

A SURVEY OF TUBERCULOSIS IN THE INDUSTRIAL COUNTY OF LANARKSHIRE, SCOTLAND

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Interest in human tuberculosis in Scotland has been centred mainly in the incidence of the different types of tubercle bacillus. Fraser (1912) examined 67 cases of bone and joint tuberculosis in children and found that 61.2% were infected with bovine bacilli. Wang (1917) reported 55% of bovine infections in 20 children under 16 years of age and 10.3% in 68 adults in the Edinburgh district. Munro & Cumming (1926) found bovine bacilli in 36.4% of 55 cases of surgical tuberculosis in the east of Scotland. Blacklock (1936) isolated the bovine bacillus from 82.2% of 73 children with primary abdominal tuberculosis and from 63.3% of 30 patients with cervical gland tuberculosis. He noted a higher incidence of bovine bacilli in country than in Glasgow children. Blacklock & Griffen (1935) found that 22% of cases of cerebral tuberculosis in children in the same west of Scotland area were due to the bovine bacillus.

The importance of factors other than the type of organism had become manifest, for it was obvious that the proportional frequency of the type of infecting organism varied greatly in different districts.

Griffith (1934), in surveying the results of typing 265 strains of tubercle bacilli isolated from cases of tuberculous meningitis occurring between 1905 and 1933 and derived from widely separated areas throughout the United Kingdom, noted that the incidence of bovine infection was higher, in general, in country places and rural towns than it was in cities. Munro & Scott (1936) reviewed the relative frequency of human and bovine bacilli recovered from cerebro-spinal fluids in patients from the east of Scotland and concluded that bovine infection was an urgent rural problem as, in the series examined, the incidence of this type was three times greater in rural areas than it was in cities. This conclusion was supported by the work of Macgregor & Green (1937) who found 2% of bovine infections in 68 cases of tuberculous meningitis occurring in the city of Edinburgh and 25% in 29 cases from the adjoining country districts.

The importance of raw milk was stressed by these workers as a possible reason for the rural preponderance of the bovine type of tubercle bacillus. However,

in an investigation of 91 patients suffering from pulmonary tuberculosis and residing in the rural areas and small towns in the north-east of Scotland, Griffith & Smith (1935) found 14.3% with bovine tubercle bacilli in the sputum. The possibility of infection of susceptibles with the bovine organism by such persons is a factor that cannot be overlooked.

Lanarkshire is a large county with a peculiar character for, although it is the most highly industrialized county in Scotland, a fact given by Barclay & Kermack (1940) in an examination of the effects of industrialization on the mortality from cancer, the industrial area occupies only about a quarter of the total acreage and there is almost a sharp line of demarcation from the rural areas.

The estimated population in 1939, according to figures supplied by the Registrar General and given to me by the Medical Officers of Health for the several administrative areas within the scope of this investigation, was 506,196 persons and the total area 536,075 acres.

Of the total population 443,772 persons resided within the purview of the industrial area of 135,187 acres and 62,424 persons occupied the rural districts that extend to 400,888 acres. From this it will be seen that the incidence of disease in industrial and rural areas may be compared.

The figures in this investigation include evidence collected from 1937 until the end of 1942 and, though they do not represent all the notified cases of non-pulmonary tuberculosis, they do represent most of the patients from whom viable tubercle bacilli were recovered during this period. The pulmonary figures are a random selection.

BACTERIOLOGICAL METHODS

Specimens of cerebro-spinal fluid were inspected for the presence of coagulum and centrifugalized at 3000 r.p.m. for half an hour. Films of the deposit were made, stained by Ziehl-Neelsen's method and examined microscopically for the presence of tubercle bacilli. All specimens were inoculated into guinea-pigs.

If sufficient fluid was submitted, direct seeding from the deposit on to selective media was carried

out but, in the presence of contamination as determined by microscopic examination, or in the event of the specimen being of smaller volume than 5 c.c., guinea-pigs were inoculated in the left groin with the entire deposit to which had been added a few c.c. of the supernatant fluid.

Inoculated animals were examined every 3 days and killed when enlargement of inguinal glands had progressed sufficiently, usually about 5-6 weeks after inoculation. At necropsy the extent of macroscopic tuberculosis was noted and microscopic examination of material from a lesion was examined for confirmation.

The inguinal gland was removed with aseptic precautions and the pus digested with 6% HCl. After half an hour's acid treatment neutralization by NaOH was carried out and the resulting suspension of debris centrifugalized for half an hour at 3000 r.p.m. The deposit was seeded on to (1) Herrold's medium, (2) Löwenstein-Jensen medium, (3) Löwenstein-Jensen glycerol medium. After incubation for a week, cultures were examined every 3 days for the appearance of growth. When colonies had been visible for about 3 weeks the strain was used for rabbit inoculation.

Rabbit inoculation. A suspension of tubercle bacilli containing approximately 0.1 mg. moist weight of culture was injected into the marginal ear vein of a fully grown adult rabbit. Animals were kept in separate cages and killed after 2 months if they had shown no evidence of advanced disease before this time. At post-mortem examination the macroscopic lesions and their distributions were noted and confirmatory microscopic examination of films from the lesions carried out. The type of organism was thus established.

Pus and tissue were examined microscopically for the presence of tubercle bacilli. Specimens were then treated with 6% HCl for half an hour, the acid neutralized by NaOH and the deposited debris, after centrifugalization, investigated by guinea-pig inoculation and direct cultural methods.

The final type differentiation of strains of tubercle bacilli isolated was determined by rabbit inoculation.

RESULTS

Pathological specimens from 464 patients suffering from extrapulmonary tuberculosis or suspected of having tuberculous lesions were examined for the tubercle bacillus.

From 321 persons strains of tubercle bacilli were isolated and an attempt made at type determination. This was successful in 311 instances and type was not established in 10 cases. In a further 9 specimens, 5 from cervical glands and 4 from bone and joint lesions, acid-alcohol-fast bacilli were demonstrated on direct film examination but isolation on

selective media was not successful and the organism did not give rise to tuberculosis on inoculation into guinea-pigs.

Strains recovered by cultural methods from the sputum of 80 persons suffering from pulmonary tuberculosis were also typed, the final criterion being taken as virulence for the rabbit.

General incidence of human and bovine types of tubercle bacillus

Of the 80 pulmonary strains investigated 78 were human and 2 bovine, giving percentages of 97.5 and 2.5 respectively.

The extrapulmonary strains gave the proportions of human tubercle bacilli as 73.3% (228 strains) and of bovine tubercle bacilli as 26.7% (83 strains) and were derived from the following sources.

Samples of cerebro-spinal fluid from 165 patients with tuberculous meningitis supplied 118 human strains (71.5%) and 47 bovine strains (28.5%).

The tubercle bacillus isolated from 72 cases of cervical adenitis was human in type in 50 instances (69.6%) and bovine in 22 (30.4%).

Material obtained from 74 persons with bone and joint infection provided 60 (81.1%) tubercle bacilli of the human type and 14 (18.9%) strains of the bovine type.

Table 1 gives the occurrence of the two types of tubercle bacillus in the different varieties of tuberculosis examined in this investigation.

Table 1. *General incidence of human and bovine strains of the tubercle bacillus*

	Pul- monary tuber- culosis	Tuber- culous menin- gitis	Cervical adenitis	Bone and joint tuber- culosis
Human	78 (97.5%)	118 (71.5%)	50 (69.6%)	60 (81.1%)
Bovine	2 (2.5%)	47 (28.5%)	22 (30.4%)	14 (18.9%)

The type of bacillary infection in relation to age-group incidence for all non-pulmonary varieties of disease is shown in Table 2.

The first 5 years of life and the 5 years from 15 to 20 years of age showed an almost equal frequency of infection and accounted for nearly half of the total number of cases.

Bovine infections were much more numerous in the younger groups and 44 of the total of 83 bovine strains of the organism were recovered from patients in the first decade.

That the greatest risk of bovine infection is in the first few years of life is borne out by these figures.

The sex incidence for all extrapulmonary tuberculous infections is given in Table 3.

Males appeared to be more liable to infection

Table 2. Age and sex incidence for all extrapulmonary tuberculosis

	Age (years)									Total
	Under 5	-10	-15	-20	-25	-30	-40	-50	-60	
Human:										
Male	30	22	15	39	5	4	4	3	4	126
Female	22	18	6	25	16	5	3	4	3	102
	52	40	21	64	21	9	7	7	7	228
Bovine:										
Male	14	11	7	2	7	1	4	—	—	46
Female	10	9	3	6	8	—	—	1	—	37
	24	20	10	8	15	1	4	1	—	83

than females. This was mainly due to the greater number of males with bone and joint lesions, a fact to which the more strenuous life of males probably contributed.

Table 3. Sex incidence of human and bovine infections in extrapulmonary tuberculosis

	Tuber- culous menin- gitis	Cervical adenitis	Bone and joint tuber- culosis	Total
Human:				
Male	59	28	39	126
Female	59	22	21	102
Bovine:				
Male	24	11	11	46
Female	23	11	3	37

Regional incidence. An analysis of the regional incidence of infection showed that 18 of 165 cases of tuberculous meningitis, 20 of 72 cases of tuberculous adenitis and 11 of 74 cases of bone and joint tuberculosis occurred in persons residing in the rural areas, a total of 49 of the 311 cases investigated in this series. The distribution of the two types of tubercle bacillus in industrial and rural areas for the extrapulmonary group of infections is considered in the ensuing paragraphs.

Tuberculous meningitis

Age incidence. In the industrial area 40 of a total of 147 cases (27.9%) of tuberculous meningitis occurred in the first 5 years of life and 40 cases (27.9%) in the period between 15 and 20 years of age, in other words, just over half of the total number of cases occurred either in the first few years of life or in the first few years of going out into the employment market. In the rural area 9 cases out of a total of 18 (50%) occurred before 5 years of age and, although there was a high incidence of infection between the ages of 15 and 25 years of age, 3 cases (16.7%) in each of the 5-year periods in this group, it was not so high or noticeable as in the industrial series. However, the figures were

sufficiently significant to show the greater liability to infection at the age groups already noted.

Type incidence. The frequency of bovine infection was 26.4% in the industrial area and 44.4% in the rural area, figures that endorse the rural preponderance of the bovine bacillus in tuberculous meningitis found by other workers (Griffith, 1934; Blacklock, 1936; Munro & Scott, 1936; Macgregor & Green, 1937).

In the 165 cases of tuberculous meningitis investigated bovine infections were more numerous in the early years of life; 17 of the 47 strains were isolated (36.2%) from children under 5 years of age and a further 10 (21.3%) from the next 5-year period showing that 57.5% of bovine infections occurred before 10 years of age.

In the rural areas the percentage of bovine bacilli isolated from persons in the first 5 years of life was 50% of the total (4 of 8 strains) and in the industrial area 33.3% (13 of 39 strains).

The relative incidence of the two types of tubercle bacillus in the industrial area was almost constant for the three 5-year groups under 15 years of age; the percentages of bovine infections were 32.5, 33.3 and 28.6 respectively. The early adolescent group from 15 to 20 years of age, the period of entry into industry, showed a tremendous preponderance of human infections with 35 out of a total of 40 cases (87.5%), but the balance was re-established in the following 5-year group with 35.3% of bovine infections, 6 cases out of a total of 17. For older persons numbers were too small for analysis.

In the rural area bovine infections accounted for 44.4% of the cases in children under 5 years of age.

Sex incidence. In the series, males and females were affected equally as regards frequency of infection and type of infecting tubercle bacillus although there were minor variations at different ages. The only significant variations were the greater number of males with human infection in the early adolescent group and this was countered by a similar preponderance in females in the early twenties.

Table 4. Age and sex incidence of tuberculous meningitis

	Age (years)								Total	
	Under 5	-10	-15	-20	-25	-30	-40	-50		-60
<i>Industrial</i>										
Human:										
Male	15	10	6	20	—	—	—	1	2	54
Female	12	8	4	15	11	1	—	2	1	54
	27	18	10	35	11	1	—	3	3	108
Bovine:										
Male	6	6	2	1	3	—	2	—	—	20
Female	7	3	2	4	3	—	—	—	—	19
	13	9	4	5	6	—	2	—	—	39
<i>Rural</i>										
Human:										
Male	2	—	2	1	—	—	—	—	—	5
Female	3	—	1	1	—	—	—	—	—	5
	5	—	3	2	—	—	—	—	—	10
Bovine:										
Male	2	—	—	—	1	—	1	—	—	4
Female	2	1	—	1	—	—	—	—	—	4
	4	1	—	1	1	—	1	—	—	8

Table 5. Age and sex incidence of tuberculous cervical adenitis

	Age (years)								Total	
	Under 5	-10	-15	-20	-25	-30	-40	-50		-60
<i>Industrial</i>										
Human:										
Male	6	5	2	2	—	—	1	—	1	17
Female	3	5	1	3	1	2	1	1	—	17
	9	10	3	5	1	2	2	1	1	34
Bovine:										
Male	2	1	4	—	—	1	1	—	—	9
Female	1	4	1	—	3	—	—	—	—	9
	3	5	5	—	3	1	1	—	—	18
<i>Rural</i>										
Human:										
Male	3	3	3	1	—	1	—	—	—	11
Female	—	3	—	—	1	—	—	—	1	5
	3	6	3	1	1	1	—	—	1	16
Bovine:										
Male	—	2	—	—	—	—	—	—	—	2
Female	—	1	—	1	—	—	—	—	—	2
	—	3	—	1	—	—	—	—	—	4

Tuberculous cervical adenitis

Age incidence. The age group with the highest frequency of infection in the 72 cases of cervical adenitis investigated was that from 5 to 10 years of age with 24 persons affected (33.3%). Of the total, 50 persons were under 15 years of age so that 69.4% of infections had taken place during preschool and school age.

In the industrial area 27 out of 34 persons with human infections (76.4%) had not reached the age of 20 at the time specimens were obtained and in the rural area, 12 out of 16 (75%) subjects from whom the human tubercle bacillus had been isolated were under 15 years of age.

From this it will be seen that a comparable majority of cases had come under observation

5 years earlier in rural districts than in industrial districts.

Type incidence. In the industrial area the relative incidence of type of infecting bacillus was 34.6% bovine and 65.4% human. There were 18 bovine and 34 human strains of tubercle bacillus isolated. In the rural area the human type of bacillus predominated with 80% of 20 cases and there were only 20% (4) bovine infections.

The majority of bovine infections had taken place before 15 years of age for, in the industrial group, 13 of 18 patients (72.2%) had been under treatment before this age had been reached and 3 out of 4 (75%) of the rural cases were under 10 years of age.

The relative incidence of human and bovine bacilli in the three quinquennia up to 15 years of age in the industrial area showed 25, 50 and 62.5% bovine infections respectively. In the rural area 33.3% of the infections in the 5-10 years' age group were bovine; there were no bovine infections under 5 years of age and none from 10 to 15 years of age.

Bovine infections were present 5 years earlier than human infections in industrial and in rural areas.

Sex incidence. The frequency of infection and the type of organism were equal for each sex except in human infections in the rural areas where there was an excess of infected males in the proportion of 11 males to 5 females. This was due to 3 males under 5 and 3 males between 10 and 14 years of age having infections and no females of those ages being affected. These 6 cases influenced the rural incidence of bovine infections (20%), for they accounted for 37.5% of the total of 16 human infections.

Bone and joint tuberculosis

Age incidence. To assess figures in bone and joint infections is always difficult and of doubtful value in determining age incidence as patients may have obvious lesions for several years before specimens are available for isolation of the tubercle bacillus. However, there was an apparent highest incidence of infection in the 5 years under 20 in the industrial series with 20 cases out of a total of 63 (31.8%); the first 5 years of life showed the next highest occurrence with 11 persons infected (17.4%).

In the rural area the small number of cases available may vitiate the significance of the occurrence between 15 and 25 years of age of 5 of the total 11 cases (45.5%).

Type incidence. In the industrial area bovine infections accounted for 10 out of 63 cases (15.9%) and in the rural area for 4 out of 11 cases (36.4%). All bovine cases in the industrial area had come under treatment before reaching 25 years of age. The percentages for the first two age groups of 5 years were 27.3 and 28.6 of bovine infections. In the 15-20 years' group only 5%, 1 case out of 20, were due to the bovine bacillus, but in the next 5 years' group bovine strains were isolated from 4 out of 10 persons (40%).

Sex incidence. Males appeared to be more susceptible to bone and joint infection than females roughly in the proportion of 2 to 1 for the entire series. In bovine infection males provided 80% of the total cases in the industrial and 75% in the rural area; in human infections males were 66% of the industrial and 57.1% of the rural subjects affected.

Table 6. Age and sex incidence of bone and joint tuberculosis

	Age (years)								Total	
	Under 5	-10	-15	-20	-25	-30	-40	-50		-60
<i>Industrial</i>										
Human:										
Male	4	3	1	15	4	3	2	2	1	35
Female	4	2	—	4	2	2	2	1	1	18
	8	5	1	19	6	5	4	3	2	53
Bovine:										
Male	3	2	—	1	2	—	—	—	—	8
Female	—	—	—	—	2	—	—	—	—	2
	3	2	—	1	4	—	—	—	—	10
<i>Rural</i>										
Human:										
Male	—	1	1	—	1	—	1	—	—	4
Female	—	—	—	2	1	—	—	—	—	3
	—	1	1	2	2	—	1	—	—	7
Bovine:										
Male	1	—	1	—	1	—	—	—	—	3
Female	—	—	—	—	—	—	—	1	—	1
	1	—	1	—	1	—	—	1	—	4

DISCUSSION

Lanarkshire is essentially an industrial county and accommodates about an eighth of the total population of Scotland so that the results of these investigations supply an essential link in the already vast chain of Scottish evidence in tuberculosis statistics. The regional variation noted by other workers is supported and the importance of the rural mode of life in infection with the bovine type of tubercle bacillus is again manifest.

The pulmonary cases included in this series were a random selection primarily investigated by cultural methods with the intention of demonstrating tubercle bacilli which microscopic examination had failed to disclose in sputa. In many instances the organism was found on subsequent examination or after digestion of the sputum.

No attempt was made to classify the patients from whom specimens were obtained and the figures are of interest as showing a percentage of bovine infection, 2.5% of 80 cases, approximating more closely to that of Griffith (1930) who found 1.4% of bovine infections in 73 pulmonary cases in Scotland than to the higher incidence found by Munro (1928), 7.1% of 70 cases in the east of Scotland and by Griffith & Smith (1935), 14.3% of 91 cases from the northern counties of Scotland.

Much work has been done on tuberculous meningitis and the regional variation in the type of infecting tubercle bacillus has been marked for Griffith (1934) in surveying a series of cases collected from 1905 to 1933 gave a bovine incidence for Scotland of 40.5%. Blacklock & Griffen (1935) gave 22% for a series in the west of Scotland, Munro & Scott (1936) found 36% of bovine infections in the east of Scotland and Macgregor & Green (1937) 24% in the Edinburgh district. For Lanarkshire 47 bovine and 118 human strains of tubercle bacilli isolated from 165 cases of tuberculous meningitis gave the bovine percentage of 28.5.

The relative incidence of human and bovine tubercle bacilli isolated from 73 cervical adenitis cases was 30.6% bovine and 69.4% human, figures that do not agree with any previously published for Scotland. Griffith (1930) found 70.6% bovine infections in 17 Scottish cases and Blacklock (1936) 63.3% in 30 children in the west of Scotland area. Möllers (1928) summarized continental statistics and for 219 cases of cervical adenitis he gave the percentage of bovine infections as 24.2 so that the figures for this investigation are between those of foreign workers and those found in the less industrialized parts of Scotland.

In bone and joint tuberculosis bovine infections provided 18.9% of the 74 strains of tubercle bacilli isolated. This figure approximates to the 20.5% of bovine infections among 88 cases examined by

Wang (1917) in Edinburgh but is much lower than the bovine incidence found by Fraser (1912) of 61.3% or the 36.4% given by Munro & Cumming (1926).

Early in this investigation it became obvious that there was a higher incidence of human infections than had been found by other workers in surveying tuberculosis in Scotland and, therefore, some factor or factors in Lanarkshire must have operated to alter the soil or increase the hazard of infection by the human type of bacillus.

Undoubtedly, it had been agreed that regional variation pointed to a higher incidence of bovine infection in rural areas and Lanarkshire could not be looked upon as rural, at least in those parts where most of the population was centred.

SUMMARY

In this investigation the hitherto unexplored field of tuberculous Lanarkshire has been surveyed.

The relative incidence of human and bovine strains of the tubercle bacillus in 80 cases of pulmonary tuberculosis and in 311 cases of extrapulmonary tuberculosis has been examined. Results have shown that bovine infections were present in 2.5% of the pulmonary cases, a figure that is in keeping with the expected incidence for an area as highly industrialized as Lanarkshire.

The extrapulmonary strains have been further subdivided into 165 strains isolated from patients suffering from tuberculous meningitis, 72 strains isolated from patients with cervical adenitis and 74 strains from patients with tuberculous lesions affecting bone or joint. Each group has been analysed separately.

In the 165 cases of tuberculous meningitis bovine infections accounted for 28.5% of the total. This figure was slightly higher than the 22% given by Blacklock & Griffen (1935) for the Glasgow area and the 24% of Macgregor & Green (1937) for the Edinburgh area, but it was lower than the 36% found by Munro & Scott (1936) in the east of Scotland and the 40.5% given for Scotland by Griffith (1934) in his general survey. The greater preponderance of bovine infections in rural areas supported the observations of these workers.

The cervical adenitis group gave the percentage of bovine infections as 30.4, a result much lower than any previously published for Scotland, but there can be no doubt that a family history of pulmonary tuberculosis obtained from 50% of the patients in the industrial group who supplied human strains must have been a most important factor in influencing the relative incidence of the two types of tubercle bacillus. There were 72 cases of cervical adenitis investigated and 52 came from the industrial area.

Seventy-four patients suffering from tuberculous

lesions affecting bone or joint gave a bovine incidence of 18·9%, a percentage that is lower than that given by Munro & Cumming (1926) of 36·4% but approximating to the 20·5% given by Wang (1917) for the Edinburgh area. Munro & Cumming were dealing with a less industrialized area than Lanarkshire which probably accounts for the variation as also does the fact that, of 7 human cases occurring in the rural part of Lanarkshire, 5 gave a family history of pulmonary tuberculosis.

These figures only serve to substantiate observations of regional variation and endorse the findings of other workers who have found a lower proportion of bovine infections in industrial districts. As Lanarkshire is the most highly industrialized county in Scotland it was to be expected that the results of this investigation might have given an even greater predominance of human infection than actually was found.

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