A Retrospective Assessment of Human Health Protection Benefits from Removal of Tuberculous Beef

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ABSTRACT

In the early 1900s, government agencies instituted two programs, Federal slaughterhouse inspection and on-farm tuberculin testing, to control the spread of bovine tuberculosis (TB). From this historical perspective, the economic benefits of these programs are estimated using four parameters: (a) an estimation of how many cattle would have had bovine TB without the programs, (b) the likelihood of those infected cattle causing human illness through aerosol contamination, penetration of the skin via cuts and nicks, cross-contamination of other foods in the home, and consumption of meat and meat products, (c) current costs of treating human cases of TB, and (d) the evaluation of the benefits of preventing the death of some individuals. Based on these four parameters, the TB control programs have possible estimated economic benefits which range from $30 to $300 million annually.

This paper examines the human health protection benefits from U.S. programs to control bovine tuberculosis (TB) and attempts to evaluate what would have occurred if no federal effort has been mounted. Bovine TB has been a serious problem worldwide. In 1958, 17 to 18% of all cattle in England were estimated to have tuberculosis. Because the disease incidence increases with age, 40% of the cattle slaughtered were tuberculous. During the 1940s the incidence of TB in milk cows was estimated at 10 to 70% in Europe, 10 to 30% in rural Latin America and higher near urban areas, 7% in Australia and New Zealand, and 18% in Peking, China. During the 75 years of the federal-state program of on-farm tuberculin testing and Federal inspection at the slaughterhouses, there has been a marked decline in number of U.S. cattle with bovine TB. In the early years of federal inspection, 25,000 head of cattle were condemned annually for TB (0.34% of cattle inspected from 1908-1911). Today, fewer than 100 cattle, on average, are condemned for TB each year although the number of cattle federally inspected now is four times greater than the number inspected from 1908-1911. Assessing the economic benefits of any public health protection program requires use of numerous assumptions and value judgments regardless of whether the program analyzed is malaria eradication, restaurant inspections, or clean air. Estimating a numerical value on the benefit of health protection from bovine TB is no exception.

Market failure is the economic rationale for government involvement in health protection programs. Consumers cannot make accurate evaluations of the safety of fresh meat and poultry offered for sale in supermarkets or restaurants. Further, consumers cannot readily buy information on the healthfulness of products since the analytical costs are prohibitive on a package-by-package basis. Pathogens, chemicals, and other toxins are undetectable with the naked eye. Consequently, the causal link of consumption of or contact with meat to human disease cannot be positively established much of the time.

In response to market failure (the inability of consumers to determine the safety of the meat they purchase), the consumer creates a demand for safety information to be supplied inexpensively by some reputable organization such as the federal government. This information could take a variety of forms, including a certification program (such as the Underwriters Laboratory for electrical safety) or a direct Federal inspection program for health hazards. If such a program is less expensive than the benefits conferred, it increases the public good.

Under the U.S. meat inspection program established in 1906, each and every bovine animal slaughtered for meat is inspected for TB. Roughly 70% of the inspector’s time on the beef slaughter line is spent examining lymph nodes for signs of a wide variety of infections or neoplastic processes, one of which is TB (Herbert Harris, USDA Food Safety and Inspection Service, personal communica-
tion). The inspector slices and inspects the lymph nodes in the head for evidence of calcium deposits indicating TB and visually examines and feels the lymph nodes in the inner cavities for such calcium deposits. Cattle carcases are condemned and removed from the human food chain if TB has spread throughout the whole body. The carcass can only be used for pet food and is almost a total economic loss to the owner. If the live animal reacted to the tuberculin test or if localized lesions in the lymph nodes are discovered (and removed), the carcass must be cooked before it is sold (Gerald Snyder, USDA Food Safety and Inspection Service, personal communication). It can be turned into lunch meats for human consumption, but the owner’s economic loss is about half of the market value.

Since 1917 USDA has coordinated a Federal-State program of on-farm tuberculin testing to identify diseased cattle. Farmers receive indemnity payments for tuberculous cattle destroyed. The program proceeds on a county-by-county basis and it took 23.5 years before all U.S. counties reached an incidence of 0.5% or less. The on-farm tuberculin testing program has been and remains largely a trace-back of tuberculous cattle detected at the slaughterhouse. The marketing channels are investigated to find the farm(s) and/or feedlot(s) producing the animal(s). Then herds are tested at these and adjoining locations.

MATERIALS AND METHODS

Epidemiology

The evidence presented in several reports was used to develop the relationship between TB in cattle and humans; i.e., to predict how many cattle would have had tuberculosis without the Federal programs, the likelihood of transmission from live cattle or their meat to humans, the size of the infective dose to humans, and the likely severity of disease. Although inhalation of bacteria is the primary method of infection, wound infections causing TB have been a serious concern among butchers and veterinarians (9).

Medical costs

The average length of both hospitalization and treatment for TB as well as the death rate and the age distribution of deaths from TB were supplied by the Centers for Disease Control (9,23,24, Kenneth G. Powell, Tuberculosis Control Division, U.S. Public Health Service, personal communication). The daily costs of hospitalization were collected by the Health Care Finance Center of the U.S. Department of Health and Human Services (Dave Gibson, Health Care Finance, H.H.S., personal communication). Although the above are standard sources for health economics data, other related medical costs (for drugs, eye tests, laboratory tests, nurse and physician visits, and tracing of contacts for testing for signs of TB) were not reported fully anywhere and the cost experience of the Washington, D.C. health clinics was used (Verdit Onar, acting tuberculosis control officer, Washington, D.C. Health Department, personal communication).

Wage data and value of human life estimates

The standard indices published by the Bureau of Labor Statistics, U.S. Department of Labor were the source of the wage data (24). While wage data were an important part of the value of human life calculation, evaluating death involved more complex, theoretical and practical issues. Two sets of figures are presented: (a) the time honored human capital approach pioneered by Dorothy Rice (3,4,5) and (b) a new approach expanding this human capital estimate to include data on “willingness-to-pay” to avoid a risk of death (12).

RESULTS

Estimating the number of infected cattle

The perspective that I used for this study assumed that the federal inspection program had never started. I also assumed TB would remain constant at a 5% disease level in cattle herds (a conservative assumption since TB spreads readily among herds especially with today's greater movement of cattle in interstate commerce). The estimated benefit of slaughterhouse inspection and on-farm tuberculin testing is based on the actual, observed decline in tuberculous cattle that has occurred since the initiation of these programs.

Other methods of reducing TB, such as vaccines, drug treatment or voluntary control by farmers, are investigated in another paper and are considered ineffective methods of reducing the incidence of bovine TB (17). Hence, the decline in bovine TB can be directly attributed to the dual programs of slaughterhouse inspection and on-farm tuberculin testing. The decline in the number of cattle with TB is approximated by the decline in infected animals inspected in the slaughterhouse.

The incidence rate of federally inspected cattle condemned for TB in 1908 through 1911 was 34 out of 10,000. Multiplying this rate by the average number of 34,419,680 cattle carcasses inspected currently during the 5-year period 1976-1980, yields 120,125 infected cattle which would have had TB if its prevalence had remained as high as it was in the early years (22). The actual number of condemnations for TB in the years 1976-1980 was only 95 carcasses annually. This leaves a net difference of 120,030 carcasses per year which represents the decline in cattle intended for the human food supply infected with Mycobacterium bovis.

Likelihood of infected animals causing human illness

The potential pathways for human exposure to bovine TB are diverse (Table 1). The four most likely pathways are underlined. The epidemiological data base for linking animal-to-human infection has been established for the first three pathways. The fourth remains hypothetical. When half of all human infections were of animal origin in 1921, drinking unpasteurized milk was the primary mode of transmission (14). Second, inhalation of bacteria was the primary method of people infecting other people and of animals infecting other animals (9). Formerly, prolonged exposures were thought necessary, but a fraction of a minute may suffice to pass tubercle bacilli (14). Thus aerosol contamination is one method of infecting farm families and slaughterhouse workers because of the proximity to live cattle (7,9). Furthermore, workers in
TABLE 1. Potential pathways of human exposure to bovine tuberculosis (most likely pathways underlined).

I. Direct contact with live animal
   - Animal bite
   - Contact with the skin, fur, tail, etc. and microorganisms found there.

II. Indirect contact with the live animal
   - Aerosol contamination of the barn and air system
   - Contamination of the walls, floor, gates, etc.
   - Animal refuse
   - Flies or fleas biting the infected animal and then biting humans and transmitting disease

III. Direct contamination by the carcass
   - Some organisms penetrate the skin of the personnel handling meat
   - Entry of organisms through cuts and nicks on the hand of slaughterhouse or processing plant workers

IV. Indirect contamination by the carcass
   - Aerosol contamination when the carcass is cut up and/or slapped onto the counter, thereby releasing pathogens
   - Contact with knives, wiping clothes, sinks, etc. where pathogens have been deposited.

V. Cross contamination of other edible products
   - Carcass contaminating other carcasses in the slaughterhouse
   - Meat products in the processing plant
   - Other raw or cooked foods in the kitchen or a private home or commercial feeding establishment.

VI. Consumption of meat and meat products

processing plants are exposed to aerosol contamination when slabs of tuberculous meat are slapped onto the counter and when the carcasses are cut-up (7,9). Third, there are documented cases of wound infections causing TB in butchers and veterinarians (9).

The fourth pathway, which encompasses the risk to the public of eating undercooked tuberculous meat, has not been clearly established. Meat of tuberculous cattle contains tubercle bacilli (9) and raw or rare-cooked meat may continue to harbor live organisms. While animals fed tuberculous meat slaughtered under primitive conditions (19th century) developed TB (7,16), under aseptic conditions they did not become ill (16). Although these data with ingested meat are inconclusive, the prevalence of human TB from drinking unpasteurized milk at the turn of the century indicates that the bacteria can survive the stomach acids. Perhaps the likelihood of human infection centers around the number of bacteria needed to cause disease.

The only reported epidemiological study with a control group was done by Sigurdsson in 1945 (7). The study took place in Denmark with 200 families. The 100 control families lived on farms with tuberculin-negative cattle. The other 100 families lived on farms with tuberculin-positive herds. On the latter farms, the proportion of tuberculin-positive persons increased steadily during childhood, reaching 75% at 15 years, indicating that these children had been infected with TB. In contrast, only 15% of the adolescents on the control farms became infected. Sigurdsson concludes that “the amount of bovine tuberculosis in human beings is directly related to the degree of tuberculosis in herds with which they have been in contact” (7).

This relatively high rate of infection in Sigurdsson’s study lends support to an estimate made by Dr. James Steele, Public Health Veterinarian, at the University of Texas and formerly Assistant Surgeon General for Veterinary Medicine in the U.S. Public Health Service. His estimate that 4 to 10 human infections (primarily among farm families and slaughterhouse workers) would be caused by each 10 infected live cattle or carcasses thereof is based on fragmentary data from several sources (James Steele, personal communication). Of those persons becoming infected, 90 to 95% should be able to resist disease and only 5 to 10% should actually develop clinical disease symptoms requiring treatment.

These estimates can be translated into the human health consequences of not inspecting for TB. For the previously estimated 12,030 tuberculous cattle entering the human food chain, between 48,000 and 120,030 humans might be infected per year (Fig. 1). Between 2,400 and 12,003 humans may develop TB and require treatment; and 144 to 720 may die.

Cost of treatment for human tuberculosis caused by Mycobacterium bovis

In 1937, Raw found that the bovine type of tubercle bacillus caused nearly every king of lesion caused by the human type, Mycobacterium tuberculosis (14). Once a tuberculous lesion develops in an organ, the appearance and course of disease is the same whether M. bovis or M. tuberculosis is isolated (9). This includes the character and extent of lesions seen at autopsy. Since the course of the two diseases is not distinguishable, the cost of treatment is assumed to be the same.

Some of the nonfatal tuberculous cases can be treated on an outpatient basis (approximately 18 months); however, other require extensive hospitalization. Kenneth E. Powell, Centers for Disease Control of the United States Public Health Service, Department of Health and Human
Services, which monitors tuberculosis, reports that a fictional "average" case in 1977 would have required 30 d of hospitalization (Kenneth E. Powell, personal communication). This average figure includes hospitalization of those who die. The movement away from TB sanitariums towards out-patient care is reflected in this decline in hospitalized days which was as high as 145 d as recently as 1970. Today, half the TB patients are in general care hospitals and half are in sanitariums (24). The average cost per day (Dave Gibson, Health Care Finance H.H.S., personal communication) multiplied by the average 30-d length of stay yields a cost of $4,500 per case when one half of the patients are in general care hospitals and one half in sanitariums (Table 2). An additional $250 is expended for drugs and approximately $1,250 for laboratory tests, chest x-rays, eye tests, nurse and physical visits and tracing of contacts (Vedit Onar, Acting Tuberculosis Control Officer, Washington, D.C. Health Department, personal communication).

On average, 2 months are lost from work, adding another $2,275 per case in lost wages. The average weekly earnings for private sector production and non-supervisory workers on nonagricultural payrolls, reported by the Bureau of Labor Statistics were $261.89 per week in December 1981. It is assumed that all persons affected would be workers or that the value of time lost to non-wage earners, children, homemakers, students, the elderly, would be roughly comparable to the value of wages lost. Thus, the total direct money cost per individual who recovered from TB would average $8,275, the sum of medical costs and lost wages (Table 2).

Benefits of preventing deaths from tuberculosis

Although treatment for TB improved dramatically after discovery of streptomycin in 1944, still around 6% of the patients die. The proper method of evaluating the economic loss of early death of humans has been much debated in the economic literature (6). Dorothy Rice, formerly of the National Center for Health Statistics, made estimates of the present value of human capital which essentially measures the loss of productive capacity caused by the death of a worker (3,4). These numbers have been updated by the National Center for Health Statistics to include imputed values for housekeeping services performed by the individual and are compared at 10% discount rate required by the Office of Management and Budget for evaluating government programs (Table 3).

Economists have long argued that the human capital approach captures an important piece of an individual’s contribution to society and Gross National Product. However, from the individual’s point of view, there are important elements of illness and death that are omitted: pain and suffering, aversion to risk, and loss of leisure (12,13).

The concept incorporating these elements is called the "willingness-to-pay" approach because it asks, "How much would an individual be willing to pay for a reduction in risk of illness?" Problems with this approach are placing a monetary value on these intangible and value-laden components as well as being dependent on the existing distribution of income. A person’s willingness-to-pay is a function both of the person’s value system and ability to command economic resources. Landefield and Seskin (12) recently published willingness-to-pay estimates which are significantly higher than the traditional human capital estimates for three reasons. First, the non-labor income such as pensions are included since these resources can be used to pay for a reduction in risk of illness. Second, risk aversion is assumed using data from life insurance purchases, which means that a family will pay more than its expected economic loss to buy peace of mind and reduce the risk of income loss due to death.

### TABLE 2. Likely costs of bovine tuberculosis.

<table>
<thead>
<tr>
<th>Type of cost</th>
<th>Cost per case</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Dollars)</td>
<td>Low estimate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,400 cases</td>
</tr>
<tr>
<td>Medical costs, total</td>
<td></td>
<td>(Million dollars)</td>
</tr>
<tr>
<td>Hospital</td>
<td>4,500</td>
<td>14.4</td>
</tr>
<tr>
<td>Physician and nurse visits</td>
<td>1,250</td>
<td>3.0</td>
</tr>
<tr>
<td>Drugs</td>
<td>250</td>
<td>0.6</td>
</tr>
<tr>
<td>Lost wages, total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Due to illness&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2,275</td>
<td>18.3</td>
</tr>
<tr>
<td>Due to death&lt;sup&gt;b&lt;/sup&gt;</td>
<td>92,000 low</td>
<td>13.2</td>
</tr>
<tr>
<td></td>
<td>294,000 high</td>
<td></td>
</tr>
<tr>
<td>Grand total</td>
<td></td>
<td>32.7</td>
</tr>
</tbody>
</table>

<sup>a</sup>The lost wages due to illness only are calculated for 2,256 individuals (low estimate and 11,284 individuals (high estimate).

<sup>b</sup>The estimated number of deaths are 144 (low estimate) or 720 (high estimate) persons and the low loss of life figure uses the human capital approach (cf. Table 3) while the higher figure is the willingness to pay approach (cf. Table 4).
of a wage earner. Third, a lower discount rate, interest rate, is used which reflects the individual’s opportunity cost of investing in other risk-reducing securities or assets—“such as installing a security system or buying a safer car” (12).

Each method of valuing life is combined with the actual age distribution of TB deaths to compute a weighted average. Landefeld and Seskin’s willingness-to-pay estimate (Table 4) is three times greater than the standard human capital value for TB (Table 3). The low estimate reported in Table 2 uses the human capital value of $92,000 per death as well as the lower probability of only 144 deaths while the high estimate uses the willingness-to-pay value of $294,000 per death and the higher probability of 720 deaths. The likely estimated loss due to deaths caused by bovine tuberculosis then ranges between $13.2 to 211.7 million annually.

**DISCUSSION**

The benefit estimation here evaluates the dual programs for bovine TB assuming that without the programs the benefit estimation would have remained unchanged throughout the 1900s. A second key assumption is that the human TB disease consequences considered in this study reflect the best medical treatment available today. A third key assumption on the number of human cases of TB that may result from exposure to infected cattle or contact with tuberculous meat is difficult to predict and was given a wide range to reflect this difficulty. Finally, economists have two different methods of evaluating loss of life; the human capital approach is used in the low estimate and the willingness-to-pay approach in the high estimate.

The low estimate assumes there would be 2,400 human cases of bovine TB and 144 deaths annually. Medical costs and lost wages for these people may total $32.7 million annually. However, this estimate is on the low side because pain and suffering due to illness, loss of leisure time, and other relatively intangible costs are not included.

The high estimate assumes that there would be 12,003 human cases of bovine TB and 720 deaths annually. The

**TABLE 3. The possible costs from deaths that may have occurred from tuberculosis, human capital method.**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Number</th>
<th>Men</th>
<th>Present value ($000)</th>
<th>Sum</th>
<th>Number</th>
<th>Women</th>
<th>Present value ($000)</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td>39</td>
<td>50.6</td>
<td>1,973.4</td>
<td>1,973.4</td>
<td>24</td>
<td>44.2</td>
<td>1,061.0</td>
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<tr>
<td>5-14</td>
<td>12</td>
<td>91.6</td>
<td>1,099.2</td>
<td>1,099.2</td>
<td>9</td>
<td>80.0</td>
<td>720.1</td>
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<tr>
<td>15-24</td>
<td>51</td>
<td>172.9</td>
<td>8,817.9</td>
<td>8,817.9</td>
<td>33</td>
<td>138.5</td>
<td>4,570.8</td>
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<tr>
<td>25-44</td>
<td>609</td>
<td>213.3</td>
<td>129,899.7</td>
<td>129,899.7</td>
<td>321</td>
<td>137.2</td>
<td>44,055.0</td>
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</tr>
<tr>
<td>45-64</td>
<td>2,437</td>
<td>108.7</td>
<td>264,932.4</td>
<td>264,932.4</td>
<td>1,041</td>
<td>83.1</td>
<td>86,524.8</td>
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<tr>
<td>65+</td>
<td>3,651</td>
<td>7.8</td>
<td>28,323.2</td>
<td>28,323.2</td>
<td>1,773</td>
<td>23.6</td>
<td>41,874.7</td>
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</table>

**GRAND TOTAL: $613,851,300 for 10,000 cases**
**Average loss per death in 1977 dollars = $61,400**
**Average loss per death in 1981 dollars = $92,000**

*Adjusted by the percentage increase in the CPI (Consumer Price Index) for 1981 vs. 1977.

**TABLE 4. The possible costs from deaths that may have occurred from tuberculosis, willingness-to-pay method.**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Number</th>
<th>Men</th>
<th>Present value ($000)</th>
<th>Sum</th>
<th>Number</th>
<th>Women</th>
<th>Present value ($000)</th>
<th>Sum</th>
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</thead>
<tbody>
<tr>
<td>0-4</td>
<td>39</td>
<td>695.4</td>
<td>27,121</td>
<td>27,121</td>
<td>24</td>
<td>475.3</td>
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<tr>
<td>5-14</td>
<td>12</td>
<td>810.5</td>
<td>9,726</td>
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<td>9</td>
<td>553.3</td>
<td>4,980</td>
<td></td>
</tr>
<tr>
<td>15-24</td>
<td>51</td>
<td>952.6</td>
<td>48,583</td>
<td>48,583</td>
<td>33</td>
<td>625.2</td>
<td>20,632</td>
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<td>502,121</td>
<td>502,121</td>
<td>321</td>
<td>498.3</td>
<td>159,954</td>
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<tr>
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<td>315.6</td>
<td>769,117</td>
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<td>1,041</td>
<td>235.9</td>
<td>245,572</td>
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<td>3,651</td>
<td>19.4</td>
<td>70,829</td>
<td>70,829</td>
<td>1,773</td>
<td>52.1</td>
<td>92,373</td>
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**GRAND TOTALS: $1,962,415,000 loss for 10,000 deaths**
**Average loss per death in 1977 dollars = $196,242**
**Average loss per death in 1981 dollars = $294,363**

*Adjusted willingness-to-pay human capital estimates based on the present value of both expected lifetime after-tax income and housekeeping services (where income is estimated from earnings by using the ratio of disposable income to wages and salaries equal to 1.33), an after-tax real rate of return equal to 3 percent; an annual increase in labor productivity of 1 percent; and a risk-aversion premium of 1.6.

*Adjusted by the percentage increase in the CPI (Consumer Price Index) for 1981 vs. 1977.*
possible costs of deaths causes two-thirds of the loss because the willingness-to-pay methodology is more comprehensive and does include pain and suffering and other relatively intangible costs. The high estimate is $309.4 million annually. If the intangible costs were also included for those ill who do not die, the estimates would be even higher.

Program benefits change over time. The public health protection benefits hinge on the treatment cost of illness which can change dramatically. Also, the costs of inspection and/or controlling disease can change dramatically as the labor cost of inspectors rises and as new laboratory tests and procedures are discovered. Each of these must be evaluated to determine the benefits and costs of particular control techniques and their overall merit with respect to human health. The range of estimates presented here for bovine TB is quite large, and further refinement by epidemiologists, and other scientists could greatly improve the confidence of the estimates.

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REFERENCES