagnosed was considered to be active, the question naturally arises whether, if this aspect of the diagnosis were considered, the screening efficiency could be improved. Table 23 presents the data for the summary reading. It will be seen that, for all readings in the case of films called tuberculosis or suspect tuberculosis, Roster II films were three to four times as likely as Roster I films to be considered to show inactive disease. On the other hand, it is also true that, except for the final reading, so small a proportion of positive films in either group was considered to be inactive that the actual gain in efficiency of screening would not have been large. So far as the final reading is concerned, where clearly a considerable increase in efficiency would be achieved by discriminating between those films considered to show inactive disease and those in which activity is at least questionable, since the final reader had both induction and separation films available for simultaneous examination, it is not at all clear to what extent the consideration of activity would be usefully employed at the induction station. The evidence of the first and second readers is that it would be of very limited usefulness, but for a reader who had a lower level of suspicion for activity, this information might be valuable.

A rather obvious conclusion from figure 2 is that independent dual reading, followed by conference on disagreements, is a considerably more efficient method of screening than is single reading: the summary reading was tuberculosis for a larger proportion of the tuberculosis roster and a smaller proportion of the control roster than either the first or the second reading.

It is interesting to note the relative positions of the curves for first and second readings separately, the combination of first and second and the summary reading. The combination is superior everywhere to the individual readings, while the summary is in turn superior to the combination. The difference between the individual readings and the combination represents the additional information contained in both readings which is not present in either alone, while the difference between the combination and the summary measures the information added at the conference itself. It can be seen, therefore, that the superiority over the individual readings of the conference reading derives from two sources: first, from the independent information contained in each of the primary readings which is not contained in the other, and, second, from the information added at the conference review of the films.

TABLE 24

Final Reading of Induction Films and CDD Ratios by Race

Final Reading of Induction Film	White			Nonwhite		
	Roster I	Roster II	CDD Ratio Per 100,000	Roster I	Roster II	CDD Ratio Per 100,000
Total	2,065	2,483	164	692	389	340
Negative	925	2,221	84	341	352	185
Pathology other than tuberculosis only	249	240	204	74	35	404
Tuberculosis or suspect tuberculosis	891	22	7,397	277	2	(1)

[1] Not calculated.

SCREENING IN RELATION TO RACE

It is quite instructive to consider the factor of race in relation to the efficacy of screening. The essential data are shown in table 24 for the final reading. It is clear from this table that while discharge for tuberculosis was about twice as common among nonwhites as among whites, this ratio cannot be easily altered by improved X-ray screening: the CDD ratio was about twice as high in nonwhites as in whites in men for whom the final reading of the induction film was negative, and also in men for whom the final reading was other pathology. In both racial groups about 40 percent of the induction films of men ultimately discharged for tuberculosis were read as tuberculosis or suspect tuberculosis. It would seem to follow that the excess of tuberculosis among nonwhites in service was by no means entirely or even largely an expression of greater likelihood of infection in the civilian environment. Further, it would appear that on the whole the screening of nonwhites which the Army performed during World War II was no less stringent than was the screening for whites.

Information regarding rejections for tuberculosis which was released by the Selective Service System appears superficially to support the notion that the screening of nonwhites was less careful than the screening of whites: thus, rejections for tuberculosis *as primary cause* per 1,000 registrants examined in the continental United States during the period January 1943–September 1943 were 12.7 for whites and 10.9 for Negroes (9). We have emphasized the phrase "as primary cause" because, in actual fact, much of the tuberculosis present in Negro registrants remained undetected because the men were rejected for other, more quickly recognizable conditions. During the period of time mentioned above 55.3 percent of Negro registrants were rejected. More than a quarter of the rejections—27.0 percent—were accomplished by the local boards, the remainder by the induction stations. However, of the 1,671 rejections of Negroes for tuberculosis as primary cause, only 205, or 12.3 percent, were as a result of local board examination. In short, if we inquire, not what proportion of all men examined had tuberculosis, the answer to which cannot be given, but ask instead how many rejections for tuberculosis each racial group generated per 1,000 men inducted into service, we find the numbers are 20.2 for whites and 24.3 for Negroes.

In short, Selective Service statistics give very little trustworthy information regarding the prevalence of tuberculosis in the two races, nor can we, by comparing rejection rates with prevalence data independently derived, draw firm conclusions regarding the care with which tuberculosis screening was accomplished for the two races. This is, in fact, recognized by the Selective Service System: (2) ". . . Also, during the war periods the figures on tuberculosis, particularly those for Negroes, were not reduced as much as during peacetime by the tendency of examining physicians to select diagnoses of venereal disease or of educational deficiency as principal cause for rejection."

RELATION TO NONTUBERCULOUS PATHOLOGY

It seem remarkable that, for each reading, among men for whom the induction film was considered to show pathology other than tuberculosis, the CDD ratio is about twice as large as among men whose films were considered to be negative. Actually, the major fraction of such other pathology consisted of pulmonary calcification, some of which was presumably of tuberculous origin. It will be recalled that the various readers displayed rather poor agreement with respect to calcification. We have, therefore, confined our attention here to those relatively few films read as showing calcification as sole pathology on the final reading, after excluding those films in which there was disagreement between the original readers without subsequent review and decision. (It will be recalled that disagreement between Readers 1 and 2 as to the presence of calcification alone was not, by itself, considered to require review.) The numbers of films so classified are shown in table 25.

TABLE 25

Relation Between Pulmonary Calcification as Sole Pathology on Induction Film and Discharge for Tuberculosis

Final Reading of Induction Film	Roster I				Roster II
	Total	Discharged for			
		Active Pulm. Tuberculosis	Inactive Pulm. Tuberculosis	Non-pulm. Tuberculosis	
	Numbers of Films				
Total	200	86	83	31	99
Calcification:					
Single spot	77	42	20	15	51
Multiple, single system	98	40	42	16	46
Multiple, widely disseminated	25	4	21	0	2
	CDD Ratios				
Total	396	170	164	61	---------
Calcification:					
Single spot	296	162	77	58	---------
Multiple, single system	418	170	179	68	---------
Multiple, widely disseminated	(1)	(1)	(1)	(1)	---------

[1] Not calculated.

The first point of some interest is that the CDD ratio for the group of men here considered is 396 per one hundred thousand—almost four times the level in men read as negative and about twice as high as in the total group read as other pathology only. Secondly, as we shall see later (table 34), the CDD ratios among men with unequivocally negative induction films are: Total, 79; active pulmonary tuberculosis, 49; inactive pulmonary tuberculosis, 11; and tuberculosis of other locations, 19. Therefore, the CDD ratio for active pulmonary tuberculosis is a little more than three times as high for men with calcification as for men with negative films (170 compared with 49), but the CDD ratio for inactive pulmonary tuberculosis is in a ratio of more than ten to one (164 compared with 11), and is particularly high for men with multiple calcified lesions. The CDD ratio for nonpulmonary tuberculosis is, however, like the ratio for active pulmonary disease, slightly more than three times as high in the men with calcification as in those with negative films (61 compared with 19). It is hard to escape the conclusion that the great majority of men discharged for inactive tuberculosis, who were noted as having pulmonary calcification, were discharged because of the calcification itself.

Of course, the fact that discharge for active disease was three times as frequent among men with calcification as among men with negative films does not imply that a majority, or even very many, of such calcifications are significant from the standpoint of tuberculosis: the proportion discharged for active disease, was, after all, only 231 per one hundred thousand (170+61).

SUMMARY ON INDUCTION SCREEN

In summary, we may conclude that it is possible to operate an induction screen at many alternative levels, depending upon manpower needs. If, for example, the manpower needs of the Army had been rather light as measured by the available pool of potential recruits, one could, by rejecting every man not called negative on the summary reading, have avoided about 60 percent of tuberculosis discharges during World War II; such a program would have cost about 1,200,000 inductions (12 percent of about 10,000,000 inductees) to prevent about 10,500 tuberculosis discharges, and would obviously have been impractical. Under certain circumstances, however, it might make good sense to reject men whose chances of being discharged for tuberculosis are only about one in one hundred. In any event, any screening program necessarily involves one in the business of making predictions regarding future performance and no such predictions can be made with absolute certainty, surely not on the basis of X-ray films. One does, however, have one degree of freedom within which to operate: one can, within limits, decide what proportion of tuberculosis discharges one wishes to screen out, provided the manpower cost of the program does not become excessive for the time and circumstances with which one is concerned.

It must be remembered, of course, that the men studied here had all been screened once, so that it is not possible to estimate the gains and losses which would be realized by the institution at induction stations of a double-reading screen comparable to ours. Further, changes in the prevalence of tuberculosis in the population of young men are probably occurring constantly. Moreover, the age range of inductees is generally lower now than during World War II, so that, on these additional counts too, it is clear that the particular numbers and percentages calculated in this study cannot be used to forecast the results of any proposed screening device. Yet one may assume that future experience, even if quantitatively different, will be qualitatively similar, that the superiority of performance of the double-screen will persist, and that the relative order of risk of the different film classifications will not change.

Finally, the hope for substantial improvement in screening efficiency would appear to rest upon the possibility of supplementing the X-ray screen with further aids, such as the tuberculin skin test, which would enable one to pick out of such groups as those displaying "pathology other than tuberculosis only" on the induction film a major group of recruits who are unequivocally negative. The tuberculin test was not practiced as a screening measure in World War II, except in occasional instances when a man was retained temporarily in a hospital, after equivocal findings at an induction station, for further study and differential diagnosis. Routine tuberculin testing was frequently and sometimes strongly recommended by non-Army tuberculosis specialists. It was totally impractical, however, under the conditions prevailing. The tuberculin test requires 48 hours for proper observation and record. In no instance was this a possible procedure at induction in World War II. The total induction station residence for screening was rarely more than 24 hours, and ordinarily was less than 12. Occasionally, where under existing train schedules no other course was possible, it was only 4 or 5 hours.

For an induction examination that included the tuberculin test an entirely different type of induction station, with sleeping and restaurant accommodations and larger maintenance staff, would have been required, and induction would have been delayed, and much more costly. Nevertheless, from a long-range standpoint, and for a proper understanding of the hazards of military service from the point of view of tuberculous infection, it would have been of great value. It is only realistic to recognize, on the other hand, that a positive tuberculin test could not have been established as a cause for assignment to limited rather than full duty, as was actually suggested by an eminent phthisiologist. Under the rigorous requirements for manpower a procedure removing 20 percent or more of men from combat assignment would have jeopardized if not totally ruined the chance for military success.

Under different circumstances, when the time element is not vital, when more attention can be paid to the cost of tuberculosis from a long-range point of view, and when Army medical records can be set up with such care that they will be an asset in the understanding of important questions in epidemiology and pathogenesis, the tuberculin test will be an invaluable aid.

5. THE SEPARATION SCREEN

ACCURACY OF SEPARATION SCREEN

Roentgenographic examination of the chest became a routine part of the physical examination for separation from service about mid-1944 and, in fact, was responsible for the discovery of much of the tuberculosis diagnosed in the Army. During the last months of 1945 and the first half of 1946 the separation centers were, however, under extremely heavy pressure: the millions of men of a victorious Army were impatient to return to their homes and vocations, as were, indeed, the medical officers charged with the responsibility for the separation physical examination. It would not, under the circumstances, have been surprising if the efficiency of the system had, to some extent, given way before these pressures. One of our objectives, therefore, in reviewing the separation films of Roster II, the "control roster," was to discover to what extent men with tuberculosis had been discharged to civilian life with a clean bill of health.

Table 26 shows the number of diagnoses of each kind made at the first, second, summary, and final readings. Plainly, there was considerable variation in opinion regarding the small proportion of films thought to show tuberculous disease.

TABLE 26

Four Readings of Separation Films; Control Roster

Interpretation	Reading (number of films)			
	First	Second	Summary	Final
Total	2,733	2,733	2,733	2.733
Tuberculosis, active	5	0	4	18
Tuberculosis, questionably active	8	4	5	4
Tuberculosis, inactive	8	31	13	5
Suspect tuberculosis	97	167	53	2
Other pathology only	187	183	287	303
Negative	2,420	2,342	2,364	2,395
Unsatisfactory	8	6	7	6

Since the best test of the accuracy of diagnosis consists in determining the course of subsequent events in any suspected individual, we have, with the cooperation of the Veterans Administration, checked through its files of hospitalization and disability compensation for the 79 individuals diagnosed as suspect tuberculosis or tuberculosis on either summary or final reading. It will be recalled that under Veterans Administration regulations in effect in August 1953 (when the check was made) active tuberculosis occurring within 3 years and 6 months of separation from service would generally be considered to be "service connected," and would entitle the veteran to disability compensation. Even in the absence of service connection, total disability entitles a veteran without other means to a pension, and service connection is not required to establish eligibility of veterans to hospitalization for tuberculosis within the Veterans Administration system. At any rate, in the experience of the Follow-up Agency of the National Research Council, the occurrence of active tuberculosis in a veteran is almost invariably a fact known to the Veterans Administration through compensation or hospitalization records.

In addition to the 79 individuals already mentioned, the files were also searched for an additional group of 205 members of Roster II who were *not* considered to show evidence of tuberculous disease on either summary or final reading. This latter group was designed to serve as a control group for the 79 suspected individuals. Table 27 displays the results of this search.

The surprising facts brought out in table 27 are, first, the relatively small amount of tuberculosis found in the cases which appeared suspect on the summary and final readings and, second, the relatively large number of cases found in the control group. The proportion found in the latter group—1.0 percent—is subject to a very large sampling error, and the true proportion may well be only a quarter of that observed.

TABLE 27

Results of Search of Veterans Administration Files, August 1953, for Men Considered To Have Suspicious Separation Films, and for Controls

Reading and Interpretation	Number of Men	Number With Notation of Subsequent Tuberculosis	Percent With Tuberculosis
Total, final or summary reading, tuberculosis or suspect tuberculosis	79	3	3.4
Final reading:			
Total, tuberculosis or suspect tuberculosis	29	3	9.4
Active tuberculosis	5	1	20.0
Summary reading:			
Total, tuberculosis or suspect tuberculosis	75	2	2.4
Active tuberculosis	13	1	6.7
Control group	205	2	1.0

In order to investigate the possibility that clinical tuberculosis occurring in the men whose X-rays were considered suspect might have been missed because the Veterans Administration was unaware of the breakdown, we sent questionnaires to the 29 men who had been designated by the final reading, and for whom no subsequent episode of tuberculosis was recorded. Fifteen such questionnaires were filled out and returned, and we succeeded in obtaining credit reports (giving employment and residence histories) for four additional men. In these nineteen instances it was plain that there had been no hospitalization for tuberculosis, and none of the fifteen questionnaires mentioned this disease, although other diseases and disabling conditions were sometimes claimed.

We may perhaps gain further insight by considering in detail the five cases (three from the group having suspect X-rays and two from the controls) who were discovered subsequently to have disease:

Case 6682: White male, entered service April 1943 at age 18. The induction film was called negative by the induction station and all readers in the present study. After 35 months of service, including 28 months in the European Theater of Operations, he was discharged routinely in March 1946. While in service he was assigned at various times to the Infantry, Field Artillery and Quartermaster Corps. He had no pertinent hospital admission in service. His separation film was read identically by all reviewers as showing moderately advanced active tuberculosis, without cavitation. On the day following separation from service he had a pulmonary hemorrhage, and was hospitalized with the diagnosis of moderately advanced active pulmonary tuberculosis.

Case 5727: White male, entered service February 1943 at age 27. His induction film was read as negative by the induction station as well as by all readers. After serving in the Corps of Engineers for 34 months, including 21 months in the European Theater of Operations, he was separated routinely in December 1945. His only recorded hospital admission in service was for syphilis, contracted in Austria. His separation film, read as negative by Reader 1, was considered by Reader 2 to show minimal active tuberculosis; on conference the two readers agreed on a diagnosis of suspect tuberculosis, minimal, of questionable activity. The reviewer changed the classification to minimal inactive tuberculosis, while the senior author on his review called the activity questionable. The separation film was not of highest quality. The patient was well until February 1948, slightly more than 2 years after separation, when there was a sudden onset of pain, on deep inspiration, moderate fever and hemoptysis. He was admitted to the Veterans Administration hospital system, and after 9 months discharged with a diagnosis of arrested minimal pulmonary tuberculosis.

Case 5475: White male, entered service December 1943 at age 28. The induction station recorded its impression of the induction film as "slight thickening of left apical pleura, otherwise negative." Our Readers 1 and 2 both thought the film suspect of minimal tuberculosis, activity questionable. The final reader called the case one of minimal inactive tuberculosis. This man served in the Corps of Engineers for 26 months, including 19 months in the European Theater of Operations, and was hospitalized for 4 months for trenchfoot. He was separated routinely in January 1946. Readers 1 and 2 both considered the separation film negative, but the final reader again diagnosed minimal inactive tuberculosis. In June 1949, three and one-half years later, he was admitted to hospital for tuberculosis. The record showed that in the interval, because of a family history of tuberculosis, he had had repeated chest X-ray examinations. Films taken in April and May 1949 raised the suspicion of tuberculosis. There had been no symptoms except some loss of weight. An X-ray film taken in June 1949, was interpreted as showing an area of infiltration of uncertain origin in the left lung. He was hospitalized and a diagnosis of tuberculosis of minimal extent was established. A left pneumothorax was instituted. The veteran was advised that under existing regulations he was not entitled to compensation on the basis of disease of service origin or aggravation. He was, however, awarded a nonservice pension on the basis of his condition in June 1949. In 1950, he was awarded presumptive service connection on the basis of interim changes in compensation regulations.

Case 6967: White male, entered service February 1943, age 22, medically discharged in January 1946 with the diagnosis "schizophrenic reaction, catatonic type." He had been in the Air Force, and had served overseas in the United Kingdom for 19 months. The induction and separation films were considered unequivocally negative by all readers. His only hospitalization in the Army was for the psychiatric diagnosis which led to discharge. He was admitted to a Veterans Administration hospital in September 1948 because of an exacerbation of his psychiatric difficulty, and a routine X-ray disclosed moderately advanced active pulmonary tuberculosis with left pleural effusion.

Case 5447: White male, entered service June 1943, age 27. He was discharged routinely in January 1946 after service in the Corps of Engineers which included 9 months in the European Theater of Operations and 3 months in the Pacific. The induction and separation films were considered to be negative at the examining station and by both readers. His only hospital admissions while in service were for venereal disease (acquired in the United States) and nasopharyngitis. In addition, he was treated as an outpatient in 1945 for low back pain of 2 days' duration. In September 1950 he was hospitalized following a 5-month history of increasing back pain on motion, and a shorter history of chills and sweats. A diagnosis of tuberculous spondylitis was established.

There can be little question regarding case 6682; it was an outright mistake at the separation screening center that permitted the soldier in this case to be separated routinely. But the situation is by no means so clear in the other instances. The soldiers in cases 5727 and 5475 were not hospitalized until 26 months and 41 months, respectively, after the X-ray films suggesting tuberculosis were made. The intervals from separation to diagnosis of tuberculosis in the two men who broke down in the group having negative separation films were 32 months and 56 months. It is certainly possible that the soldiers in cases 5727 and 5475 became sick as a result of infection acquired after leaving service. Moreover, while case 6967 looks much like that of a man who was infected after separation from service, in case 5447 the infection may well have been contracted prior to service or during service. In this case, a routine chest film would not be expected to have disclosed the spondylitis, even had it been present.

It seems remarkable that of five men diagnosed by the final reading and fifteen by the summary reading as having active pulmonary tuberculosis at the time of separation, only one man, in a subsequent period of about 7 years, has become clinically ill. The implication of this finding is that our readings, on the whole, erred in the direction of too high a level of suspicion. Recalling that our sampling ratio for the two rosters was 550 to 1, we should conclude that if as many as 5 of the men on Roster II really had active pulmonary tuberculosis undetected by the separation screen, at the time of separation, we should multiply the figure of 5 by 550 to obtain an estimated total of the cases missed by the screen; this number, viz, 2,750, could properly be compared with the 3,099 men discharged for tuberculosis. We would have to infer, then, that a substantial proportion of the cases of tuberculosis among men in the Army which were detectable radiologically were missed by the separation screen.

It is, of course, quite true that in the estimate of 2,750 there is a very large sampling error, but we can assert with 95 percent confidence that the proportionate number considered on final reading to show active pulmonary tuberculosis is at least 1,100 (for 2 is the 95 percent lower confidence limit on the expected value of a Poisson distribution for which the single observation of 5 has been made).

Finally, it is not too much to say that, no matter what proportion really had the disease among those men on whom our summary and final readers made a diagnosis of active tuberculosis, these men should at least have been held for further study. Their X-rays clearly presented sufficient grounds to warrant careful examination. Without going so far as to assert that in fact thousands of men with active tuberculosis were unwittingly discharged, one can assert that thousands who deserved more careful study, for their own welfare and that of their families and society, failed to receive sufficient consideration in the Army's rapid demobilization.

6. TUBERCULOSIS IN THE ARMY

Tables 28 through 31 show, for whites and nonwhites separately, the final diagnoses made by Army hospitals, and within each diagnostic group the distributions of the final readings of the induction and separation films. For these tables we have supplemented our final readings in some instances where films were not recovered by using the radiological reports made at Army hospitals. Such reports were coded for 26 of the 340 induction films which we could not find for men on the tuberculosis roster and for 630 of the 637 missing separation films.

It should be noted that the ordinary practice of the Medical Department of the Army is to record as the "final" diagnosis that pathological condition which is ultimately determined to have been the original cause of admission to hospital.

Characteristic differences in the distributions of diagnoses between whites and nonwhites are evident by comparison of tables 28 and 29. The relative proportions carrying diagnoses of active pulmonary disease are roughly equivalent, but inactive pulmonary tuberculosis accounts for a much larger proportion of diagnoses among whites (22.8 percent) than among nonwhites (12.2 percent). Conversely, diagnoses more frequently found among nonwhites are tuberculosis of the external lymph nodes (6.3 percent versus 1.3 percent), bone or joint (3.8 percent versus 1.4 percent) and genito-urinary tuberculosis (4.1 percent versus 2.7 percent).

TYPES AND STAGES OF TUBERCULOSIS

The relationship shown in table 28 between the stage of disease and the final reading of the induction film is noteworthy. Thus, in 41 percent of men separated for minimal tuberculosis the induction film was read as negative, as contrasted with 51 percent in the case of those separated for far advanced disease. The corresponding percentages for active tuberculosis are 29 percent and 41 percent. Thus, the far advanced cases show a much greater degree of polarity in the readings of the induction films than do the men discharged for minimal disease: for the former group, less than 2 percent of induction films were read as inactive or questionably active tuberculosis while for the latter group 20 percent were so read. The pattern among nonwhites (table 29) is similar.

Relatively few men discharged for inactive disease were considered to have negative induction films; in fact, 40 percent of the films were read as either inactive tuberculosis or calcification only.

Turning to tables 30 and 31, we find a fair degree of correspondence between the Army diagnoses and our final readings of the separation films for men discharged for active pulmonary tuberculosis. Among whites almost all (97.5 per cent) of men discharged for far advanced disease were

TABLE 28

The Tuberculosis Roster by Diagnosis and Final Reading of Induction Film; Whites

Type of Tuberculosis Diagnosed	Total		Final Reading of Induction Film																			
			Total Read		Tuberculosis								Suspect Tuberculosis		Wet Pleurisy		Dry Pleurisy		Calcification		Othe Pathology	
					Negative		Inactive		Questionable Activity		Active											
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Total	2,343	100.0	2,088	100.0	925	44.3	178	8.5	133	6.4	583	27.9	9	0.4	1	0.0	18	0.9	202	9.7	39	1.9
Pulmonary:																						
Primary, active	10	.4	7	100.0	4	57.1					2	28.6							1	14.3		
Disseminated hematogenous	4	.2	4	100.0	2	50.0					1	25.0									1	25.0
Acute	161	6.9	144	100.0	68	47.2	3	2.1	4	2.8	51	35.4					2	1.4	15	10.4	1	.7
Chronic, active, minimal	320	13.7	280	100.0	114	40.7	29	10.4	27	9.6	80	28.6	3	1.1					21	7.5	6	2.1
Chronic, active, mod. advanced	474	20.2	420	99.9	206	49.0	9	2.1	16	3.8	147	35.0					5	1.2	31	7.4	6	1.4
Chronic, active, far advanced	240	10.2	217	100.0	111	51.2	1	.5	2	.9	89	41.0							10	4.6	4	1.8
Chronic, active, stage not stated	305	13.0	274	99.9	93	33.9	23	8.4	19	6.9	120	43.8					1	.4	13	4.7	5	1.8
Activity not stated	21	.9	19	100.0	5	26.3			6	31.6	5	26.3							2	10.5	1	5.3
Inactive	534	22.8	474	100.0	123	25.9	106	22.4	58	12.2	83	17.5	4	.8			5	1.1	89	18.8	6	1.3
Nonpulmonary:																						
Trachea or bronchi	3	.1	3	99.9	3	100.0																
Pleura	131	5.6	120	100.0	101	84.2	1	.8			3	2.5			1	.8	3	2.5	7	5.8	4	3.3
External lymph nodes	30	1.3	27	100.0	21	77.8	1	3.7									1	3.7	3	11.1	1	3.7
Bone or joint	32	1.4	29	100.0	24	82.8	2	6.9	1	3.4									2	6.9		
Genito-urinary	63	2.7	58	99.9	41	70.7	2	3.4			1	1.7	2	3.4			1	1.7	7	12.1	4	6.9
Other	15	.6	12	99.9	9	75.0	1	8.3			1	8.3							1	8.3		

TABLE 29

The Tuberculosis Roster by Diagnosis and Final Reading of Induction Film; Not White

Type of Tuberculosis Diagnosed	Total		Final Reading of Induction Film																				
			Total Read		Tuberculosis								Suspect Tuberculosis		Wet Pleurisy		Dry Pleurisy		Calcification		Other Pathology	
					Negative		Inactive		Questionable Activity		Active											
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Total	756	100.1	695	100.1	341	49.1	29	4.2	36	5.2	214	30.8	1	0.1	2	0.3	9	1.3	45	6.5	18	2.6
Pulmonary:																						
Primary, active	6	.8	5	100.0	3	60.0					2	40.0										
Disseminated hematogenous	3	.4	3	100.0	3	100.0																
Acute	64	8.5	61	99.9	25	41.0	1	1.6	1	1.6	26	42.6					1	1.6	4	6.6	3	4.9
Chronic, active, minimal	79	10.5	71	100.0	33	46.5	9	12.7	8	11.3	13	18.3					1	1.4	3	4.2	4	5.6
Chronic, active, mod. advanced	125	16.5	112	100.0	51	45.5			8	7.1	47	42.0							6	5.4		
Chronic, active, far advanced	111	14.7	102	100.0	56	54.9			1	1.0	39	38.2							6	5.9		
Chronic, active, stage not stated	104	13.8	96	100.0	33	34.4			1	1.0	52	54.2			1	1.0	2	2.1	4	4.2	3	3.1
Activity not stated	10	1.3	10	100.0	1	10.0	1	10.0	2	20.0	6	60.0										
Inactive	92	12.2	84	100.1	24	28.6	14	16.7	11	13.1	23	27.4					1	1.2	8	9.5	3	3.6
Nonpulmonary:																						
Trachea or bronchi																						
Pleura	40	5.3	35	100.1	28	80.0					3	8.6					1	2.9	2	5.7	1	2.9
External lymph nodes	48	6.3	46	99.9	34	73.9	2	4.3			1	2.2					2	4.3	6	13.0	1	2.2
Bone or joint	29	3.8	27	100.0	23	85.2					1	3.7	1	3.7			1	3.7	1	3.7		
Genito-urinary	31	4.1	29	100.0	17	58.6	1	3.5	3	10.3					1	3.5			5	17.2	2	6.9
Other	14	1.9	14	99.8	10	71.4	1	7.1	1	7.1	1	7.1									1	7.1

considered to show active tuberculosis radiologically. Of those discharged for moderately advanced disease, we read 89.9 percent as showing active tuberculosis, 4.6 percent as tuberculosis of questionable activity and 2.5 percent as inactive tuberculosis. Finally, among those whom the Army found to have minimal active disease, on final reading about two-thirds of the separation films were called active tuberculosis, 12.2 percent tuberculosis of questionable activity, and 13.1 percent inactive tuberculosis.

A less encouraging feature of table 30 is the lack of agreement regarding inactive pulmonary tuberculosis: about one-third of white men so diagnosed by the Army were considered to show active disease on the final reading of the separation film.

As might be expected, of men diagnosed as having nonpulmonary tuberculosis, except for tuberculosis of the pleura, the majority were considered to have negative separation films.

For nonwhites, the relationship between the readings of the separation films and the Army diagnoses is quite similar to that found in whites; the variations in percentages generally do not exceed what we might reasonably expect in view of the relatively small numbers of nonwhites in most of the diagnostic categories.

LENGTH OF SERVICE BEFORE MEDICAL DISCHARGE

Table 32 shows the amount of service which the Army obtained from the men discharged for tuberculosis. We have subtracted from total length of service the amount of time spent in hospital because of the tuberculosis; this is shown separately in table 33. We have included in the inactive group the relatively small number of men for whom the discharge diagnosis was silent regarding activity. These men constituted less than 5 percent of the 656 men discharged for inactive disease, and from the distribution of the final readings of the separation films (table 30) it would appear that the group actually was a mixture of active and inactive cases. This is the only diagnosis for which a large proportion of the separation films (over one-third) were called tuberculosis of questionable activity.

The length of service distributions vary somewhat among the three diagnostic classes (table 32) as do those for duration of hospitalization (table 33). For Roster I as a whole the average duration from entry on active duty to separation from service was 22.7 months, of which 5.5 months were spent in the hospital because of tuberculosis. The 3,099 men on Roster I had a total of 1,417 man-years of hospitalization; since we employed a 33 percent sampling ratio we estimate that the group of about 9,300 men who met the criteria for eligibility for this study had a total of about 4,300 man-years of hospitalization for tuberculosis.

It is customary to measure the incidence of disease in a population in terms of the proportion of persons first diagnosed as having the disease in a given unit of time, but it must be recognized that this may be deceptive when we have to do with a disease like tuberculosis, which may be present, although undetected, for considerable periods of time prior to diagnosis.

TABLE 30

The Tuberculosis Roster by Diagnosis and Final Reading of Separation Film; Whites

Type of Tuberculosis Diagnosed	Total		Final Reading of Separation Film																			
			Total Read		Tuberculosis								Suspect Tuberculosis		Wet Pleurisy		Dry Pleurisy		Calcification		Other Pathology	
					Negative		Inactive		Questionable Activity		Active											
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Total	2,343	100.0	2,340	100.0	148	6.3	258	11.0	196	8.4	1,514	64.7	14	0.6	46	2.0	33	1.4	106	4.5	25	1.1
Pulmonary:																						
Primary, active	10	.4	10	100.0					1	10.0	7	70.0					1	10.0	1	10.0		
Disseminated hematogenous	4	.2	4	100.0							3	75.0									1	25.0
Acute	161	6.9	161	99.9	8	5.0	4	2.5	10	6.2	135	83.8			1	.6	2	1.2	1	.6		
Chronic, active, minimal	320	13.7	320	100.0	9	2.8	42	13.1	39	12.2	214	66.9	3	.9	1	.3	3	.9	5	1.6	4	1.3
Chronic, active, mod. advanced	474	20.2	474	99.9	5	1.1	12	2.5	22	4.6	426	89.9					2	.4	3	.6	4	.8
Chronic, active, far advanced	240	10.2	240	100.0	1	.4	1	.4	4	1.7	234	97.5										
Chronic, active, stage not stated	305	13.0	305	100.0	6	2.0	22	7.2	28	9.2	237	77.7	2	.7	1	.3	1	.3	5	1.6	3	1.0
Activity not stated	21	.9	21	100.2	1	4.8	1	4.8	8	38.1	9	42.9							1	4.8	1	4.8
Inactive	534	22.8	532	100.1	17	3.2	170	32.0	73	13.7	183	34.4	2	.4	1	.2	2	.4	75	14.1	9	1.7
Nonpulmonary:																						
Trachea or bronchi	3	.1	3	99.9	1	33.3													1	33.3	1	33.3
Pleura	131	5.6	130	100.0	3	2.3	1	.8	5	3.8	59	45.4	5	3.8	40	30.8	15	11.5	1	.8	1	.8
External lymph nodes	30	1.3	30	100.0	20	66.7	1	3.3	2	6.7	1	3.3					2	6.7	3	10.0	1	3.3
Bone or joint	32	1.4	32	100.1	22	68.8	2	6.3	1	3.1	1	3.1			2	6.3	1	3.1	3	9.4		
Genito-urinary	63	2.7	63	100.0	46	73.0	1	1.6	1	1.6	4	6.3	2	3.2			3	4.8	6	9.5		
Other	15	.6	15	100.1	9	60.0	1	6.7	2	13.3	1	6.7					1	6.7	1	6.7		

TABLE 31

The Tuberculosis Roster by Diagnosis and Final Reading of Separation Film; Not White

Type of Tuberculosis Diagnosed	Total		Final Reading of Separation Film																			
			Total Read		Tuberculosis								Suspect Tuberculosis		Wet Pleurisy		Dry Pleurisy		Calcification		Other Pathology	
					Negative		Inactive		Questionable Activity		Active											
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Total	756	100.1	751	100.1	86	11.5	45	6.0	45	6.0	494	65.8	7	0.9	20	2.7	15	2.0	27	3.6	12	1.6
Pulmonary:																						
Primary, active	6	.8	6	100.1	1	16.7					4	66.7			1	16.7						
Disseminated hematogenous	3	.4	3	100.0							2	66.7			1	33.3						
Acute	64	8.5	64	100.1	3	4.7			1	1.6	54	84.4			3	4.7			2	3.1	1	1.6
Chronic, active, minimal	79	10.5	78	100.0	5	6.4	9	11.5	9	11.5	46	59.0	2	2.6	1	1.3	2	2.6	2	2.6	2	2.6
Chronic, active, mod. advanced	125	16.5	124	99.9	1	.8	1	.8	6	4.8	114	91.9	1	.8							1	.8
Chronic, active, far advanced	111	14.7	109	100.0					3	2.8	106	97.2										
Chronic, active, stage not stated	104	13.8	104	99.9	4	3.8			3	2.9	93	89.4					2	1.9	2	1.9		
Activity not stated	10	1.3	10	100.0			1	10.0	2	20.0	7	70.0										
Inactive	92	12.2	92	100.1	3	3.3	26	28.3	15	16.3	36	39.1			1	1.1	1	1.1	8	8.7	2	2.2
Nonpulmonary:																						
Trachea or bronchi																						
Pleura	40	5.3	40	100.0	2	5.0	1	2.5	1	2.5	20	50.0			13	32.5	2	5.0	1	2.5		
External lymph nodes	48	6.3	48	99.9	28	58.3	3	6.2	2	4.2	3	6.2	2	4.2			3	6.2	5	10.4	2	4.2
Bone or joint	29	3.8	29	99.8	13	44.8			1	3.4	7	24.1	2	6.9			3	10.3	1	3.4	2	6.9
Genito-urinary	31	4.1	30	99.9	20	66.7	3	10.0	1	3.3							1	3.3	4	13.3	1	3.3
Other	14	1.9	14	99.7	6	42.9	1	7.1	1	7.1	2	14.2					1	7.1	2	14.2	1	7.1

TABLE 32

Length of Service, Excluding Time in Hospital for Tuberculosis; Roster I

Length of Service	Diagnosis at Discharge								
	Active Pulmonary Tuberculosis			Inactive Pulmonary Tuberculosis			Nonpulmonary Tuberculosis		
	Number of Men	Percent		Number of Men	Percent		Number of Men	Percent	
		This Length	This Length or More		This Length	This Length or More		This Length	This Length or More
Total known	2,003	100.1	-------	656	100.0	-------	436	100.0	-------
0–6 months	430	21.5	100.1	253	38.6	100.0	108	24.8	100.0
7–12 months	373	18.6	78.6	95	14.5	61.4	79	18.1	75.2
13–24 months	582	29.1	60.0	79	12.0	46.9	129	29.6	57.1
25–36 months	492	24.6	30.9	151	23.0	34.9	115	26.4	27.5
37 months or more	126	6.3	6.3	78	11.9	11.9	5	1.1	1.1

TABLE 33

Duration of Hospitalization in Army for Tuberculosis; Roster I

Duration of Hospitalization	Diagnosis at Discharge								
	Active Pulmonary Tuberculosis			Inactive Pulmonary Tuberculosis			Nonpulmonary Tuberculosis		
	Number of Men	Percent		Number of Men	Percent		Number of Men	Percent	
		This Duration	This Duration or More		This Duration	This Duration or More		This Duration	This Duration or More
Total known	1,986	100.0	-------	651	100.1	-------	433	100.0	-------
Less than 1 month	19	1.0	100.1	33	5.1	100.1	4	.9	99.1
1 month	278	14.0	99.1	124	19.0	95.0	33	7.6	98.8
2 months	315	15.9	85.1	108	16.6	76.0	42	9.7	91.5
3 months	237	11.9	69.2	57	8.8	59.4	59	13.6	81.8
4 months	206	10.4	57.3	43	6.6	50.6	57	13.2	68.2
5 months	177	8.9	46.9	54	8.3	44.0	63	14.5	55.0
6 months	161	8.1	38.0	49	7.5	35.7	45	10.4	40.5
7–9 months	365	18.4	29.9	126	19.4	28.2	81	18.7	30.1
10–12 months	186	9.4	11.5	48	7.4	8.8	31	7.2	11.4
13–15 months	42	2.1	2.1	9	1.4	1.4	18	4.2	4.2

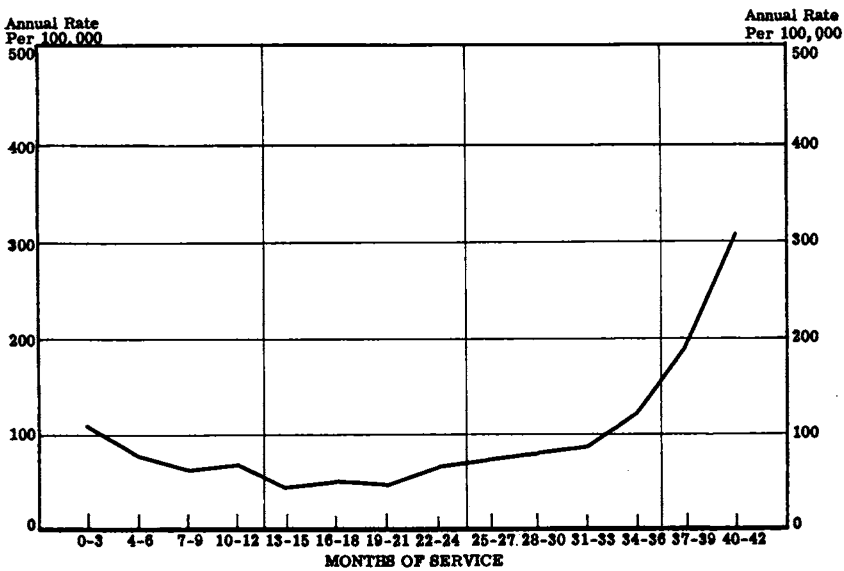
We tend naturally to think of such a rate as measuring the incidence of disease, but actually it measures the rate of *recognition* of disease, and as such is very strongly influenced by variability in the intensity of application of case-finding techniques. Figure 3 shows the rate at which men destined to be discharged for tuberculosis were hospitalized as a function of length of service. We have charted the data in this way in order to remove the effects of varying durations of hospitalization among the men discharged for tuberculosis. It will be seen that the annual rate began at the relatively high level of 112 per one hundred thousand per annum, then declined during the first year of service to a plateau in the region of 50–60 which was maintained during the second year of service, and finally rose at a constantly increasing pace, achieving a rate of 301 per one hundred thousand per annum during the second quarter of the fourth year of service.

The explanation for this variability is believed to be simple: During the first months of service many of the more obvious mistakes made at the induction station were being corrected, as a result both of review of the induction films and of the advent of actual illness. During the third and fourth years of service men were being tested by the separation X-ray screen and relatively large numbers of cases of tuberculosis were brought to light, some of which were service acquired, while others represented men mistakenly inducted. In short, our rates actually represent an unknown mixture of incidence and prevalence. In general, if two groups of men have different average lengths of service, the group with shorter service will manifest a higher annual rate of tuberculosis, other things being equal, because the relatively constant prevalence portion of the numerator of the rate will be divided by a smaller denominator.

We can obtain a little further insight into the situation through figures 4, 5 and 6. Figure 4 shows the admission rate for active pulmonary tuberculosis as a function of length of service, and, in addition, provides a breakdown of these admissions according to whether our final reading of the induction film was or was not negative. It will be seen that the rate for which the numerator is men with final reading negative increases constantly, and particularly rapidly around 36 months of service. On the other hand, the rate curve for men for whom the induction film was not

FIGURE 3

Annual Admission Rates for Tuberculosis by Length of Service*



* Restricted to men subsequently discharged for tuberculosis.

considered negative has a U-shaped appearance. The reason is that those men who became sick early (and who were mistakenly inducted) are heavily concentrated in the group for whom the induction film was not negative. The curve for all discharges for active pulmonary tuberculosis, which is the sum of the two other curves, has a J-shape.

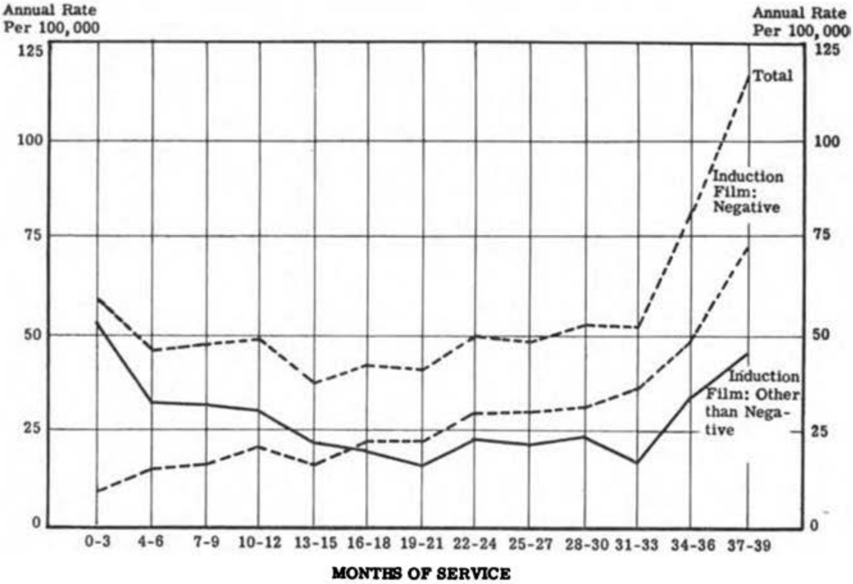
Figure 5 shows the admission rates for inactive pulmonary tuberculosis and we see that very few men for whom our final reading of the induction film is negative were discovered except as found by the separation screen. The rates are uniformly very low until the third year of service, when suddenly they increase sharply. On the contrary, men for whom the final reading is not negative show again the same U-shaped curve that we saw in figure 4, although the trough is much lower here; very few of these men were hospitalized, except as they were detected by the induction or separation X-ray examination. The sum of the two curves is the J-shaped curve which we have seen before.

Figure 6, depicting the annual rate of admission for nonpulmonary tuberculosis, is quite different from the two preceeding charts: first, all curves are on a much lower level (the vertical scale has been expanded to avoid squeezing the curves along the horizontal axis), and we have no J- or U-shaped curves. In general, the curves appear to be falling off somewhat as length of service increases, and most men have negative induction films as interpreted by us on final reading. The lesson seems plain: Here we have a kind of disease which is characteristically not detectable by chest X-ray examination. Hence, we do not have the peculiarities which are introduced into the other rate curves by the induction and separation screens. Further, the fact that the curves fall off in time seems to imply that what we are witnessing is the gradual exhaustion of disease which the men brought into service with them. This does not imply that there was no risk of infection in service, or that no men were infected in service, but it does seem to indicate that the rate of development of new infections was smaller in service than it had been in the civilian environment from which the men came.

For the reasons cited above, we shall, in general, avoid the use of time-rates when comparing the amount of tuberculosis in different groups of men, and instead employ either the CDD ratio or similar measurements of the proportion of men who became sick. While this measure undeniably suffers from the defect that it is not independent of the average duration of exposure of the group under study, this disadvantage can be minimized in this study if we confine our attention to groups for whom the average duration of exposure was about equal. This precaution is necessary, on other grounds, when considering characteristics of service, as we shall see; and so far as background characteristics are concerned, such factors as schooling, residence, height, weight, and age, bear little relation to length of service. Our method of coping with the problem is, of course, an imperfect solution of the difficulty, but unfortunately no wholly satisfactory way out of the dilemma appears to be available.

FIGURE 4

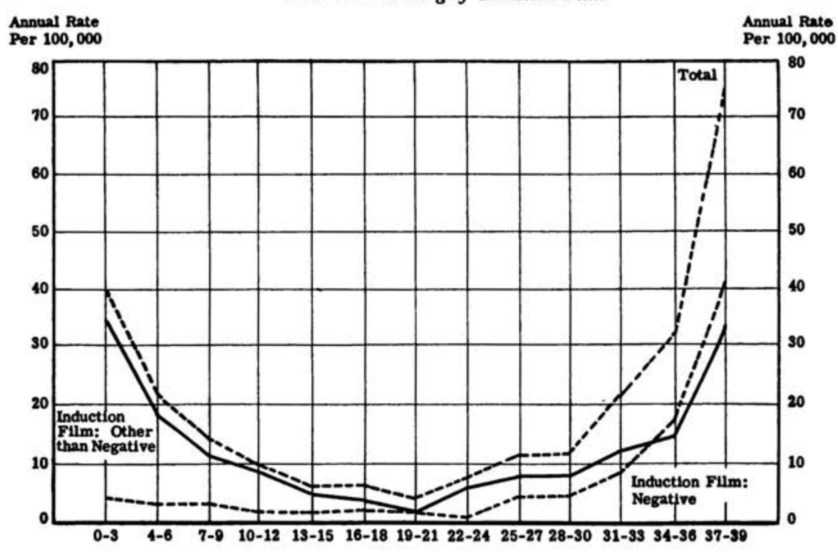
Annual Admission Rates for Active Pulmonary Tuberculosis by Length of Service and Final Reading of Induction Film*



* Restricted to men subsequently discharged for tuberculosis

FIGURE 5

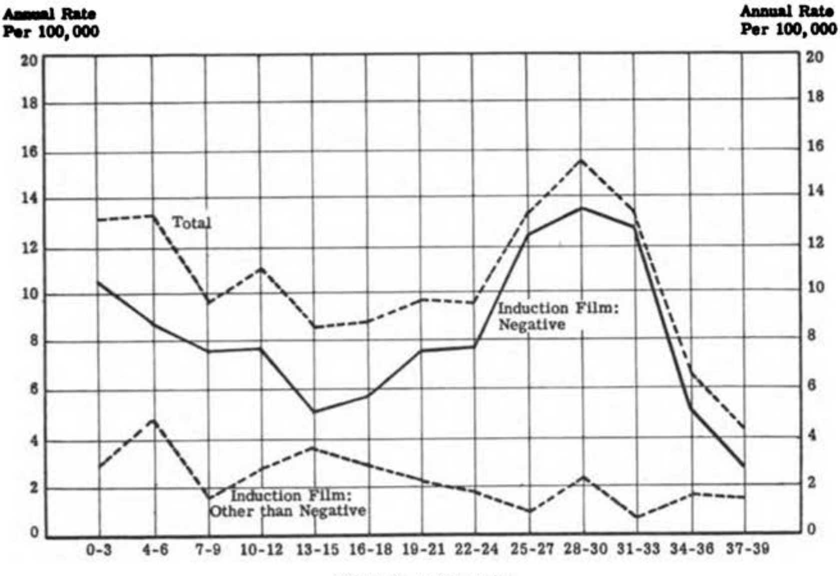
Annual Admission Rates for Inactive or Arrested Pulmonary Tuberculosis by Length of Service and Final Reading of Induction Film*



* Restricted to men subsequently discharged for tuberculosis.

FIGURE 6

Annual Admission Rates for Nonpulmonary Tuberculosis by Length of Service and Final Reading of Induction Film*



* Restricted to men subsequently discharged for tuberculosis.

SERVICE CONNECTION IN DISCHARGED MEN

It will be recalled from table 20 that the overall proportion of men discharged for tuberculosis during World War II was 187 per one hundred thousand men discharged, while the proportions per one hundred thousand among men whose induction films were called negative by the first, second, summary, and final readings, respectively, were 101, 95, 84, and 96. It therefore follows that the summary reading was most successful in excluding from the negative group men whose films showed evidence of disease. Since the proportion was only 79 per one hundred thousand among men whose films were called negative by the first and second readings independently, we may conclude that 79 per one hundred thousand represents an upper limit on the proportion of men discharged for tuberculosis acquired in service, although actually even this figure is probably too high. Needless to say, no system of interpreting chest X-ray films will detect *every* infection in a screened group. Some infections must have been so early or so small that no signs could be apparent. However, it seems clear that *at most* 42 percent (that is to say, 79/187) of men discharged for tuberculosis acquired the disease while in the Army and *at least* 58 percent were discharged by reason of infections which they brought into service with them.

One would expect the proportion of service-acquired disease to be different for men discharged for active tuberculosis or inactive tuberculosis, and we can perform a like analysis in these terms. Table 34 shows the results.

We find that the proportions discharged among men with negative induction films (as independently determined by both readers), when compared with the proportions discharged among all men, are:

All types	42 percent
Active pulmonary tuberculosis	40 percent
Inactive pulmonary tuberculosis	28 percent
Tuberculosis of other locations	70 percent

It appears, then, that at least 60 percent (the complement of 40 percent) of the active pulmonary tuberculosis discovered in the Army existed prior to induction, and that at least 72 percent of the inactive pulmonary tuberculosis was present at induction. Regarding nonpulmonary tuberculosis we can only assert that at least 30 percent represented prior infection, although here we probably underestimate considerably, since our statements rest on a review of chest films.[3]

TABLE 34

CDD Ratios Partitioned by Kind of Disease for All Men and for Men With Unequivocally Negative Induction Films

	First and Second Readings of Induction Film	
	All Films	Both Readings Negative
Roster I—Total	2,759	939
Discharged for:		
Active pulmonary tuberculosis	1,791	587
Inactive pulmonary tuberculosis	567	134
Tuberculosis of other locations	401	218
Roster II—Total	2,873	2,311
Proportions discharged per 100,000 men inducted:		
Total	188	79
Active pulmonary tuberculosis	121	49
Inactive pulmonary tuberculosis	40	11
Tuberculosis of other locations	27	19

RELATION OF TUBERCULOSIS TO PREVIOUS RESIDENCE

We may test these notions before accepting them by appeal to quite different data. It seems reasonable to believe that if we compare men inducted into service from different places we should find that men who, as civilians, resided in places where there was little tuberculosis brought less disease into service with them than did men who resided in places of high tuberculosis prevalence. We have, therefore, ranked the States (including the District of Columbia, but excluding Arizona because of its extraordinarily high rate) according to the tuberculosis death rate in 1940 among white inhabitants. We have used death rates because adequate prevalence data are unobtainable, and restrict them to white inhabitants to avoid the

[3] Waring and Roper (10), in a study of minimal tuberculosis detected in the Army, like ourselves concluded that a high percentage of cases had been overlooked on entry.

confounding which would otherwise result from the dissimilar geographical distribution of the white and nonwhite portions of the population. After ordering the States in this way, we divided them into ten groups, each group consisting of States with roughly similar tuberculosis death rates. Table 35 shows the grouping, and exhibits for each group of States the 1940 tuberculosis death rate in white inhabitants, the proportion of men examined for induction in the period April 1942–March 1943 who were rejected for tuberculosis as principal cause, and the proportion of white enlisted men inducted from those States who were discharged for tuberculosis. This latter proportion was calculated from our two samples.

Figure 7 shows the relationship between the Selective Service rejection rate for tuberculosis and the tuberculosis death rate. It seems clear that the relation is linear. In 1940, a zero tuberculosis death rate in a group of States would have implied the virtual absence of tuberculosis. Hence, for such a group of States, we should expect a zero rejection rate. We have, therefore, fitted a least squares line passing through the origin. The fit is quite good, the correlation being .89.

Figure 8 shows the proportion of men who were discharged for tuberculosis as a function of the tuberculosis death rate. Here again the points appear to fall along a line, and if we extend the least squares fitted line back to the vertical axis we find that the estimated proportion of men separated for tuberculosis corresponding to places with a zero tuberculosis death rate would be 84 per one hundred thousand. On the assumption that any tuberculosis which occurred among men previously resident in places with a zero tuberculosis death rate would be service acquired, we

TABLE 35

Tuberculosis Death Rate, White Inhabitants, 1940; Selective Service Rejections for Tuberculosis Among White Registrants; and Proportions of White Enlisted Men Discharged for Tuberculosis for Groups of States

Group of States	Tuberculosis Death Rate, 1940, White Inhabitants [1] (Rate, per 100,000)	Proportion of White Registrants Rejected for Tuberculosis as Primary Cause [2] (per 1,000) (Apr. 1942–Mar. 1943)	Proportion of White Enlisted Men Discharged for Tuberculosis [3]
1. Kentucky, New Mexico, Tennessee	60.4	22.4	232
2. Texas, Nevada, California	52.8	19.2	216
3. Maryland, Vermont, Colorado, District of Columbia, West Virginia, Missouri	41.2	20.5	179
4. New York, Louisiana, Illinois	38.3	15.2	147
5. Arkansas, Oklahoma, Virginia, Indiana, Pennsylvania, Massachusetts, New Jersey, Delaware, Washington	36.0	14.7	148
6. Connecticut, Ohio, Rhode Island, Montana	32.9	16.2	166
7. Alabama, Maine, Michigan, Georgia	28.8	9.3	154
8. Florida, Mississippi, Minnesota, Oregon, Wisconsin	25.3	11.5	191
9. New Hampshire, North Carolina, Kansas, South Carolina	22.5	8.1	142
10. Iowa, South Dakota, North Dakota, Utah, Nebraska, Idaho, Wyoming	16.1	9.3	101

[1] Source: Calculated from: Vital Statistics of the United States, 1941, Part II, U. S. Department of Commerce, Bureau of the Census and Sixteenth Census of the United States, 1940, Vol. 1 Ibid.
[2] Source: Calculated from: Periodic Reports of Physical Examination, Vol. 1, Summary and Detailed Reports April 1942–Sept. 1943, National Headquarters Selective Service System.
[3] Calculated from observed proportions of Rosters I and II.

FIGURE 7

Number Rejected for Tuberculosis as Primary Cause Per 1,000 White Registrants and Tuberculosis Death Rates Among Whites, for Groups of States

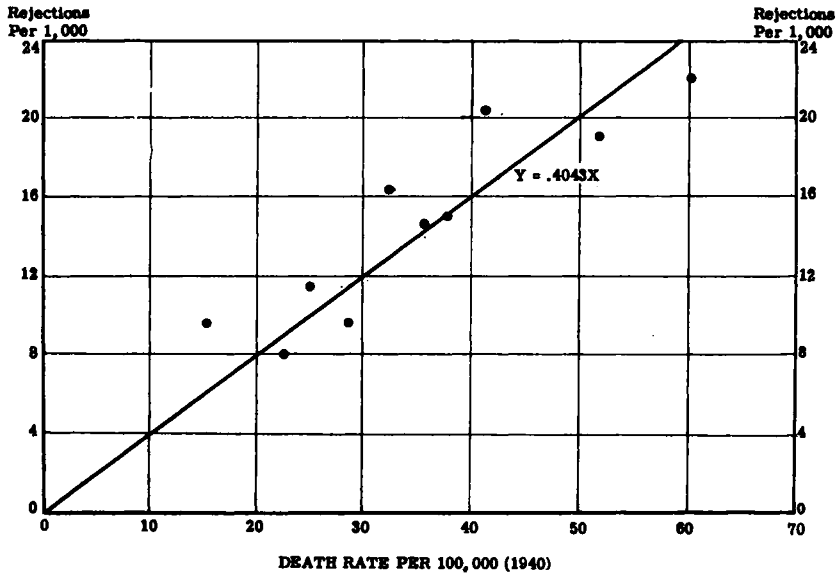
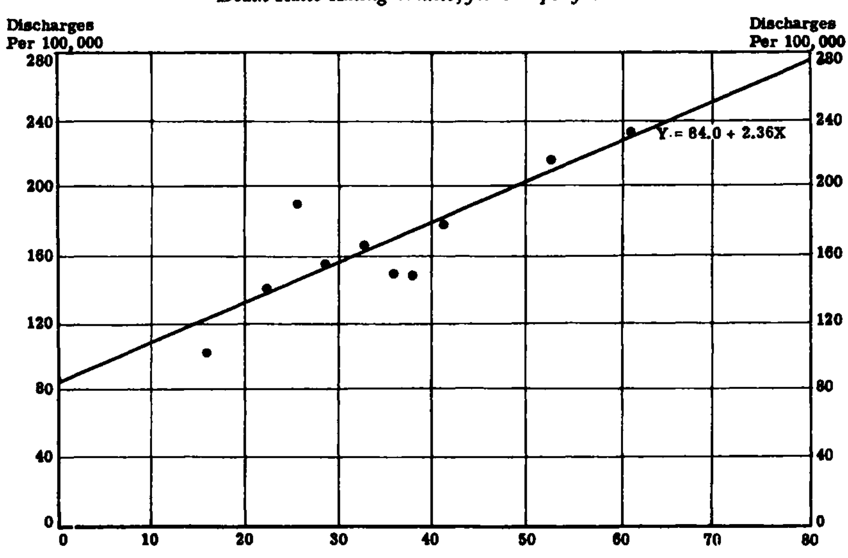


FIGURE 8

Discharges of White Enlisted Men for Tuberculosis Per 100,000 Discharges and Tuberculosis Death Rates Among Whites, for Groups of States



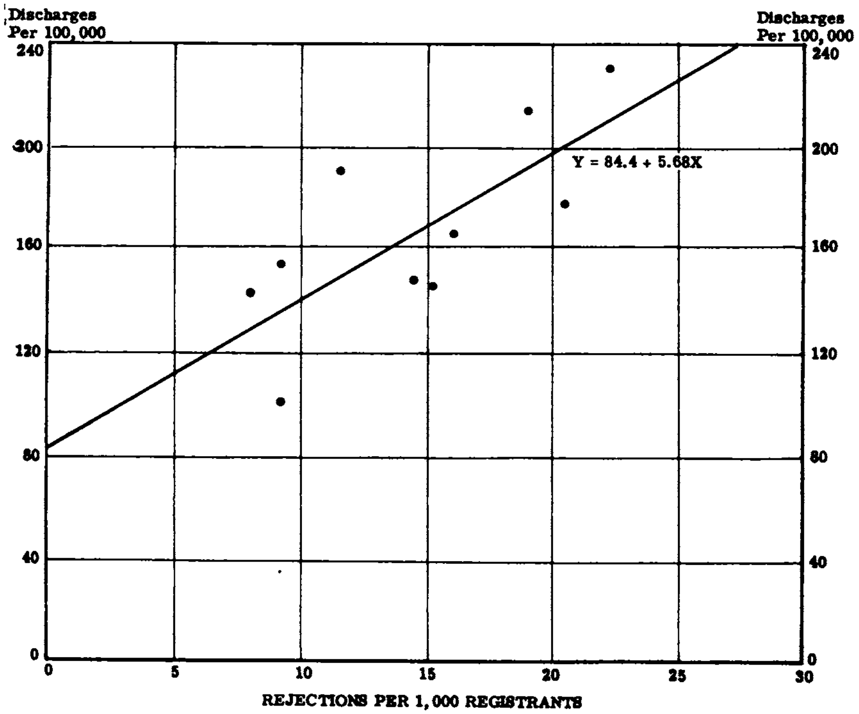
have a tentative estimate of the proportion of white men who were separated for tuberculosis acquired in service.

Figure 9 shows the proportion of men separated from service for tuberculosis as a function of the rejection rate for tuberculosis as primary cause. If we assume to have been service-acquired any tuberculosis which later occurred in men who came from places in which no men were rejected for this disease, we obtain an estimate of 84 per one hundred thousand as the proportion of white inductees separated for service-acquired tuberculosis.

These estimates of the proportions of white inductees separated for service-acquired tuberculosis—84.0 and 84.4 per one hundred thousand—are, of course, very near to the proportion 82 per one hundred thousand that we previously obtained (table 24) as the proportion discharged for tuberculosis among whites for whom the final reading of the induction film was negative. This consistency between estimates reached in quite different ways gives us some confidence that the proportion of men who were separated for tuberculosis acquired while in the Army was, for whites, in the neighborhood of 80 per one hundred thousand. Since the CDD ratio for whites was 164 per one hundred thousand (table 24), we may conclude that about half of the tuberculosis that appeared in white soldiers and led to medical discharge was service-acquired.

FIGURE 9

Discharges of White Enlisted Men for Tuberculosis Per 100,000 Discharges and Number Rejected for Tuberculosis as Primary Cause Per 1,000 White Registrants, for Groups of States



The position of the Medical Department of the Army and that of the Veterans Administration with respect to service origin of tuberculous disease would have been immeasurably strengthened had it been possible to set up the tuberculin test as a routine procedure at the time of entry examination. A positive reaction on discharge in soldiers whose entry test was negative would have established the fact for practical purposes that tuberculous disease, if it did develop, was the sequel of a tuberculous infection acquired in service.

On the other hand, the development of tuberculous disease in a soldier who had a positive test on entry would not necessarily establish a connection between the two, for superinfection from without is generally conceded to be quite possible in men already carrying a minor and latent infection responsible for a positive test. In other words, development of disease under such circumstances could not have been considered as of proven endogenous origin from infection already present. In most cases, probably, the actual origin of the disease in a previously tuberculin-positive person would have been indeterminable. However, the fortification of medical diagnosis through this one test in cases where a conversion from negative to positive occurred might often have been of decisive significance.

COURSE OF DISEASE DURING SERVICE IN MEN WITH TUBERCULOSIS AT INDUCTION

We turn our attention now to those men discharged for tuberculosis in whom the disease was present at the time of induction. We were interested in determining the course of the disease in these men during the time they were in service. To this end we compared the final readings of the induction and separation films for those men who were considered to show evidence of infection at the time of induction. The information is presented in tables 36–39.

It should be noted that the diagnoses which are compared are radiological diagnoses and are subject to error on that account. Nevertheless, they are as near to theoretically perfect readings as we could achieve.

TABLE 36

Activation and Arrest of Tuberculosis During Service Among Men Infected at Induction, by Race

Final Reading of Induction Film	Final Reading of Separation Film	Number of Men	Average Length of Service (Months)	Transitions: Percent of Men	Transitions: Rate Per Thousand Men Per Year
	White				
Inactive tuberculosis	Active tuberculosis	26	21.7	8.3	52.5
	Inactive tuberculosis	289	18.6		
Active tuberculosis	Active tuberculosis	540	18.5		
	Inactive tuberculosis	40	21.3	6.9	44.3
	Nonwhite				
Inactive tuberculosis	Active tuberculosis	4	25.0	6.1	36.4
	Inactive tuberculosis	62	19.7		
Active tuberculosis	Active tuberculosis	198	17.4		
	Inactive tuberculosis	13	27.5	6.2	40.9

It appears from table 36 that few men who had inactive or questionably active tuberculosis at induction had active tuberculosis at separation: only 8.3 percent of white and 6.1 percent of nonwhite recruits underwent the indicated "transition." The complementary transition—from activity at the time of induction to inactivity or questionable activity at separation—occurred somewhat more frequently so far as absolute numbers are concerned. However, when account is taken of the much larger numbers of men who had active disease at induction it is seen that the proportions of men with inactive (or questionably active) disease who developed active disease in service are larger than the proportions of men with active disease at induction whose course was in the reverse direction.

We may reasonably inquire, in view of the relatively small percentages of men who underwent transitions as shown in this table, whether the transitions may not in large part represent radiological error, which cannot be entirely absent even from our best readings. Our confidence in the essential correctness of our classifications is somewhat strengthened by the observation that in table 36, in each of the four instances the men alleged to have changed status had longer service on the average than did men of comparable status at induction but who remained in the same status. For white recruits, where the numbers of men classified are large enough to lend some stability to the averages, the mean length of service of men whose status did not change was about 18½ months, while the men whose status did change served, on the average, about 3 months longer. For nonwhite recruits the numbers of men whose status changed are so small that the averages of length of service are subject to considerable sampling error; still it seems significant that even for nonwhites the differences in length of service are in the same direction as those observed among whites.

TABLE 37

Progression and Retrogression of Stage of Tuberculosis Between Minimal and Moderately or Far Advanced During Service, by Race

Final Reading of Induction Film	Final Reading of Separation Film	Number of Men	Average Length of Service (Months)	Transitions: Percent of Men	Transitions: Rate Per Thousand Men Per Year
	White				
Minimal tuberculosis	Moderately or far advanced tuberculosis.	258	23.2	36.5	227.7
	Minimal tuberculosis	449	17.0		
Moderately or far advanced tuberculosis.	Moderately or far advanced tuberculosis.	162	16.1		
	Minimal tuberculosis	14	20.9	8.0	58.0
	Nonwhite				
Minimal tuberculosis	Moderately or far advanced tuberculosis.	95	20.4	46.3	290.8
	Minimal tuberculosis	110	18.0		
Moderately or far advanced tuberculosis.	Moderately or far advanced tuberculosis.	60	17.2		
	Minimal tuberculosis	4	10.8	6.3	44.7

A much more definitive picture than that just discussed is revealed by table 37, in which we examine changes between induction and separation in the stage of the disease as revealed by shifts from minimal to moderately or far advanced tuberculosis. Progressions of disease from minimal to more advanced stages were quite frequent: more than one-third of the men who had minimal tuberculosis at induction could no longer be considered to have only minimal disease at separation. On the other hand, there were relatively few transitions of stage in the reverse direction. Since about 95 percent of the men who were considered to have changed status were thought to have moved in the direction of increased severity of disease, we can safely infer that the overwhelming majority of apparent transitions in this direction were real changes and not merely the result of radiologic error: for putative transitions which were in reality merely the result of a faulty diagnosis by the final reading of either the induction or separation X-ray film should have occurred with equal frequency in both directions.

A point of some interest is the rather large difference in average length of service in men with minimal tuberculosis at induction between those who did and those who did not exhibit progression at the time of separation. White men inducted and separated with minimal tuberculosis had, on the average, less than 1½ years of service, while the average service for men whose disease was thought to have progressed was almost 2 years.

It is interesting to note that the apparent proportion of men who showed progression of disease was greater among nonwhites (46.3 percent) than among whites (36.5 percent); this difference is statistically significant.

Progression of disease during the period of service as between moderately and far advanced tuberculosis is shown in table 38. Here, again, we find that the number of men whose disease apparently grew worse while in service is many times the number for whom there was apparent improvement, and that the average length of service for men whose disease changed in status was greater than that of men whose disease remained unchanged.

A rather clear picture is shown by table 39, wherein we examine the apparent appearance and disappearance of cavities during service among men thought to have had active tuberculosis both at induction and separation. Few men were thought to have had cavities at the time of induction; but of the men who had active disease without cavities at induction 28.8 percent of whites and 38.1 percent of nonwhites developed cavities while they were in the Army. The difference between these percentages is statistically significant (on the five-percent level) and points again to the tendency of tuberculosis to run a more virulent course in nonwhites than in whites.

It is difficult to assess the few instances in which cavities were thought to have vanished during service; the average length of service for the men for whom this phenomenon was noted is quite short—only about a year in both whites and nonwhites. We are inclined, therefore, to think that in all likelihood most, if not all, of the nine apparent instances noted in both races were produced by radiological error.

In summary, it would appear that relatively few men whose disease was inactive at induction showed evidence of activity at separation, but of the men who had active disease at induction a large proportion progressed during service as evidenced by advances in stage and the development of cavities.

TABLE 38

Progression and Retrogression of Stage of Tuberculosis Between Moderately Advanced and Far Advanced During Service, by Race

Final Reading of Induction Film	Final Reading of Separation Film	Number of Men	Average Length of Service (Months)	Transitions	
				Percent of Men	Rate Per Thousand Men Per Year
	White				
Moderately advanced tuberculosis.	Far advanced tuberculosis	37	18.7	25.5	188.1
	Moderately advanced tuberculosis.	108	15.4	----------	----------
Far advanced tuberculosis	Far advanced tuberculosis	12	13.7	----------	----------
	Moderately advanced tuberculosis.	4	16.5	25.0	208.7
	Nonwhite				
Moderately advanced tuberculosis.	Far advanced tuberculosis	16	19.9	28.6	192.6
	Moderately advanced tuberculosis.	40	17.0	----------	----------
Far advanced tuberculosis	Far advanced tuberculosis	4	8.8	----------	----------
	Moderately advanced tuberculosis.	----------	----------	----------	----------

TABLE 39

Appearance and Disappearance of Cavities During Service Among Men With Active Tuberculosis at Induction and Separation, by Race

Final Reading of Induction Film	Final Reading of Separation Film	Number of Men	Average Length of Service (Months)	Transitions	
				Percent of Men	Rate Per Thousand Men Per Year
	White				
Active tuberculosis, no cavities.	Active tuberculosis, cavities	145	21.2	28.8	185.1
	Active tuberculosis, no cavities.	359	17.6	----------	----------
Active tuberculosis, cavities	Active tuberculosis cavities	30	16.7	----------	----------
	Active tubrculosis, no cavities.	6	14.8	16.7	122.2
	Nonwhite				
Active tuberculosis, no cavities.	Active tuberculosis, cavities	72	21.4	38.1	257.9
	Active tuberculosis, no cavities.	117	15.5	----------	----------
Active tuberculosis, cavities	Active tuberculosis, cavities	6	11.0	----------	----------
	Active tuberculosis, no cavities.	3	12.5	33.3	348.0

7. BACKGROUND CHARACTERISTICS OF MEN DISCHARGED FOR TUBERCULOSIS

It is a little surprising to us that some of the sociological factors which might have been thought to be strongly associated with the incidence of tuberculosis did not prove in this material to be of striking importance. The factor of race, to be sure, operated strongly, but age, occupation, education, and residence appeared to be of limited importance with reference to the probability of discharge for tuberculosis.

RACE

Table 40 presents the data with respect to race. The proportion of nonwhite enlisted men who were discharged for tuberculosis of some form is about double the proportion for white soldiers; the proportion who contracted active pulmonary tuberculosis is about twice as large for nonwhites as for whites, and the proportion who contracted nonpulmonary tuberculosis about three and one-half times as large. On the other hand, the proportions diagnosed as having inactive pulmonary tuberculosis are nearly the same. While these ratios are indicative of the general nature of the differences between whites and nonwhites with respect to susceptibility to tuberculosis and to nonpulmonary forms of the disease, it must be remembered that the ratios may be quite different from what would be found in the population at large in the same age range, for we are dealing here with a screened population. To the extent that the nonpulmonary forms of tuberculosis are more likely to escape notice at induction, we may assume that our data on the differential probabilities of this form in the two races bear a closer resemblance to the situation in an unscreened group.

TABLE 40

Discharges for Tuberculosis in Relation to Race

	White	Nonwhite
	Number of Men	
Roster I		
Total	2,343	756
Active pulmonary tuberculosis	1,514	492
Inactive pulmonary tuberculosis	555	102
Nonpulmonary tuberculosis	274	162
Roster II	2,507	403
	Number Discharged for Tuberculosis Per 100,000	
Total	164	340
Active pulmonary tuberculosis	106	221
Inactive pulmonary tuberculosis	39	46
Nonpulmonary tuberculosis	19	73

If we construct a similar table, as in table 41, which is restricted to individuals for whom we considered the induction film to be negative on our final reading, we pass to a group which is about as well screened at the point of induction as could reasonably be expected on the basis of the evidence provided by a single X-ray examination. Comparing table 41 with table 40, we see that in both races, the proportion who are discharged for active pulmonary tuberculosis in the more highly screened group is only half of the proportion among all soldiers (53 vs. 106 for whites and 111 vs. 221 for nonwhites); the proportions discharged for inactive pulmonary tuberculosis are reduced to little more than a quarter of the overall proportions (11 vs. 39 for whites and 13 vs. 46 for nonwhites), while the proportions discharged for nonpulmonary tuberculosis are only slightly reduced (18 vs. 19 for whites and 61 vs. 73 for nonwhites). Even in this highly screened group the proportion of nonwhite troops who developed active pulmonary tuberculosis was about double the proportion for whites, and the proportion who developed nonpulmonary tuberculosis about three times as large in nonwhite troops, while the proportions who were discharged for inactive pulmonary tuberculosis were about the same. The fact that the ratios of the incidences of these categories in white and nonwhite troops vary so little when we restrict ourselves to a highly screened group (table 41 as compared with table 40), would tend to support the notion that perhaps our ratios are, after all, not much affected by the initial screening and come close to measuring the characteristic differences of the two race groups with respect to susceptibility to infection by the tubercle bacillus and to nonpulmonary forms of disease.

TABLE 41

Discharges for Tuberculosis in Relation to Race Among Men for Whom the Induction Film was Called Negative on Final Reading

	White	Nonwhite
	Number of Men	
Roster I		
Total	926	341
Active pulmonary tuberculosis	598	204
Inactive pulmonary tuberculosis	128	25
Nonpulmonary tuberculosis	199	112
Roster II	2,221	352
	Number Discharged for Tuberculosis Per 100,000	
Total	82	185
Active pulmonary tuberculosis	53	111
Inactive pulmonary tuberculosis	11	13
Nonpulmonary tuberculosis	18	61

AGE

Table 42 shows the number of tuberculosis discharges of each kind (active pulmonary, inactive pulmonary, and nonpulmonary) in terms of age at induction and race. Within the active pulmonary group a breakdown is given according to our final reading of the induction film. In table 43 these data are shown in the form of CDD ratios. Figures 10 and 11 show the CDD ratios graphically for white enlisted men.

In figure 10 the curve for inactive pulmonary tuberculosis behaves as one might expect, increasing rather steadily with advancing age, but the curves for active pulmonary and nonpulmonary disease are quite different: nonpulmonary tuberculosis appears to be substantially independent of age, while the curve for active pulmonary tuberculosis appears to peak at ages 19–20 and then declines, reaching a minimum at 27–28, after which it rises abruptly. The curve for all discharges is, of course, merely the sum of the three constituent pieces.

The reason why the curve for active pulmonary disease behaves as it does may readily be seen in figure 11. Discharges of white soldiers with negative induction films are at a peak among men aged 19–20 at induction, the curve thereafter declining to ages 23–24, after which it appears to remain

TABLE 42

Discharge for Tuberculosis in Relation to Age at Induction, Type of Diagnosis and Race

NUMBER OF MEN DISCHARGED

Age at Induction	Control Roster	Tuberculosis Roster						
		Total	Active Pulmonary Tuberculosis				Inactive Pulmonary Tuberculosis	Nonpulmonary Tuberculosis
			Final Reading, Induction Film					
			Total	Negative	Not Negative	Not Read		
	White Inductees							
Total	2,597	2,343	1,514	598	748	168	555	274
18 and under	477	290	188	98	72	18	48	54
19–20	555	539	367	176	142	49	100	72
21–22	380	348	244	110	108	26	66	38
23–24	216	192	114	42	57	15	55	23
25–26	229	173	110	40	59	11	43	20
27–28	209	156	94	36	50	8	46	16
29–30	147	142	87	27	53	7	39	16
31–35	272	318	199	47	126	26	91	28
36 and over	110	185	111	22	81	8	67	7
Unknown	2	--------	--------	--------	--------	--------	--------	--------
	Nonwhite Inductees							
Total	403	756	492	204	246	42	102	162
20 and under	120	239	150	62	74	14	32	57
21–24	132	216	145	62	71	12	26	45
25–30	69	162	109	51	49	9	18	35
31 and over	73	134	85	27	51	7	25	24
Unknown	9	5	3	2	1	--------	1	1

TABLE 43

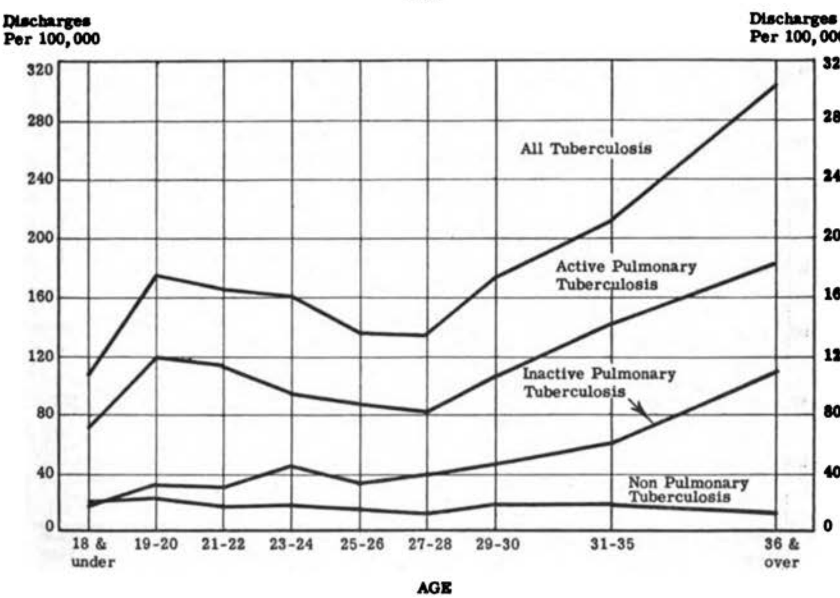
Discharge for Tuberculosis in Relation to Age at Induction, Type of Diagnosis and Race

ODD RATIOS PER 100,000 DISCHARGES

Age at Induction	Total	Active Pulmonary Tuberculosis — Final Reading, Induction Film: Total	Negative	Not Negative	Not Read	Inactive Pulmonary Tuberculosis	Nonpulmonary Tuberculosis
	White Inductees						
Average	164	106	42	52	12	39	19
18 and under	110	72	37	27	7	18	21
19–20	176	120	58	46	16	33	24
21–22	166	116	53	52	12	32	18
23–24	161	96	35	48	13	46	19
25–26	137	87	32	47	9	34	16
27–28	135	82	31	43	7	40	14
29–30	175	107	33	65	9	48	20
31–35	212	133	31	84	17	61	19
36 and over	305	183	36	133	13	110	12
	Nonwhite Inductees						
Average	340	221	92	111	19	46	73
20 and under	355	223	92	110	21	48	85
21–24	292	196	84	96	16	35	61
25–30	418	281	132	127	23	46	90
31 and over	327	208	66	125	---------	61	59

FIGURE 10

Discharges for Tuberculosis, by Type, Per 100,000 Discharges by Age at Induction; White Enlisted Men

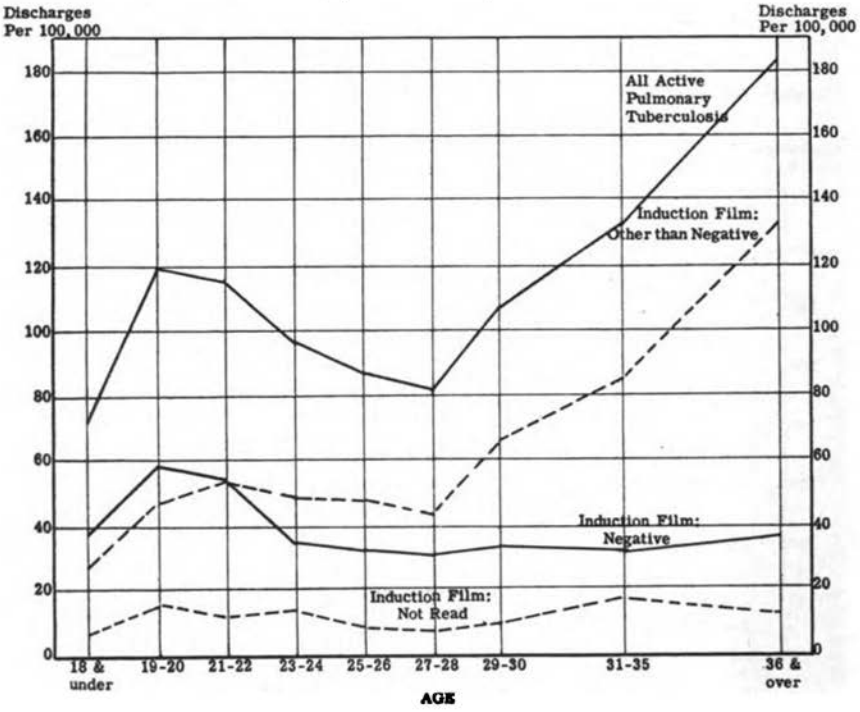


essentially constant. However, the curve representing discharges of men for whom the induction film was not considered to be negative rises rather sharply, particularly after ages 27–28. We may perhaps think of the two groups of tuberculosis discharges as being very largely in the one instance men who were infected while in service, and in the other men who were already infected at the time of induction. It is by no means surprising that the proportion of men infected at the time of induction should be an increasing function of age, for older men have for a longer time been subject to the risk of infection. The curve for the presumably uninfected men, on the other hand, seems to imply that the incidence rate of new clinical disease is at a maximum at about age 20. An analysis in terms of length of service disclosed that the shape of this curve is not merely a reflection of differences in length of exposure for men of different ages: variation in average length of service accounts for but little of the observed variation in the probability of discharge for tuberculosis.

For nonwhite soldiers the situation is quite different from that among white soldiers: the average CDD ratios for all ages differ markedly from the averages for whites, while no evidence of the kinds of age patterns found for whites can be observed. The CDD ratios in general move up and down

FIGURE 11

Discharges for Active Pulmonary Tuberculosis Per 100,000 Discharges by Age at Induction and Final Reading of Induction Film; White Enlisted Men



in erratic fashion as age increases, and the movement in general does not exceed what we might expect chance variation to produce. Only in the discharges for inactive pulmonary tuberculosis is there a suggestion of a rising ratio as age increases, and even here the rise is much slower than the rise in the corresponding ratios for white soldiers.

RESIDENCE

Men coming from different sections of the country differed somewhat in their relative chances of being discharged for tuberculosis. This undoubtedly reflects, at least in part, the variability among service commands in efficiency of induction screening which we have already noted. Table 44 shows the probability of discharge as a function of residence at induction and birthplace. For each race, the two proportions for each census division are generally quite similar. Analysis of patterns of migration from birth to induction did not reveal any striking correlation with the development of tuberculosis.

URBAN AND RURAL BACKGROUND

Comparison of men with urban and rural backgrounds was disappointing in that no consistent pattern could be seen. Table 45 exhibits the proportions discharged for tuberculosis in relation to race and the population in 1940 of the birthplace and place of induction residence. The variability within columns in this table is not impressive. Further analysis in terms of roentgenographic interpretations of the induction films was not fruitful: there was no evidence among whites or nonwhites either that men with tuberculosis at the time of induction tended more frequently to come from rural or metropolitan areas, or that this factor was associated with a variable probability of development of tuberculosis in the Army.

TABLE 44

Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Census Division of Induction Residence and Birthplace

Census Division	ODD Ratio/100,000			
	White		Nonwhite	
	Induction Residence	Birthplace	Induction Residence	Birthplace
Total	164	164	340	340
New England	154	152	(1)	(1)
Middle Atlantic	126	122	298	255
South Atlantic	170	179	293	285
East North Central	165	170	355	499
East South Central	214	230	358	335
West North Central	141	137	(1)	(1)
West South Central	195	186	364	361
Mountain	179	176	(1)	(1)
Pacific	220	282	416	700

[1] Not computed.

TABLE 45

Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Size of City of Induction Residence and Birthplace

Population (1940)	CDD Ratio/100,000			
	White		Nonwhite	
	Induction Residence	Birthplace	Induction Residence	Birthplace
Total	164	164	340	340
1,000,000 or more	147	143	352	309
250,000–999,999	197	168	283	305
50,000–249,999	166	167	371	272
10,000–49,999	165	171	325	371
2,500–9,999	164	134	288	304
Less than 2,500	156	179	405	380

EDUCATIONAL STATUS

Analysis by educational status is more rewarding (table 46): among whites, there is clear indication of a declining proportion of discharges for tuberculosis as the educational level increases through men who graduated from high school. In contrast, however, an increasing prevalence is found among men who went on to college. Among nonwhites, on the other hand, the very lowest proportions are found among men who attended college. We can see from figure 12, wherein the CDD ratios are shown graphically for white men, that the variability of the ratio with educational status results almost wholly from variation in the proportions of men who are sick when inducted. The development of disease in men with negative induction films is practically independent of the number of school years completed at the time of induction. Just why men of intermediate educational level (high school graduates) should be less likely than men who attended college to have tuberculosis lesions at the time of induction we do not know; a like analysis for nonwhites indicates a consistent decline in the prevalence of tuberculosis with increase in education. Presumably, the advantage which high school graduates exhibit when they are compared with men with less education reflects the superior socio-economic environment from which they come.

An interesting parallel is to be found in table 47: here it will be seen that, among whites, professional and semiprofessional workers have a significantly higher proportion of tuberculosis discharges than do other workers. On the other hand, "operatives" have a very favorable experience. However, the pattern of variation among nonwhites is quite different from that among whites: among the nonwhites farmers seem to be at high risk, although the sample is not sufficiently large for this difference to achieve statistical significance.

FIGURE 12

Discharges for Tuberculosis Per 100,000 Discharges by Education at Induction and Final Reading of Induction Film; White Enlisted Men

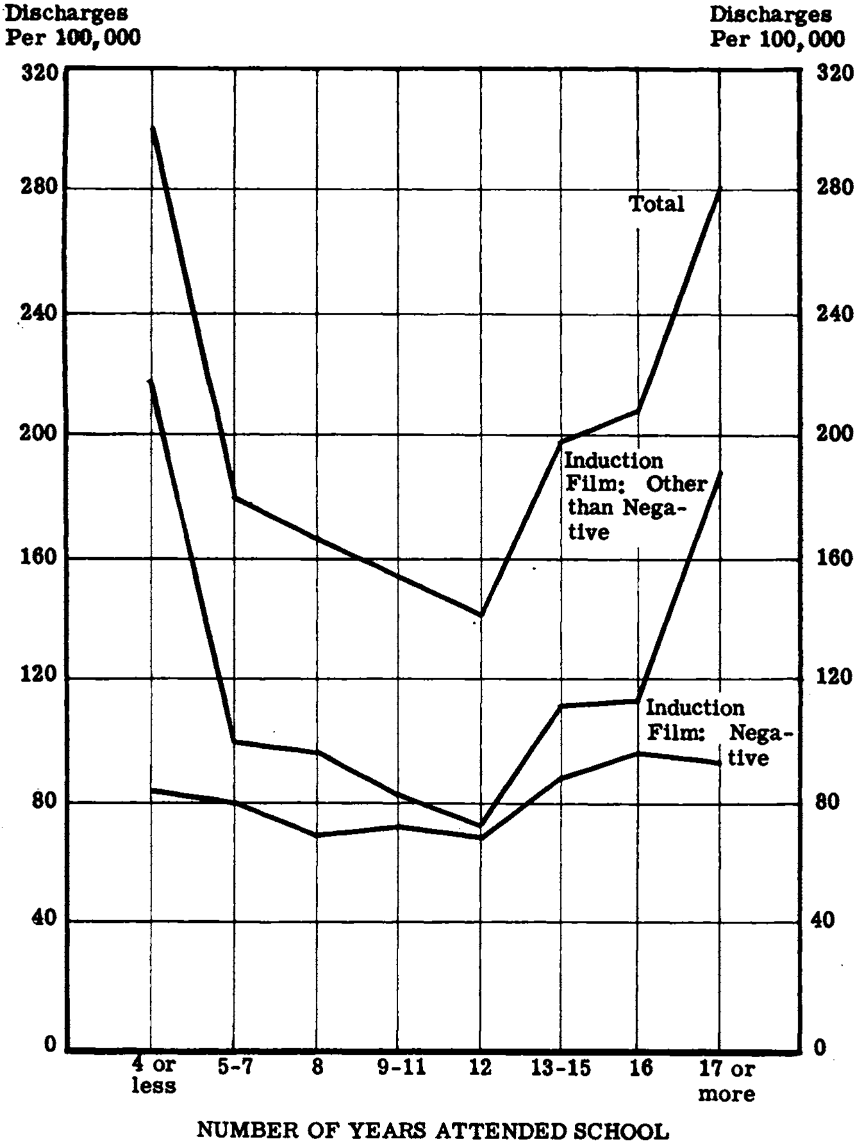


TABLE 46

Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Education at Induction

Years of Education at Induction	CDD Ratio/100,000	
	White	Nonwhite
Total	164	340
4 or less	299	382
5–7	178	346
8	166	380
9–11	153	332
12	141	309
13–15	198	
16	208	243
Over 16	281	

TABLE 47

Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Civilian Occupation

Civilian Occupation	CDD Ratio/100,000	
	White	Nonwhite
Total	164	340
Professional, semiprofessional	261	[1]
Farmers and farm laborers	163	442
Proprietors, officials	161	[1]
Clerical or sales personnel	174	441
Craftsmen and foremen	169	368
Operatives	142	302
Welders	165	[1]
Service workers, except protective service	227	307
Protective service workers	183	[1]
Students	143	245
Laborers	190	333

[1] Not computed.

BODY BUILD

If the sociological variables discussed thus far seem more remarkable for the weakness of their association with the development of tuberculosis, the same is not true of the factor of body-build. An association between build and tuberculosis has long been noted [3] and we are impressed with the very great strength of this association. Table 48 and figure 13 exhibit the proportions of recruits ultimately discharged for tuberculosis according to height at induction. Among white enlisted men the increase of this proportion with height is quite regular and for the tallest men (over 72 inches) achieves a level more than twice as great as in the shortest men (63 inches and under). For nonwhites, on the other hand, while there is some suggestion of an upward trend in the incidence of tuberculosis with increasing height, it is by no means unequivocal, and the picture is much obscured by a relatively large sampling variability. Even if the suggestive trend among nonwhites be taken at face value, however, the relative increase in incidence from men of least to men of greatest height is very much smaller than the corresponding change among whites.

[3] See example Reed and Love (11). These authors quote Huntington as making this same observation in 1876.

Of even greater effect than height is the factor of thinness. We have categorized men according to the ratio of their weight when inducted to the median weight for men of that height. The basis for this classification was a sample of 67,995 Army recruits examined at induction stations during January and May 1943 (12). The results are shown in table 49 and figure 14.

FIGURE 13

Discharges for Tuberculosis Per 100,000 Discharges by Height at Induction and Race

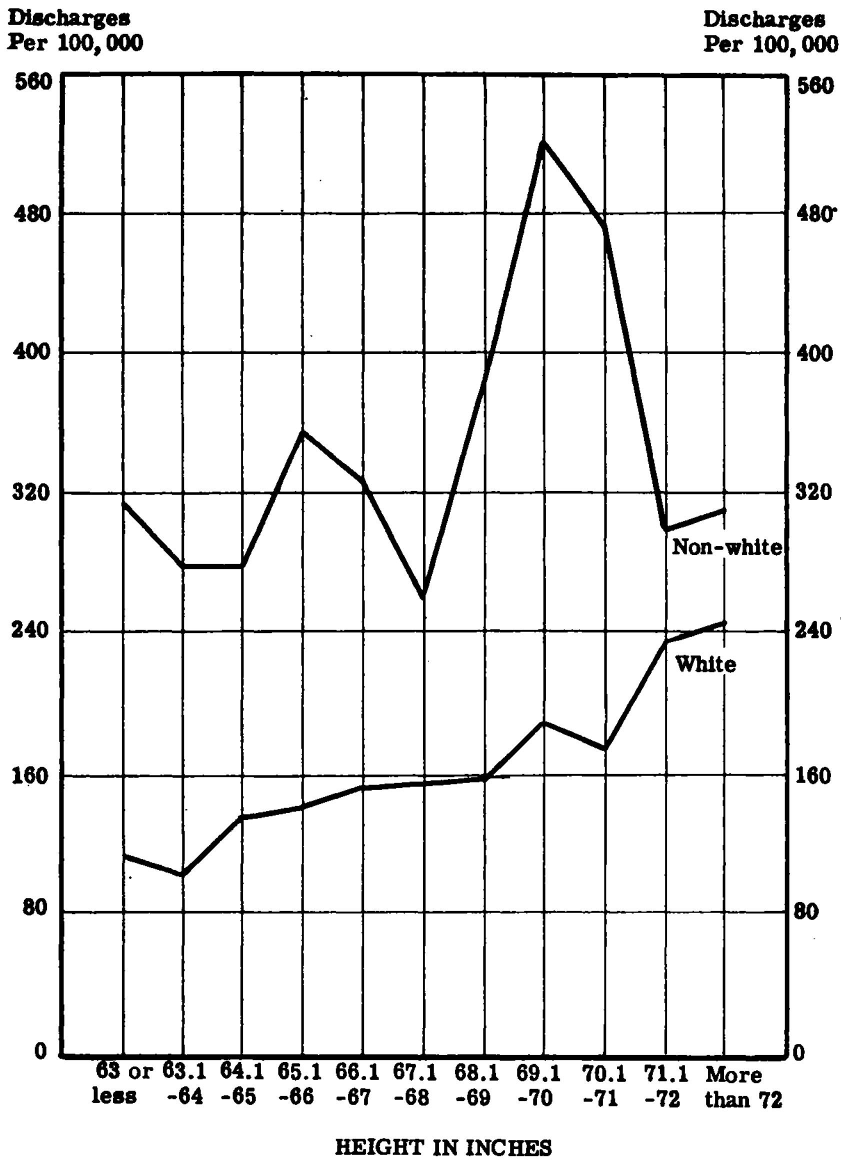


TABLE 48

Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Height

Height at Induction	CDD Ratio/100,000			
	White	95 Percent Confidence Limits	Nonwhite	95 Percent Confidence Limits
Total	164	155-173	340	301-385
63 inches and under	117	80-167	312	182-584
63.1-64 inches	109	78-148	274	144-500
64.1-65 inches	133	92-188	274	184-422
65.1-66 inches	138	102-183	354	251-525
66.1-67 inches	152	130-177	324	233-467
67.1-68 inches	154	133-178	255	190-350
68.1-69 inches	155	135-179	383	280-544
69.1-70 inches	190	163-221	522	368-801
70.1-71 inches	174	145-207	466	306-785
71.1-72 inches	235	189-294	299	184-519
72.1 inches and over	244	198-304	309	178-591

TABLE 49

Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Ratio of Weight at Induction to Median Weight for Height

Ratio of Weight to Median Weight for Height (Percent)	White				Nonwhite			
	Roster I Number	Roster II Number	CDD Ratio Per 100,000		Roster I Number	Roster II Number	CDD Ratio Per 100,000	
			Estimated	95 Percent Confidence Limits			Estimated	95 Percent Confidence Limits
Total known	2,342	2,596	164	155-173	749	395	340	302-385
85 percent or less	374	195	349	294-415	87	26	598	403-990
86 to 90 percent	441	340	235	205-272	106	45	422	304-616
91 to 95 percent	462	436	192	169-219	154	65	424	323-578
96 to 104 percent	635	818	141	127-156	260	144	324	266-399
105 to 109 percent	182	258	128	106-154	67	44	273	189-408
110 to 114 percent	92	189	88	68-112	40	35	205	130-328
115 to 124 percent	103	204	92	72-115	22	22	180	98-330
125 percent or more	53	156	62	44-83	13	14	167	75-364

It will be observed that the decline in the proportion discharged for tuberculosis as weight increases (for fixed height) is truly precipitous, for both whites and nonwhites: the proportion for the most obese group is less than one-fifth of the proportion in the slimmest group, for each racial group. The two curves follow about the same trend, the nonwhite proportions remaining generally at about twice the level of the proportions for whites.

The remarkable feature of this relationship is that it is found even if the analysis is restricted to those individuals whose induction X-ray films were considered by us to be unequivocally negative on the so-called final reading. Table 50 and figure 15 show the results for white inductees. Unfortunately, the number of nonwhite recruits in our samples is not large enough to support a parallel analysis. It will be seen that the curve which expresses the relationship between weight and the probability of discharge for tuberculosis for this restricted group resembles in shape the curve in figure 14 for white recruits; the level is lower, but the shape and slope of the curve are quite similar. Table 51 shows why this is so; here percentage distributions are shown for white enlisted men for the control roster and also for the tuberculosis roster, divided into three parts according to the final reading of the induction film. The weight distributions in the tuberculosis roster are all quite similar and are apparently unrelated to the reading of the induction film, but are all quite different from the distribution of weights found in the control roster. The evidence suggests, therefore, that while disease preexisting at the time of induction may contribute in a small way to the displacement of the weight distribution in the tuberculosis roster in the direction of slimness, the most important reason for this

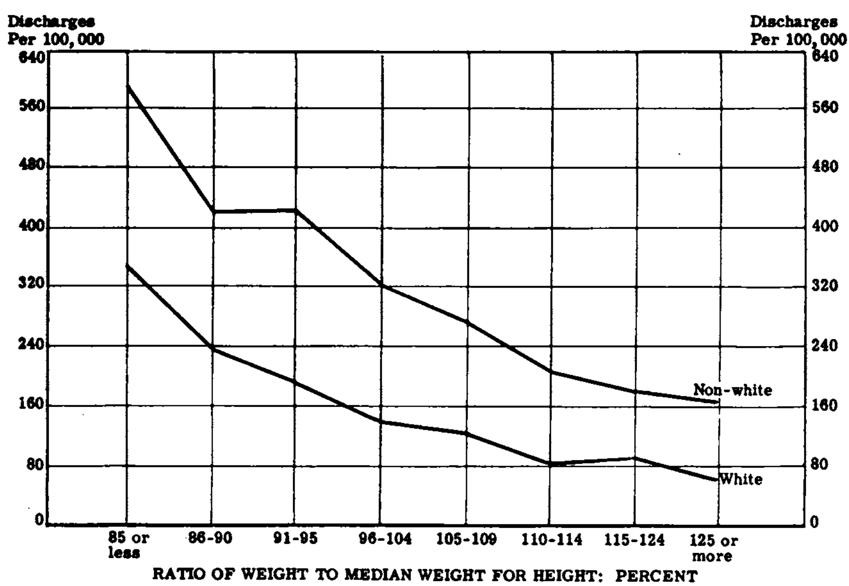
TABLE 50

Number Discharged for Tuberculosis Per 100,000 Discharges in Relation to Ratio of Weight at Induction to Median Weight for Height; White Enlisted Men, Final Reading of Induction Film Negative

Ratio of Weight to Media, Weight for Height	CDD Ratio/100,000
Total	82
85 percent or less	193
86 to 90 percent	120
91 to 95 percent	92
96 to 104 percent	67
105 to 109 percent	73
110 to 114 percent	37
115 to 124 percent	38
125 percent or more	35

FIGURE 14

Discharges for Tuberculosis Per 100,000 Discharges by Relative Weight at Induction and Race



shift is a tendency toward greater susceptibility to disease on the part of thin men and greater resistance on the part of men of normal weight or men who are even obese. The correlation between susceptibility to tuberculosis and height noted above tends to strengthen this conclusion. Moreover, the relationship with height would imply that the correlation of physical build with susceptibility is probably not entirely on a nutritional basis but, at least in part, rests on some other mechanism.

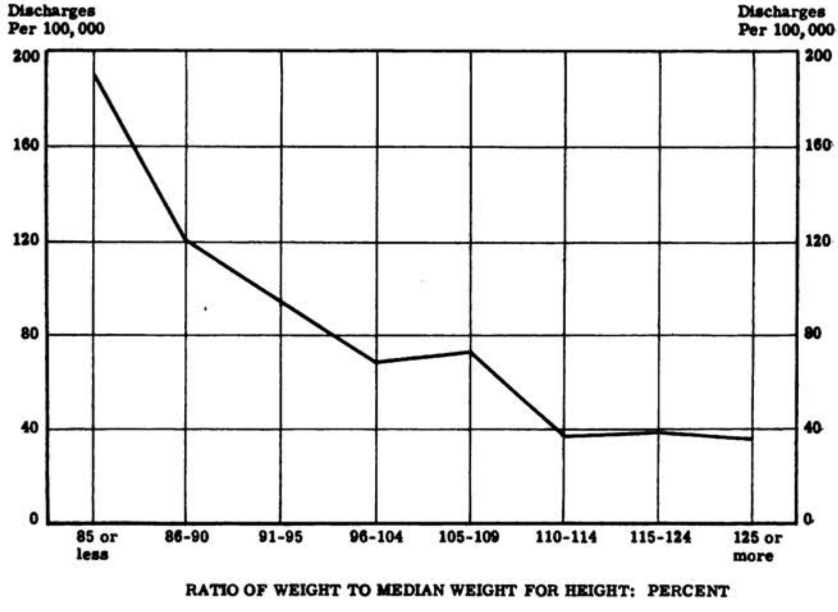
TABLE 51

Distribution of Weight at Induction in Relation to Roster and Final Reading of Induction Film for the Tuberculosis Roster, White Recruits

Ratio of Weight to Median Weight for Height	Control Roster	Tuberculosis Roster, Final Reading of Induction Film		
		Negative	Tuberculosis	Other Pathology Only
Total (percent)	100.1	100.1	100.0	100.0
Total number	2,482	925	902	260
85 percent or less	7.7	17.9	17.0	10.4
86–90 percent	13.1	19.1	17.6	15.4
91–95 percent	17.1	19.4	20.2	25.0
96–104 percent	31.3	25.4	28.4	26.5
105–109 percent	9.9	8.5	6.8	8.1
110–114 percent	7.2	3.4	4.4	4.2
115–124 percent	7.8	3.7	4.2	5.8
125 percent or more	6.0	2.7	1.4	4.6

FIGURE 15

Discharges for Tuberculosis Per 100,000 Discharges by Relative Weight at Induction; White Enlisted Men, Induction Film Negative on Final Reading



8. ASPECTS OF MILITARY SERVICE IN RELATION TO THE DEVELOPMENT OF TUBERCULOSIS

UNITED STATES AND FOREIGN SERVICE

A great deal of interest is naturally attached to such questions as "What increase in the risk of contracting tuberculosis, if any, is associated with foreign service? Which are the places of particularly high risk"? Unfortunately, we can answer such questions only in a tentative way, for at least two reasons. First, as was remarked above, incidence rates for tuberculosis measure recognition of disease, not infection. For this reason, we should expect to find that the "incidence" of tuberculosis for troops in the continental United States during World War II far exceeded that in foreign theaters for the reason that men were in the United States when subjected to the separation X-ray screen, and we have seen that a very large proportion of the tuberculosis diagnosed in troops during World War II was apparently detected only by the separation screen. In other words the incidence rate associates the occurrence of tuberculosis with the characteristics of the patient at the time the diagnosis is first made, while, as we know, tuberculosis may not become manifested as a clinical entity for many months after infection occurs. We therefore use instead of the incidence rate the CDD ratio, which simply measures the proportion of men having any given characteristic who were ultimately discharged for tuberculosis. In this way we associate a diagnosis of tuberculosis in a soldier with each of the characteristics of his service prior to the diagnosis, not merely the characteristics at the time the disease is first recognized.

The real difficulty, however, cannot be overcome so simply, for it results from the fact that the experiment in nature which we are trying to exploit for our own purposes, unfortunately, confounds the variables under study. Thus, it is plain that, wholly apart from any tendency for the risk of infection to be different in overseas theaters from that in the United States, the occurrence of tuberculosis is not unrelated to the chance of overseas service: men who manifested tuberculosis after, say, 8 months of service, but before being sent overseas, had no chance of going overseas. This tends to inflate the CDD ratio unduly for the United States and to deflate it for overseas. This may be made clear by a simple example: suppose 100,000 men were inducted, of whom 200 had tuberculosis and would eventually be discharged for this disease. Suppose half, or 50,000 men, were to serve only in the United States, so that of these 50,000 men 100 were CDD'd. Suppose further that of the 100 tuberculosis discharges occurring in the 50,000 destined for foreign service, half, or 50, occurred before overseas shipment; these 50 men, then, did not go overseas and would be debited to the United States group. So we have at the end, for the United States group, 150 discharges for tuberculosis out of a total of 50,050 men serving in the United States only, for a ratio of about 300 per 100,000, and only 50 such discharges out of a total of 49,950 men who served overseas, for a ratio of only about 100 per 100,000. This difference does not in any way depend upon length of service, or time overseas, or any other factor save the all important one, that the occurrence of tuberculosis can affect the classification under study (here overseas vs. United States). In fact, the example cited is not grossly exaggerated: if, in our data, we calculate CDD ratios per 100,000 for enlisted men who served overseas and in the United States only, we obtain 119 and 406, respectively. Much the same kind of argument can be applied to other variables we wish to study, such as military occupation and particular theaters of service among men who served overseas. The reason that this problem affects theater comparisons is exemplified by the comparison between men for whom the place of longest overseas service was the Philippines and those for whom it was the Southwest Pacific: the CDD ratio for the Southwest Pacific is much higher than that for the Philippines. One reason for this somewhat surprising result is that most of the men who went to the Philippines had come from the Southwest Pacific; men who broke down with active tuberculosis while in the Southwest Pacific were debited to that theater, while their companions who failed to break down went on to be credited to the Philippines as controls.

Granting the difficulties mentioned above, we wish, nevertheless, if it is possible, to obtain at least first approximations to answers to the questions of interest, and we believe that this may be done by placing suitable restrictions no the cases of tuberculosis studied. Thus, could we restrict ourselves to those cases of tuberculosis detected by the separation screen, our problems would disappear, for there is no possibility that tuberculosis thus detected could have affected the characteristics of service. Unfortunately, the records usually did not distinguish unequivocally between cases of tuberculosis discovered by the separation X-ray screen and other cases; so we must approximate this restriction by indirect means.

We should expect that the cases detected by the separation screen in general had longer periods of service before the detection of their tuberculosis than did men who reported sick. Therefore, we may hope that by invoking a suitable minimum length of service (apart from time spent in hospital because of the tuberculosis), we should restrict the group under consideration largely to the cases discovered by this separation screen. The particular restriction employed was to consider only those men who served more than 2 years apart from time spent in hospitals with the diagnosis of tuberculosis or any other diagnosis referable to the chest. Of our 3,000 controls, 2,120 (or 71 percent) met this criterion, while of our 3,099 men discharged for tuberculosis, 983 (or 32 percent) had such long service prior to hospitalization. Secondly, we sharpened our focus by considering only those men discharged for active pulmonary tuberculosis. This resulted in a further reduction of our Roster I cases to 611, or 62 percent of those eligible on the basis of length of service and 20 percent of the entire roster. Finally, we also imposed on the Roster I cases the condition that our final reading of the induction film be negative; this reduced the roster to 323 men, or about 10 percent of the original number.

These Draconian restrictions, while they seriously interfered with our ability to subdivide our data according to different characteristics of service, nevertheless, do possess the advantage that, having made them, we may reasonably hope that any apparent differences in the occurrence of tuberculosis found really represent differences either in the risk of infection or in the probability that infection will result in clinical disease, or both.

PRISONERS OF WAR

Table 52 shows the data with respect to overseas service and prisoner-of-war status. The right-most column, labeled "Relative Chance of Tuberculosis," was obtained by dividing the second column by the fourth and is an index showing the degree of risk for persons in the stated category relative to the race group as a whole, the average risk being taken as 100. Thus, among whites, for men with overseas service who were not taken prisoner, the risk was 99, while for those captured the risk was 340. It should be noted that almost all of the prisoners in this study were captured by the Germans: most of our troops who were captured by the Japanese were inducted into the Army too early to be eligible for this study, since it will be recalled that we employed the restriction that men must have been inducted on or after 1 July 1942. In a study of prisoners of war (13) Cohen and Cooper found that the proportions of prisoners who had active tuberculosis diagnosed at the time of liberation or shortly thereafter was about 37 per thousand for former prisoners of the Japanese as compared with about 6 per thousand in liberated prisoners of the Germans. In addition, probably much of the very heavy mortality in Japanese prisoner-of-war camps was attributable to tuberculosis. It must be recognized, therefore, that our statement of relative risk applies only to prisoners in the European theater.

It will be seen from table 52 that the effect of the restrictions we have made has been to eliminate the spurious appearance of an excessive risk of tuberculosis among men who served in the United States only. In fact, the risks among men with and without overseas service (excluding men who were captured) were substantially equal: the differences are small, are in opposite directions in the two racial groups, and are not statistically significant. The contrast between prisoners and men with overseas service who were not prisoners is, on the other hand, highly significant among whites. For nonwhites, the number of prisoners was so small that the corresponding difference, although very large, does not by itself achieve statistical significance, although there can be little doubt that nonwhites, too, while in prison camps, were subject to very high risk of infection.

TABLE 52

Development of Tuberculosis in Relation to Overseas Service and Prisoner-of-War Status; Men With 25 Months or More of Service Excluding Time in Hospital for Chest Disease

	Roster I[1]		Roster II		Relative Chance of Tuberculosis
	Number	Percent	Number	Percent	
	White				
Total known	255	100.0	1,826	100.0	100
No overseas service	32	12.5	280	15.3	82
Overseas service	223	87.5	1,546	84.7	103
Not prisoner of war	210	82.4	1,519	83.2	99
Prisoner of war	13	5.1	27	1.5	345
	Nonwhite				
Total known	68	100.0	290	100.0	100
No overseas service	11	16.2	43	14.8	109
Overseas service	57	83.8	247	85.2	98
Not prisoner of war	55	80.9	246	84.8	95
Prisoner of war	2	2.9	1	0.3	(2)

[1] Limited to men discharged for active pulmonary tuberculosis for whom final reading of induction film is negative.
[2] Not calculated.

PLACE OF FOREIGN SERVICE

The influence of place of foreign service may be seen in table 53. The variation by place in the relative chance of acquiring tuberculosis, among whites, was not significant and may be attributed to chance, but among nonwhites, the Mediterranean area (North Africa, Italy, Southern France) was associated with quite high risk and the Pacific area (Central Pacific, Southwest Pacific) with very low risk. While the reasons for the significant variation from the average in these two areas cannot be explicitly demonstrated, it seems significant that for nonwhites the Mediterranean area had an extremely high venereal disease rate and the Pacific area quite a low rate. The Mediterranean theater early became one in which large numbers of rear area troops, whose mission was logistic support to the front, were in close contact (as manifested by the high venereal disease rate) with a civilian population in which there was a high prevalence of tuberculosis.

Analysis of the geography of foreign service within theaters proved to be impractical because of the great mobility of the Army during World War II: most men served in many places within the same theater, and it was not always easy to tell from the individual records how much time a soldier with European Theater of Operations service had spent in the United Kingdom, France, Belgium, and Germany, respectively. On the other hand, it seems plain from an analysis of venereal disease rates that contact between troops and the civilian population was not very close during active fighting; thus, it was not until after the capture of Paris that venereal disease rates began to soar in France. We may conclude, then, that a civilian population in which tuberculosis is prevalent probably constitutes a potential menace to the health of troops when the overall situation is one which favors relatively close contact between that population and the troops, and that the absence of such close contact materially diminishes the danger. In short, perhaps the most striking feature of table 53 is the relative homogeneity of risk by theater which it displays, particularly among white troops.

We were not able, however, in our sample to demonstrate a direct relationship between the incidence of venereal disease (and scabies) and the risk of tuberculosis. In fact, as table 54 shows, the relationship seems, if anything, to be inverse. In this table the risk of tuberculosis for each subgroup defined by foreign service is taken to be 100; the risk for men whose records did or did not show diagnoses of venereal disease is then computed relatively to this base. Thus, white soldiers who served in the European Theater of Operations who acquired venereal disease (or scabies) in that theater were only 97 percent as likely to be discharged for (presumably) service-acquired active pulmonary tuberculosis as were men generally who served in that theater. However, this apparent decreased risk of tuberculosis in white men who acquired venereal disease in the European Theater of Operations is not statistically significant, nor is there for any theater, for whites or nonwhites, significant evidence of association between tuberculosis and venereal disease, whether direct or inverse. Nevertheless, it is

TABLE 53

Development of Tuberculosis in Relation to Place of Longest Overseas Service; Men With 25 Months or More of Service Excluding Time in Hospital for Chest Disease

Longest Overseas Service	Roster I [1]		Roster II		Relative Chance of Tuberculosis
	Number	Percent	Number	Percent	
	White				
Total	221	100.1	1,521	100.0	100
North America	3	1.4	47	3.1	44
Central and South America	3	1.4	29	1.9	71
Europe	121	54.8	754	49.6	110
Mediterranean	17	7.7	160	10.5	73
Middle East	6	2.7	51	3.4	81
Asia	11	5.0	63	4.1	120
Pacific	60	27.1	417	27.4	99
	Nonwhite				
Total	56	100.0	245	100.0	100
North America	1	1.8	2	.8	(2)
Europe	27	48.2	108	44.1	109
Mediterranean	12	21.4	22	9.0	239
Middle East	1	1.8	7	2.9	(2)
Asia	5	8.9	18	7.3	122
Pacific	10	17.9	88	35.9	50

[1] Limited to men discharged for active pulmonary tuberculosis for whom final reading of induction film is negative.
[2] Not calculated.

striking that in seven out of eight instances (four theaters each for whites and nonwhites), the apparent risk of tuberculosis was lower for men with venereal disease. This, combined with the observation that among nonwhites the Mediterranean Theater of Operations showed both high tuberculosis and high venereal disease rates, while the Pacific theater had low rates for both kinds of disease, suggests the possibility that a defect in the Army clinical records may be obscuring the picture. If, in fact, there were a real association between the incidence of venereal disease and the incidence of tuberculosis, but venereal disease diagnosed in an individual hospitalized for tuberculosis might sometimes go unrecorded in the face of the other more serious condition, then we should expect that the recorded experience might look much like what we see in table 54. However, this

TABLE 54

Development of Tuberculosis in Relation to Venereal Disease and Theater of Overseas Service; Men With 25 Months or More of Service Excluding Time in Hospital for Chest Disease

	Roster I[1]		Roster II		Relative Chance of Tuberculosis
	Number	Percent	Number	Percent	
White					
ETO—Total	121	100.0	754	100.0	100
With ETO venereal disease	13	10.7	60	8.0	135
Without ETO venereal disease	108	89.3	694	92.0	97
MTO—Total	17	100.0	160	100.0	100
With MTO venereal disease	1	5.9	21	13.1	45
Without MTO venereal disease	16	94.1	139	86.9	108
PAC—Total	60	100.0	417	100.0	100
With PAC venereal disease	1	1.7	16	3.8	43
Without PAC venereal disease	59	98.3	401	96.2	102
Other Theaters—Total	25	100.0	215	100.0	100
With overseas venereal disease	----------	----------	17	7.9	----------
Without overseas venereal disease	25	100.0	198	92.1	109
Nonwhite					
ETO—Total	27	100.0	108	100.0	100
With ETO venereal disease	2	7.4	25	23.1	32
Without ETO venereal disease	25	92.6	83	76.9	120
MTO—Total	12	100.0	22	100.0	100
With MTO venereal disease	1	8.3	9	40.9	20
Without MTO venereal disease	11	91.7	13	59.1	155
PAC—Total	10	100.0	88	100.0	100
With PAC venereal disease	1	10.0	12	13.6	73
Without PAC venereal disease	9	90.0	76	86.4	104
Other Theaters—Total	8	100.0	29	100.0	100
With overseas venereal disease	----------	----------	3	10.3	----------
Without overseas venereal disease	8	100.0	26	89.7	112

[1] Limited to men discharged for active pulmonary tuberculosis for whom final reading of induction film is negative.

suggestion is highly speculative; there is no evidence in our data of association between the two conditions. Only a small number of men (about 8 percent) on our rosters were noted as having been admitted to hospital for these conditions, and there was no evidence of an increased incidence of tuberculosis among these men. Similarly, just under 5 percent of the combined rosters had suffered battle wounds, but no association was found between the incidence of wounding and the prevalence of tuberculosis.

MILITARY ARM AND OCCUPATION

No distinguishable effect was found to be associated either with arm (table 55) or military occupation (table 56) except for the consistent finding that men who served in the Medical Department, or who had medical duties, had a substantially enhanced risk of contracting tuberculosis: for white soldiers, the risk associated with such duties was somewhat less than twice the general risk, while for nonwhite soldiers the risk was just about doubled. While the differences in risk for nonwhite soldiers with medical duties are not by themselves sufficiently large to achieve statistical significance in view of the relatively small number of men involved, the corresponding differences for white soldiers do exceed chance expectation on the 5 percent

TABLE 55

Development of Tuberculosis in Relation to Arm or Service; Men With 25 Months or More of Service Excluding Time Spent in Hospital for Chest Disease

Arm or Service	Roster I[1]		Roster II		Relative Chance of Tuberculosis
	Number	Percent	Number	Percent	
	White				
Total known[2]	255	100.0	1,826	100.0	100
Infantry, cavalry, armored	67	26.3	433	23.7	111
Field artillery	12	4.7	156	8.5	55
Coast Artillery Corps	19	7.5	151	8.3	90
Corps of Engineers	23	9.0	248	13.6	66
Quartermaster Corps	9	3.5	104	5.7	61
Medical Corps	44	17.3	179	9.8	177
Other services	45	17.6	389	21.3	83
Air Corps	68	26.7	501	27.4	97
Unknown or unassigned	1	.4	6	.3	(3)
	Nonwhite				
Total known[2]	68	100.0	290	100.0	100
Infantry, cavalry, armored	9	13.2	30	10.3	128
Field artillery	2	2.9	19	6.6	44
Coast Artillery Corps	4	5.9	11	3.8	155
Corps of Engineers	7	10.3	52	17.9	58
Quartermaster Corps	22	32.4	124	42.8	76
Medical Corps	6	8.8	12	4.1	215
Other services	17	25.0	65	22.4	112
Air Corps	14	20.6	50	17.2	120
Unknown or unassigned	----------	----------	2	.7	(3)

[1] Limited to men discharged for active pulmonary tuberculosis for whom final reading of induction film is negative.
[2] Totals shown are numbers of men studied; since some men had more than one assignment, column sums exceed the totals.
[3] Not calculated.

TABLE 56

Development of Tuberculosis in Relation to Military Occupation; Men With 25 Months or More of Service Excluding Time Spent in Hospital for Chest Disease

Military Occupation	Roster I [1]		Roster II		Relative Chance of Tuberculosis
	Number	Percent	Number	Percent	
	White				
Total [2]	255	100.0	1,828	100.0	100
Gunnery and gunnery control	102	40.0	678	37.1	108
Intelligence, security, reconnaissance	29	11.4	176	9.6	119
Communications	35	13.7	216	11.8	116
Transportation	50	19.6	407	22.3	88
Supply	39	15.3	249	13.6	113
Maintenance	55	21.6	452	24.7	87
Medical	31	12.2	135	7.4	165
Construction and engineering	11	4.3	94	5.1	84
Administrative, technical, misc	68	26.7	526	28.8	93
	Nonwhite				
Total [2]	68	100.0	292	100.0	100
Gunnery and gunnery control	13	19.1	56	19.2	99
Intelligence, security, reconnaissance	1	1.5	10	3.4	43
Communications	6	8.8	14	4.8	183
Transportation	16	23.5	100	34.2	69
Supply	16	23.5	72	24.7	95
Maintenance, construction, engineering	10	14.7	65	22.3	66
Medical	6	8.8	11	3.8	234
Administrative, technical, misc	32	47.1	145	49.7	95

[1] Limited to men discharged for active pulmonary tuberculosis for whom final reading of induction film is negative.
[2] Totals shown are numbers of men studied; since some men had more than one assignment, column sums exceed the totals.

significance level. If we accept this finding for whites as indicative of a real enhancement of risk, it would seem logical to suppose that the apparent enhancement of risk for nonwhites, too, was real and not merely a coincidental finding.

We must assume that the increased risk associated with service in the Medical Department reflected exposure to tuberculous patients. While the age distributions of men serving in different arms were not identical, differences in age do not account for the excessive risk among medical personnel: age differences were not sufficiently dramatic in view of the rather moderate variability of the age-prevalence curve over the age range with which we are concerned. Thus, the proportion of white males discharged for active pulmonary tuberculosis with negative induction films (final reading) was 42 per 100,000 (table 43); if we apply the age distribution of white Medical Department personnel in Roster II to the corresponding age-specific white CDD ratios taken from the third column of table 43, we obtain the ratio 41 per 100,000.

We must confess to a certain surprise at the results enumerated above. In brief, what we have found is that prisoners of war had substantially more tuberculosis than their fellows, that men with medical duties had a high prevalence of disease, and that, for nonwhite soldiers, service in the Mediterranean theater was associated with high tuberculosis prevalence and service in the Pacific with low. Apart, however, from these few findings, the picture is one of relatively bland uniformity of risk whether in relation to arm, military occupation, overseas service, theater of service, or civilian contact as measured by venereal disease rates; the differences in risk which are observed are no greater than those one would expect to be produced by the vagaries of sampling. It does not seem unreasonable to infer, therefore, that in all probability the majority of cases of tuberculosis originally contracted by men while in service resulted from infection by their fellow soldiers, particularly among white troops. We have already seen that the evidence is strong that thousands of men with tuberculosis were inducted into the Army, and indeed we have estimated that about half of the tuberculosis which appeared in the Army and led to discharge was present at induction. If, on the average, two men inducted with tuberculosis infected one additional fellow soldier, then, half of the men who acquired tuberculosis in service would have been infected by their barracks mates. Just what proportion of the tuberculosis actually did result from infection by our own troops we cannot estimate, but that it was not inconsiderable would seem to follow from the fact that troops who served in areas wherein the prevalence in civilians was low, contracted the disease with about the same frequency as did men who served where prevalence was high. If all or even a large fraction of the infections were acquired from civilians it is hard to see how prevalence in troops could be in such large measure independent of the degree of infectivity of the civilian population.

9. SUMMARY

Comparison of the induction and separation chest X-ray films of approximately 3,000 randomly selected veterans discharged for tuberculosis and 3,000 veterans similarly selected for the study who were not discharged for tuberculosis, brought out a number of facts of significance both for military purposes and for the more general understanding of tuberculosis. These are summarized in the following paragraphs.

Approximately half of the men discharged for tuberculosis had the disease in roentgenographically detectable form at the time of acceptance for service. Their lesions were overlooked in the induction examination for reasons not always evident in the films themselves. It is noteworthy that the failure of detection was most frequent at induction stations known to have inferior medical service.

The incidence of apparently new tuberculosis developing in service in men under comparable environmental conditions was significantly greater in non-white than in white men. This fact is in agreement with many observations on racial differences in the prevalence of tuberculosis.

The peak of breakdown from tuberculosis among men not having lesions at induction was at the low age of 19–22 years, while breakdowns among men with lesions at induction tended to occur at older ages. Thus our results are consistent with Frost's data which appear to indicate that the current trend toward greatest prevalence of tuberculosis beyond the years of middle life is caused by the breakdown of old lesions which date back to an era in which infection with tuberculosis was much more frequent than it has been of recent years.

The data indicate clearly that tall, thin men developed tuberculosis more frequently than men of other physical types. The significance of this observation is not obvious in the light of the present tendency to belittle such gross constitutional factors as body build in comparison with intensity of exposure to infection, environmental factors depressing resistance, and more finely drawn physiological constitutional factors. The finding was not a confusion of cause and effect.

Educational background and premilitary civilian occupation exerted no well defined effect with reference to the development of tuberculosis in the Army. The scattering of cases in groups of different educational levels appeared to indicate that, at least under the circumstances of military occupation, these social factors did not have a determining influence on the likelihood of breakdown. Soldiers who came from urban and rural backgrounds seemed not to differ with respect to the probability of developing clinical tuberculosis.

With one exception, viz, service in the Medical Department, there was no significant relation of Army arm or occupation to development of tuberculosis. A relatively high rate of development of the disease occurred in the Medical Department, which might well have been due to excessive exposure in the occupation itself.

Foreign service *per se* did not affect the incidence of development of tuberculosis significantly, although abnormally great exposure in certain theaters was associated with increased rates of breakdown.

The incidence of tuberculosis was excessively high in prisoners of war. The high rate is most easily explained by the fact that prisoners of war are frequently subjected to greater exposure to infection than soldiers in their accustomed lines of duty, and that prisoners suffer hardships which lower their resistance to tuberculosis.

The men discharged for tuberculosis served for an average period of 22.7 months before separation; about a third served for more than two years. Only 17.2 months, on the average, were spent on active duty, while 5.5 months were spent in hospital.

The data indicate that endogenous and exogenous tuberculosis are both important in military service and that constitutional factors are concerned in resistance. Tuberculin tests would have been of great value in understanding sources and causes of clinical disease, had it been possible to carry them out as part of the induction procedure.

All films studied were read independently by two roentgenologists. A substantial extent of disagreement between the two was found. One reader was more cautious than the other with respect to definitive diagnosis of tuberculosis. A still greater difference of opinion was noted with respect to stage of the disease when there was agreement as to its presence. Disagreement was fairly high with respect to activity, but only in a border-line range; disagreement as to unequivocally active or inactive disease was infrequent. Agreement with respect to the presence or absence of calcification, and its extent, was low. Disagreement with respect to the presence or absence of non-tuberculous disease, particularly cardiac abnormality, was great. Disagreement was greater with standard size (14 x 17 inches) than miniature (4 x 5 and 4 x 10 inches) films.

A check on each reader's self-agreement was made by assigning a representative set of films from the tuberculosis and non-tuberculosis rosters of the study for rereading several months after the first reading. Self-disagreement comparable to disagreement between readers was noted; however, it was chiefly within a border-line range, rather than in the range of frank positive or negative diagnosis.

Relatively few men whose disease was read by the radiologists of this study as inactive at induction showed active disease at separation. Of the men, on the other hand, who had active disease at induction, a large proportion suffered progression during service as evidenced by advances in stage and the development of cavities. The 3,099 men on the tuberculosis roster, representing a 33 percent sample of the men inducted and discharged for tuberculosis during the time interval studied, had had 1,417 man-years of Army hospitalization for this disease.

The results of dual reading of chest X-ray films at induction stations are much more reliable than diagnoses from single readings. If the induction films had each been read by two different radiologists, undoubtedly many more of the men who were tuberculous at entry could have been excluded from service. However, the difficulties of interpretation of small lesions are such that in order to exclude all of the infected men, it would have been necessary to exclude also many men whose X-ray films were similarly subject to suspicion, but who did not have tuberculosis. The hope for substantial improvement in screening efficiency rests on the use of supplements such as the tuberculin skin test and a revision of the examination procedure permitting adequate follow-up observation. In the absence of these aids, it would appear that the most reliable and practical screen is dual reading followed by a conference on disagreement.

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INDEX

Page

Age:
discharge for tuberculosis by 62–65
non-pulmonary tuberculosis and 62
Birthplace, development of tuberculosis and 65–66
Body build, development of tuberculosis and 68–72
Calcification 13–14, 33–34
Cardiac abnormality, diagnosis of 15
Educational status, development of tuberculosis and 66–68
Final interpretation:
definition of 5–6
of induction films, efficiency of 29, 31
of separation films, efficiency of 36, 37
Foreign service, tuberculosis and 73–81
Height, development of tuberculosis and 68, 69
Hospitalization, length of 44–47
Induction screen:
efficiency of 34–35
at different induction stations 24–25
multiple interpretation and 26–31
non-tuberculous pathology and 33–34
race and 32
Induction stations:
efficiency of screening 24–25, 65
Length of service, tuberculosis and 44, 47–51
Military arm, development of tuberculosis by 79–80
Military occupation, development of tuberculosis by 79–80
Mobilization Regulations (MR 1–9) 13
Other pathology than tuberculosis 14, 15
Pleural effusion: (See Pleurisy, wet)
Pleurisy, dry 14–15
Pleurisy, wet 14
Prisoner of war status, tuberculosis and 75
Progression of tuberculosis in service 56–59
Race:
diagnosis of tuberculosis by 41, 58
discharge for tuberculosis by 60–65
educational status and 66–68
non-pulmonary tuberculosis and 41, 60, 61
progression of tuberculosis and 60
susceptibility to tuberculosis by 61
tuberculosis and .... 25, 26, 32 and *pari passu* throughout

Regression of tuberculosis in service........................ 56–59
Residence, previous, and tuberculosis.................. 52–54, 65–66
Sampling:
adequacy of.. 6–8
methods of... 3
Sarcoidosis, diagnosis of.............................. 15
Scabies, tuberculosis and.............................. 77, 78
Separation screen, efficiency of....................... 36–40
Service commands, efficiency of induction stations in............ 25
Service connection of tuberculosis..................... 51–56
Summary interpretation:
definition of...................................... 5
of induction films, efficiency of.................. 34
of separation films, efficiency of................. 36, 37
Susceptibility to tuberculosis:
body build and..................................... 68–72
race and... 60–61
Tuberculin test.. 35, 56
Stage at diagnosis of tuberculosis..................... 41–44
Tumor, diagnosis of.................................... 15
Type of tuberculosis................................... 41–44
Venereal disease, tuberculosis and..................... 77–78
Weight, development of tuberculosis and................ 69–72
X-ray film interpretation:
definition of discrepancy in....................... 4–5
dual, advantages of................................ 34, 35
"error" in, definition of.......................... 5, 19
multiple readings in relation to
activity of tuberculosis........................ 12–13
calcification................................... 13–14
extent of tuberculosis.......................... 11–12
location of tuberculosis........................ 13
other pathology than tuberculosis............... 14–15
type of film.................................... 15–18
X-ray screen, levels of efficiency of.................. 26ff

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