Estimated Annual Costs of *Campylobacter*-Associated Guillain-Barré Syndrome. By Jean C. Buzby, Tanya Roberts, Food and Consumer Economics Division, Economic Research Service, U.S. Department of Agriculture, and Ban Mishu Allos, Vanderbilt University, School of Medicine. Agricultural Economic Report No. 756.

Abstract

Guillain-Barré syndrome (GBS) is an autoimmune reaction that can cause acute neuromuscular paralysis. Of an estimated 2,628 to 9,575 new U.S. cases with GBS annually, 526 to 3,830 are triggered by infection with *Campylobacter*, the most frequently isolated cause of foodborne diarrhea. Estimated total annual costs of *Campylobacter*-associated GBS of $0.2 to $1.8 billion plus previously estimated costs of campylobacteriosis ($1.3 to $6.2 billion) add to total annual costs from *Campylobacter* of $1.5 to $8.0 billion (1995 dollars). Assuming 55-70 percent of costs are attributable to foodborne sources, costs of campylobacteriosis from food sources ($0.7 to $4.3 billion) and costs of associated GBS ($0.1 to $1.3 billion) combined equal total annual costs of $0.8 to $5.6 billion from foodborne *Campylobacter*. Reducing *Campylobacter* in food could prevent up to $5.6 billion in costs annually.

Keywords: *Campylobacter*, cost-of-illness, foodborne pathogens, Guillain-Barré syndrome, lost productivity, medical costs.

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Summary

Microbial pathogens in food cause between 6.5 million and 33 million cases of human illness and up to 9,000 deaths each year in the United States. These illnesses and deaths cost the United States billions of dollars each year in medical costs and lost productivity. *Campylobacter* is one of the most common causes of foodborne diarrheal illness in the United States. Sources of *Campylobacter* include raw and undercooked poultry, raw milk, and polluted water. Up to $5.6 billion in human illness costs could be saved each year in the United States by reducing *Campylobacter* in food.

Out of an estimated 2,628 to 9,575 patients diagnosed with Guillain Barré syndrome (GBS) in the United States each year, 526 to 3,830 (20-40 percent) are triggered by *Campylobacter* infection. GBS is a disease of the nervous system characterized by a rapid onset, various degrees of numbness, pain, and progressive weakness or paralysis. GBS is believed to be an autoimmune reaction that is triggered by factors such as gastrointestinal or respiratory illness. Two percent die from the illness, and up to 65 percent of patients with GBS report neurological pain. Other potential lingering disabilities include abnormalities of the nervous system and changes in heart rate, blood pressure, vision, and body temperature. Most patients are hospitalized and some have relapses.

This report estimates:

- the annual U.S. cost of *Campylobacter*-associated GBS: $0.2 to $1.8 billion (1995 dollars);
- the annual U.S. cost from *Campylobacter* infections of $1.5-8.0 billion (total annual costs of *Campylobacter*-associated GBS plus costs of campylobacteriosis ($1.3-$6.2 billion)); and
- costs attributable to foodborne sources. Assuming that 55-70 percent of all *Campylobacter* infections are attributable to foodborne sources, costs of foodborne campylobacteriosis ($0.7-$4.3 billion) and associated GBS ($0.1-$1.3 billion) equal $0.8-$5.6 billion each year.

These costs of foodborne *Campylobacter* can be used in cost-effectiveness studies or benefit-cost analyses of programs that prevent *Campylobacter* contamination of food. Although there are several different triggering factors for GBS, no single factor appears to cause a greater proportion of GBS cases than does *Campylobacter*. Ways to reduce GBS triggered by other factors such as surgery are less understood. Therefore, societal efforts to reduce GBS caused by *Campylobacter* may have higher net returns than efforts to reduce GBS caused by other triggering factors.

As with other cost-of-illness (COI) estimates, the COI estimates for *Campylobacter*-associated GBS understate true values because they do not include such components as pain and suffering, lost leisure time, the cost of preventive actions, travel costs, resources spent on research, and lawsuits. The estimates are also conservative in that they do not reflect the productivity losses of those patients with GBS who returned to work but had to take a lower paying job because of their illness.

Abbreviations

BLS	Bureau of Labor Statistics
CDC	Centers for Disease Control and Prevention
COI	Cost-of-illness
CPI	Consumer Price Index
ERS	Economic Research Service
GBS	Guillain-Barré syndrome
GPO	Government Printing Office
HCFA	Health Care Finance Administration
ICD-9	International Classification of Diseases Codes—9th edition
ICU	Intensive care unit
IVIG	Immunoglobulin treatments
LS	Landefeld and Seskin
MV	Mechanical ventilation
NHDS	National Hospital Discharge Survey
PE	Plasma exchange
USDA	United States Department of Agriculture
VOSL	Value of a statistical life
WTP	Willingness to pay

Estimated Annual Costs of *Campylobacter*-Associated Guillain-Barré Syndrome

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Introduction

Microbial pathogens in food include bacteria, viruses, parasites, and fungi. These pathogens cause between 6.5 million and 33 million cases of human illness and up to 9,000 deaths each year in the United States (Council for Agricultural Science and Technology, 1994). These illnesses and deaths cost the United States billions of dollars each year in medical costs and lost productivity (Buzby and Roberts, 1996).

The fundamental economic issues surrounding microbial food safety are asymmetric information and market failure. Because most pathogens are invisible to the naked eye, consumers generally are unable to determine the risk of foodborne illness posed by their food consumption choices (Crutchfield *et al.*, 1997). Meanwhile, producers are likely (but not necessarily) to be better informed than consumers about the food safety risks of the foods they produce. However, producers have no direct incentive to supply this information. This asymmetry in food safety information and the lack of producer incentive to supply such information means that most food safety risks are not incorporated into market prices and quantities. This market failure leads to more pathogens in the food supply, greater risk to human health, and higher levels of illness and mortality related to foodborne pathogens (Crutchfield *et al.*, 1997).

Incorporating economics into food safety decisions would help society achieve a target level of food safety that either maximizes economic benefits or minimizes costs. The role of economics in microbial food safety is to define the savings of resources associated with pathogen reduction, and to assess the costs and benefits of achieving social goals like the provision of more healthful foods. This requires information about the baseline costs posed by foodborne illnesses. This study estimates the annual costs of one complication of a foodborne illness—Guillain-Barré syndrome (GBS) that follows some *Campylobacter* infections. ERS embarked on this project because foodborne data indicate *Campylobacter* is the most common cause of bacterial foodborne illness in the United States (CDC, 1997) and because quantifying societal costs of a foodborne illness entails a cost analysis of both acute and secondary complications.

Guillain-Barré syndrome is the leading cause of acute neuromuscular paralysis in the United States now that polio has been virtually eliminated by vaccination programs (Parry, 1993, p. 10; Mishu *et al.*, 1993, p. 947). Although paralysis from GBS is generally reversible to some extent over time, some patients die prematurely because of the illness while others are bedridden for life.

Although the cause of GBS is not well defined, many believe it is an autoimmune reaction triggered by factors such as some gastrointestinal or respiratory illnesses, surgery, and certain vaccinations. In particular, one potential trigger of GBS is infection caused by *Campylobacter*, a common foodborne and waterborne pathogen that causes the gastrointestinal

illness, campylobacteriosis.[1] The Centers for Disease Control and Prevention (CDC) estimate that roughly 1 in 100 people are diagnosed with symptoms of *Campylobacter* infection in the United States each year (Tauxe, 1992, p. 3). Tauxe (1992) estimated that of 2.5 million people ill with campylobacteriosis in the United States each year, 200 to 730 die because of their illness. Although only a small percentage of campylobacteriosis cases develop GBS, there appears to be a strong link between *Campylobacter* and GBS. An estimated 20 to 40 percent of GBS cases are caused by *Campylobacter* infections (Mishu and Blaser, 1993).

People can get campylobacteriosis by drinking water or raw milk contaminated with *Campylobacter* and by consuming contaminated raw or undercooked meat (Skirrow and Blaser, 1992). Consuming contaminated poultry is the predominant source of sporadic cases of *Campylobacter* infections (Tauxe, 1992, p. 12). The intestine of birds and warm-blooded animals is a natural habitat for *Campylobacter* (Park *et al.*, 1991, p. 101S) and studies show that chicken slaughter and processing leads to heavy surface contamination (Park *et al.*, 1991; Skirrow and Blaser, 1992, p. 6; Sjögren and Kaijser, 1988, p. 3). Up to 80 percent of poultry at retail are contaminated with *Campylobacter* (Skirrow and Blaser, 1992, p. 4), and this contamination appears to peak between July and October (Tauxe *et al.*, 1988; Harris *et al.*, 1986, p. 404). To a lesser extent, turkey, raw milk, cake icing, raw clams, raw hamburger, water, and contact with pets have been epidemiologically linked with campylobacteriosis in the United States (Blaser *et al.*, 1983, p. 163; Stern, 1992, p. 50; Tauxe *et al.*, 1988; CAST, 1994, p. 11).

This study estimates the annual cost-of-illness of GBS caused by all *Campylobacter* infections and by foodborne *Campylobacter* infections in the United States. Medical costs and the costs of lost productivity provide public health cost estimates of *Campylobacter*-associated GBS. These cost-of-illness estimates can be compared against the estimated annual costs of new procedures that reduce *Campylobacter* in the food chain.

One potential procedure to reduce the incidence of GBS is a *Campylobacter* vaccination program for people. A high proportion of campylobacteriosis cases are foodborne (estimated at 55-70 percent) and 75 percent of these foodborne cases are attributed to meat and poultry (*Federal Register*, July 25, 1996).[2] The 1996 U.S. Department of Agriculture's (USDA) regulation on Hazard Analysis and Critical Control Point (HACCP) systems for meat and poultry can indirectly reduce the annual incidence of GBS by reducing the load of *Campylobacter* in meat and poultry. There are other ways to partially reduce the likelihood of foodborne *Campylobacter* infections, such as thoroughly cooking meat and poultry and preventing raw meat and poultry juices from commingling with cooked meat and poultry or with other foods. New or expanded educational programs could help educate consumers and food handlers about safe food handling techniques to prevent campylobacteriosis and other foodborne diseases. Therefore, some portion of the estimated annual costs of GBS in the United States could be avoided by reducing the incidence of campylobacteriosis.

Other than *Campylobacter*, triggering factors for GBS include viral infections, surgery, systemic illness, and vaccinations (Parry, 1993). However, no single factor appears to cause a greater proportion of GBS cases than does *Campylobacter*. Ways to reduce GBS triggered by other factors such as surgery are less understood. Therefore, societal efforts to reduce GBS caused by *Campylobacter* may have higher net returns than efforts to reduce GBS caused by other triggering factors.

For those key data points not supported by strong consensus, sensitivity analyses were performed to

[1] Because infections with *C. jejuni* and *C. coli* are clinically indistinguishable and because more than 99 percent of *Campylobacter* isolates in the United States are *C. jejuni* (Tauxe, 1992), the term *Campylobacter* is used here to include both *C. jejuni* and *C. coli*.

[2] Roughly 55 to 70 percent of all *Campylobacter* infections are estimated to be foodborne. In a Seattle-King County Department of Public Health surveillance study (1984, p. 153), roughly 55 percent of all *Campylobacter* cases were attributed to food origins: drinking raw milk (5.2 percent) and eating poultry (48.2 percent). Tauxe (1992, p. 15) summarized Deming *et al.*'s (1987) results of a study of campylobacteriosis cases in students at a Georgia college, and found that 70 percent were attributed to eating chicken (30 percent attributed to contact with cats). Raw chicken could also have cross-contaminated other foods in the kitchen.

determine the impact on costs of variations in adjusted productivity losses, days on mechanical ventilation (MV),[3] and probabilities of patients with *Campylobacter*-associated GBS who require MV, plasma exchange (PE), and intravenous immunoglobulin (IVIG) treatments.[4]

Estimates of the total annual costs of GBS caused by all *Campylobacter* infections and by foodborne *Campylobacter* infections can be added to previously estimated annual costs of campylobacteriosis (Buzby *et al.*, 1996; Buzby and Roberts, 1996) in the United States to obtain a more complete accounting of the economic impact of *Campylobacter* to Americans. These estimates are also compared with cost-of-illness estimates for other foodborne pathogens to estimate the relative impact of the pathogens on society.

Guillain-Barré Syndrome

Each year, there are an estimated 2,628 to 9,575 people who develop GBS in the United States. [See appendix for details on characterization of disease, medical care, and estimated cases.] Final outcomes range considerably. Although most patients with GBS recover from the paralysis with only minor residual symptoms, others are permanently bedridden, wheelchair-bound, or beset by fatal complications. Most patients with GBS are hospitalized and some have relapses. GBS can affect people of all ages but older patients with GBS are more likely to have a poor prognosis than are younger patients with GBS.

The current standard of care for treating patients with GBS includes plasma exchange and/or intravenous immunoglobulin treatments. In recent studies, approximately 20 percent of all patients with GBS required mechanical ventilation to assist breathing. Sunderrajan and Davenport (1985) found that the probability that patients with GBS will be put on mechanical ventilation increases with age. The average age of those patients with GBS requiring mechanical ventilation was roughly 47 years and the average age of those patients with GBS who did not require ventilation was roughly 30 years. We assumed these values in the baseline analysis in this study.

Several participants of the 1995 American Neurology Association meeting suggested that the overall case fatality rate for patients with GBS has decreased and is currently around 2 percent. More seriously ill patients with GBS who are mechanically ventilated are more likely to die than those less severely ill. In Sunderrajan and Davenport's (1985) sample of 40 patients with GBS, 28 percent of the mechanically ventilated patients died while there were no deaths among those not on mechanical ventilation.

Since the first report of *Campylobacter* infection complicated by GBS was published in 1982 (Rhodes and Tattersfield, 1982), evidence has accumulated that these infections may be an important trigger of GBS. Serologic and cultural studies have confirmed that 20-40 percent of patients with GBS had infection with *C. jejuni* in the 1-3 weeks prior to the onset of neurologic symptoms (Mishu and Blaser, 1993; Kuroki *et al.*, 1993; Rees *et al.*, 1995). Assuming that 20 to 40 percent of all patients with GBS have prior *Campylobacter* infections, there are an estimated 526 to 3,830 new patients diagnosed with *Campylobacter*-associated GBS each year in the United States.

There is little evidence to suggest that significant person-to-person transmission of *Campylobacter* takes place (Tauxe, 1992, p. 11). However, there have been a few documented cases of pregnant women with bacteremia that have been associated with severe fetal infections (Blaser *et al.*, 1983a, p. 165).

This report estimates annual costs for all patients with GBS who had prior *Campylobacter* infections, regardless of the source of *Campylobacter* infection (foodborne, waterborne, etc.). The study then estimates the annual costs of GBS caused by foodborne *Campylobacter* assuming that 55 to 70 percent of all

[3] Mechanical ventilation is where breathing is regulated by a mechanical ventilator in an intubated patient. MV may be required in patients with GBS whose weakness or paralysis is severe.

[4] In plasma exchange (PE/plasmapheresis), "blood is removed from the patient, plasma is separated from blood cells and discarded, and blood cells are suspended in colloid solution and reinfused" (Thornton and Griggs, 1994, p. 262). Thornton and Griggs (p. 260) state "it is likely that plasma exchange acts by removing pathogenic antibodies" and they offer seven possible explanations of how IVIG, where pooled human IgG (a plasma protein) is intravenously administered, works.

Campylobacter infections are foodborne.[5] Although some studies suggest that *Campylobacter*-associated GBS is more severe than GBS caused by other factors (Molnar *et al.*, 1982; Rhodes and Tattersfield, 1982; Constant *et al.*, 1983), this distinction is not made here because of data limitations.

The Cost-of-Illness Method

The cost-of-illness (COI) method, developed by Malzberg (1950) and codified by Rice (1966), is a damage function approach and sums the costs borne by all individuals afflicted with a given disease. Most COI studies on foodborne illness estimate the present value of lifetime medical costs and lost productivity (i.e., forgone income and household production caused by the illness) to obtain partial estimates of annual costs (e.g., Cohen *et al.*, 1978; Roberts, 1989; Todd, 1989; Buzby *et al.*, 1996). One could argue, following Harberger's (1971) argument confirmed by Willig (1976), that the opportunity cost of the resources consumed in treating (or preventing) acute and chronic foodborne illnesses is a reasonable measure of society's welfare loss. A more complete accounting of cost categories would include evaluation of the loss of leisure time, pain and suffering, industry costs, and public health expenditures by the government.

Without other information such as the availability of treatment options and their effectiveness, cost-of-illness studies cannot tell us whether or not scarce health-care resources should be allocated to treating (or preventing) the diseases studied (Drummond, 1992, p. 2). Cost-of-illness estimates can, however, serve as useful inputs in cost-effectiveness analyses, cost-benefit analyses, cost-utility analyses, and other applied research that may in turn be used to prioritize resource allocation by policymakers.[6] For example, the cost-of-illness estimates for selected foodborne illnesses (Buzby *et al.*, 1996) were used in the U.S. Department of Agriculture's cost-benefit analysis for its Hazard Analysis and Critical Control Point (HACCP) rule, which was designed to improve the safety of meat and poultry (Federal Register, July 25, 1996). Other COI studies have estimated the economic costs of an assortment of diseases including obesity (Colditz, 1992); dyspepsia and schizophrenia (Ament and Evers, 1993); and asthma, lung cancer, and coronary artery disease (Abt Associates Inc., 1992).[7]

On the macro level, it is the value of the total societal burden that should influence the allocation of resources (Ament and Evers, 1993, p. 31). This value can be determined by methods such as willingness-to-accept (WTA) and willingness-to-pay (WTP). "In these methods human life and limb are valued according to the amount people are willing to spend to obtain reductions in the probability of death, injury, or disability (WTP) or, alternatively, the amount by which they must be compensated in order to accept an increased risk (WTA)" (Ament and Evers, 1993, p. 31).

However, obtaining WTP or WTA for a specific illness or injury may be prohibitively time-consuming or expensive. WTP methods use a variety of techniques ranging from direct questioning to experimental auctions to determine values for nonmarket goods. And, even if a WTP estimate for a food-safety hazard is available, the estimate is not easily applied elsewhere since the hazard may have a different incidence or case fatality rate. For food safety, what is being valued are reductions in the risk of acute illness, chronic complications, and premature death associated with foodborne pathogens. The one WTP application to foodborne disease by Hayes *et al.* (1995) found experimental-auction participants willing to pay $0.40 to $1.00 to purchase a safer sandwich.[8]

Most cost-of-illness estimates account only for medical costs and costs of lost productivity, and therefore, underestimate the true economic burden to society. The scope of COI studies can vary from a spe-

[5] Buzby and Roberts (1996) assumed that 55 to 70 percent of *Campylobacter* infections were foodborne and estimated that annual medical costs and productivity losses for campylobacteriosis from food sources ranged from $0.7 billion to $4.3 billion in 1995 dollars.

[6] Hodgson (1994) provides a thorough review of COI estimates in cost-effectiveness analysis. Haddix *et al.* (1996) provides a review of cost-benefit analysis, cost-effectiveness analysis, and cost-utility analysis with an emphasis on the valuation of health outcomes.

[7] Jarvinen (1988) provides an annotated bibliography of about 600 cost-of-illness studies.

[8] Bids did not vary with risk levels, suggesting future work is needed to understand exactly what the bids reflect.

cific disease with only one type of cost to several diseases with an exhaustive cost accounting (Hodgson and Meiners, 1982, p. 437). The COI method is easy to apply and uses accessible data on personal earnings and medical expenditures (French, 1990, p. 1118). Also, these data are precise enough to allow for sensitivity analyses of the COI estimates to changes in medical costs, demographic profiles of affected individuals, or outcome severities.

One conceptual difficulty with the COI method is that it usually requires a proxy monetary value for productivity losses for injury- or illness-related death and/or a proxy monetary value for premature retirement. One commonly used proxy is an estimate of the value of a statistical life (VOSL). Though there is no universally accepted method to estimate the VOSL (Cropper and Oates, 1992; Hayes *et al.*, 1995; Randall, 1993; Smith, 1992; Viscusi, 1992), there are two conceptual approaches: the human capital (HC) approach and the willingness-to-pay (WTP) approach (Landefeld and Seskin, 1982).[9] The HC approach aims to capture forgone earnings whereas the WTP approach aims to capture the value that people place on small changes in their probability of survival. Note that analysts use the term "value of a statistical life" very loosely, especially in the case of HC estimates, which are crude representations of this controversial and ambiguous value, a value likely to be only loosely related to income.

Human Capital (HC) Approach

The human capital (HC) approach assumes that the value of an individual's life from a societal perspective can be measured by an individual's future production potential. This production potential can be approximated by the discounted present value of future labor earnings forgone due to premature death or retirement.

Expected earnings are discounted back to the year of the incidence (Van Doorslaer and Bouter, 1990, p. 259) and therefore one measurement problem is the choice of the appropriate discount rate. A frequent ethical/philosophical objection to the HC approach is that some demographic groups are valued more highly than others: values are higher for men than for women and values are higher for young and middle-aged adults than for the elderly and children. The HC approach places little value on reducing risk of the elderly, because they have low future earnings to forgo. Similarly, the method typically attaches low values to risk reduction for children because future earnings are discounted to present values. Assigning low values for reducing risks to children and the elderly seems illogical because people can and do spend substantial amounts on risk avoidance for those groups, especially children. Also, in periods of high unemployment, it is likely that deceased or sick workers will not only be replaced but at little cost (Ament and Evers, 1993, p. 32).

Although the HC approach is criticized because it incompletely measures the value of a statistical life, it does measure the earnings component of the burden of a disease (e.g., part of the value lost to mortality or morbidity) (Hodgson and Meiners, 1982, p. 438-439). Time lost from work and other productive activities is a valuable economic resource that is unavailable for other uses. Although the WTP approach is more grounded in economic theory, the HC approach has some theoretical foundation. Given the assumption that earnings reflect productivity, the HC approach can be supported by the economic theory of marginal productivity (Hodgson and Meiners, 1982, p. 442).

Willingness-To-Pay Approach

The WTP approach is conceptually appealing because it can cover more of the potential costs of an illness or injury than can the HC approach and because it has some foundation in Pareto's theory of optimality (Hodgson and Meiners, 1982, p. 443).[10] While there are several methods that attempt to iso-

[9] In estimating the societal costs of a particular illness or injury, WTP estimates can be useful in two ways. First, WTP estimates can be used as a direct and theoretically preferable replacement for cost-of-illness estimates if the WTP estimates are available for the specific illness/injury, incidence rate, and mortality rate of interest. Second, WTP estimates for reductions in other mortality risks can be used in a cost-of-illness analysis as a proxy monetary value for adjusted productivity losses for those who die prematurely or are unable to ever return to work because of an illness or injury.

[10] A Pareto efficient allocation of resources is where "it is not possible (through further reallocations) to make one person better off without making someone else worse off" (Nicholson, 1989, p. 476).

late willingness-to-pay, recent attention in estimating the value of a statistical life has focused on the wage-risk estimation in labor markets.[11] Wage-risk studies derive the value of risk reduction by statistically estimating the effect of occupational mortality and injury risks on wages. Typically, employers must offer workers higher wages to induce them to take a job with some injury risks, as opposed to a similar job with no such risks. Conversely, workers accept jobs with lower wages, given that those jobs offer minimal risks. The "risk premium" is then the increased wage needed to attract workers to riskier jobs. However, wage-risk estimates can be biased downwards if real or perceived barriers (e.g., long-term labor contracts) prevent workers from reacting to changes in workplace risks or if workers underestimate their true exposure to these risks (French, 1990, p. 118).

The typical wage-risk study uses a measure of mortality risk, and measures the effects of a small change in mortality risk on wages; a typical study might find that an increase in mortality risk of 1 in 10,000 (one extra death in a year for every 10,000 workers in the relevant population) would be associated with a wage increase of $300. In an industry with 10,000 workers, then, we could expect one additional worker to die each year on average, and as a result total wage payments would be $3 million higher ($300 times 10,000 workers). In that case we would say that the value of a statistical life was estimated to be $3 million, because industry had to pay that amount to induce workers to take on a risk that would likely leave one dead. Alternatively, one could say that workers would, in the aggregate, be willing to pay $3 million through wage reductions in order to purchase a reduction in risk that prevents one death.

In practice, WTP estimates face measurement difficulties and are rarely found in cost-of-illness studies (Hodgson and Meiners, 1982, p. 443; Ament and Evers, 1993, p. 31). Most cost-of-illness studies are based on HC estimates (Van Doorslaer and Bouter, 1990, p. 259; Ament and Evers, 1993, p. 31). In wage-risk studies, the VOSL "is not a universal constant, but reflects the wage-risk tradeoff pertinent to the preferences of the workers in a particular sample" (Viscusi, 1993, p. 1930). Viscusi (1993) found that estimates from wage-risk studies ranged between $0.6 million and $16.2 million in 1990 dollars due to differences in methodology and data sets. These broad ranges complicate resource allocation decisions.

[11] Fisher *et al.* (1989, p. 89) divide the WTP approach into three categories of studies: (1) contingent market studies, (2) consumer market studies, and (3) wage-risk [hedonic-wage] studies. Here, we discuss only wage-risk studies because they are the most applicable to food safety.

Landefeld and Seskin Hybrid Approach

The Landefeld and Seskin (LS)(1982) approach is a hybrid of the HC and WTP approaches. LS estimates include more than the forgone earnings found in HC estimates while capturing considerably less than what WTP aims to capture (i.e., LS does not capture reductions in the risk of items such as pain, suffering, and lost leisure time). The LS approach generates the present value of expected lifetime income and housekeeping services at a 3-percent real rate of return, adjusted for an annual 1-percent increase in labor productivity, and a risk-aversion factor of 1.6. Total income in Landefeld and Seskin (1982, p. 561) includes labor income adjusted upwards to include nonlabor monetary income sources such as rents, royalties, interest, and transfer payments as well as nonlabor nonmonetary factors such as the value of housekeeping, which is excluded from the U.S. gross national product. The risk-aversion factor increases the present value of expected forgone earnings by 60 percent. The risk-aversion factor is based on the ratio of life insurance premium payments to life insurance loss payments (Bailey, 1980). In most cases, life insurance premiums represent "household WTP for potential losses associated with the death of an income-earning household member" (Landefeld and Seskin, 1982, p. 562).

LS estimates are primarily human capital estimates of forgone earnings with a few adjustments, and thus can be considered as "adjusted productivity losses" rather than "VOSL." In our baseline analysis, we use LS estimates to represent productivity losses for those patients with GBS who die prematurely or who are no longer able to return to work. The LS formula for adjusted productivity losses is:

$$\textit{Adjusted productivity losses} = \left[\sum_{t=0}^{T} \frac{Y_t}{(1+r)^t}\right] \alpha$$

where T = remaining lifetime, t = a particular year, Y_t = after-tax income (labor plus nonlabor) and the market value of household production, r = household's opportunity cost of investing in risk-reducing activities, and α = risk-aversion factor.[12] We interpolated the LS estimates between LS's 4-year age groups, averaged the LS estimates across gender for each age category, and updated to 1995 dollars using the change in usual and average weekly earnings from the U.S. Bureau of Labor Statistics.

For our baseline analysis, we used LS estimates because they are more conservative than WTP estimates, and more importantly, they incorporate valuable information on age-specific outcomes. The LS estimates of adjusted-productivity losses are low compared with VOSL estimates based on the risk premium in labor markets, a willingness-to-accept measure which theory tells us mirrors WTP.[13] For example, Viscusi's (1993, p. 1930) review of labor-market (wage-risk) studies found that most VOSL estimates ranged between $3 million and $7 million in 1990 dollars. After updating to 1995 dollars, LS estimates ranged from $15,000 to $1,979,000 (depending on the age of the representative individual). This difference is not surprising as the WTP approach aims to directly capture more than does the LS approach. This report provides a sensitivity analysis that shows estimated total costs when the LS estimates of adjusted-productivity losses are replaced by the more comprehensive $5-million VOSL estimate.

Costs of *Campylobacter*-Associated Guillain-Barré Syndrome

Prior to the actual cost estimation of *Campylobacter*-associated GBS, it was necessary to focus the analysis through assumptions. Assumptions were made where accurate or representative data were lacking and sensitivity analyses were performed on the most critical data points that are not supported by consensus.

[12] Landefeld and Seskin (1982) used a 3-percent discount rate.

[13] Willingness-to-accept is particularly apt for valuing risks due to foodborne pathogens. When purchasing food with pathogens, one is tacitly accepting the pathogens along with the food.

Assumptions Used in Cost-of-Illness Analysis

Table 1 provides the assumptions used in estimating the annual cost of *Campylobacter*-associated GBS. We also assume that people can be infected by *Campylobacter*, at most, once a year. This assumption is reasonable because the antibody response to infection with *Campylobacter* should provide temporary protection from re-infection. All patients with GBS are assumed to require hospitalization because of the difficulty in diagnosing GBS and because of the typical severity and duration of paralysis associated with this illness.

For this study, the estimation of the annual cost of GBS using the cost-of-illness method was complicated by demographic differences in patients with GBS and by the broad array of possible GBS symptoms, subsequent medical costs, and final outcomes. Patients with GBS were categorized into workable groups for cost estimation.

We divided the annual number of patients with GBS into two age/ventilation categories: mechanically ventilated patients and those not on mechanical ventilation (fig. 1). The first age/ventilation category used a 30-year-old individual to represent patients with GBS who were not mechanically ventilated.[14] The second age/ventilation category used a 47-year-old individual to represent more seriously paralyzed patients with GBS who were mechanically ventilated to assist breathing.[15] Those who are mechanically ventilated face more serious complications and prognoses than those who are not. For each age/ventilation category, three outcomes are considered: those who (1) resume work, (2) cannot return to work, and (3) die. Those patients who return to work include

[14] Sunderrajan and Davenport (1985) found that the average age of mechanically ventilated patients with GBS was 47.0 +/- 5.6 years and the average age of those patients with GBS who did not require ventilation was 30.1 +/- 4.3 years.

[15] Had we not focused on mechanical ventilation and had we wanted to select two representative ages, we might have chosen a broader span between our representative ages. Halls *et al.* (1988), Moore and James (1981), and Storey *et al.* (1989) found bimodal age distributions that suggest a broader age span. Because Sunderrajan and Davenport's (1985) average age of ventilated and nonventilated patients are means, they are more centrally located. For example, although older patients with GBS are more likely to require mechanical ventilation, a few very young patients with GBS who are mechanically ventilated can pull the mean toward the center of a natural age span.

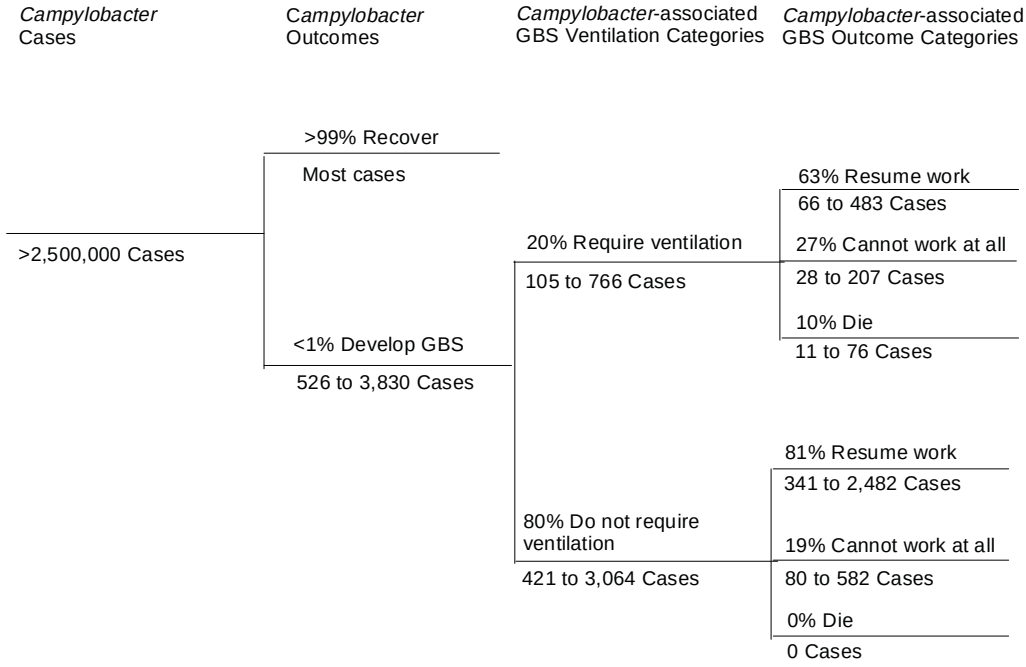
Table 1—Assumptions used to estimate the annual costs of *Campylobacter*-associated Guillain-Barré syndrome in the United States, 1995[1]

Cost category	Assumptions
General Assumptions	* 55 to 70 percent of *Campylobacter* infections are foodborne (Deming *et al.,* 1987; Seattle-King County Dept. of Public Health, 1984). * 20 to 40 percent of all patients with GBS were caused by *Campylobacter* infections. * 20 percent were mechanically ventilated, 80 percent were not, and all patients required hospitalization.
Medical Costs	* Total fees for physician care, laboratory tests, and other medical items were assumed to be equal to hospital room costs but were updated to 1995 dollars using different Consumer Price Index (CPI), as appropriate. A regular hospital room costs $978 per day and associated fees are $962 per day. An Intensive care unit (ICU) hospital room costs double the cost of a regular room per day (or $1,956) with $1,924 in fees/day. * Plasma exchange (PE) and intravenous immunoglobulin treatments (IVIG) were computed separately. 71 percent of all patients were treated with PE and 37 percent were treated with IVIG. PE costs $5,500 per patient and IVIG costs $5,700 per patient. <u>Patients on mechanical ventilation</u> * Mean hospital stay; 98.5 days. * 68.4 days in ICU, 30.1 days in regular hospital room. * Mean duration of mechanical ventilation is 68 days. <u>Patients not on mechanical ventilation</u> * Mean hospital stay; 19.1 days. * 6 days in ICU, 13.1 days in regular hospital room.
Productivity Losses	* The value of an hour of time is the same for all patients of any race, gender, or geographical location in the United States. <u>Patients on mechanical ventilation</u> * For the 27 percent that cannot work at all and the 10 percent that died, estimated productivity losses for a 47-year-old individual were used. * 63 percent resumed work. <u>Patients not on mechanical ventilation</u> * For the 19 percent that cannot work at all, estimated productivity losses for a 30 year-old individual were used. * 81 percent resumed work. <u>For those who resumed work:</u> * The number of days spent recuperating at home is twice the number of days spent in the hospital, adjusted for weekends. * Productivity loss uses the Bureau of Labor Statistics usual weekly earnings for all part-time and full-time wage and salary earners (pre-tax, no nonsalary benefits) plus an additional 40 percent to account for nonsalary benefits, divided by 5 work days to get a daily rate, and multiplied by the estimated days lost from work (sum of work days hospitalized and work days recuperating at home, adjusted for weekends). <u>For those who did not go back to work:</u> * The present value of adjusted productivity losses was computed as the average of male and female values given by Landefeld and Seskin (1982) interpolated to the appropriate age (47 or 30) and updated to 1995 values using the change in average weekly earnings (BLS).
Other costs[2]	* Excluded due to lack of reliable measurement.

1 Case estimates were divided into those who were mechanically ventilated and those who were not.
In this table, "patients with GBS" refers to patients with *Campylobacter*-associated GBS.

2 "Other costs" include physical, psychological, and other social costs.

Figure 1
Estimated annual cases and disease outcomes of *Campylobacter*-associated Guillain-Barré syndrome



patients with GBS who recover completely or find a less demanding job.

For the 80 percent of the patients with GBS who were not mechanically ventilated, we used Sunderrajan and Davenport's (1985) probabilities: all survived, 81 percent returned to work, and 19 percent did not return to work. Several participants of the 1995 American Neurology Association meeting suggested that we use an overall case fatality rate of 2 percent for patients with GBS. Because all the patients who died in Sunderrajan and Davenport's (1985) study were mechanically ventilated, we adjusted the outcome probabilities for mechanically ventilated patients to reflect this lower case fatality rate.[16] In our study, out of the 105 to 766 patients with *Campylobacter*-associated GBS on mechanical ventilation, 11 to 76 die (10 percent) and none of those not on mechanical ventilation died, for an overall case fatality rate of 2 percent.

Annual Medical Costs

The annual medical costs of *Campylobacter*-associated GBS, for each of the two ventilation categories, are comprised of: (1) IVIG (immunoglobulin treatments), (2) plasma exchange, (3) regular hospital room, (4) Intensive Care Unit (ICU) hospital room, (5) regular hospital room fees, and (6) ICU hospital room fees (table 2).[17]

Costs varied depending on the number of days spent in ICU and the number of days spent in a regular hospital room. Total annual costs for the two types of hospital rooms and associated fees were calculated by multiplying the daily cost of each component by the number of days the component is used and by the number of patients with GBS receiving that component. The costs of mechanical ventilation were assumed to be included in the fees associated with an ICU room. Total costs for IVIG and plasma exchange were calculated by multiplying the cost per treatment by the average number of treatments per

[16] In the Sunderrajan and Davenport (1985) study, out of the mechanically ventilated patients with GBS, 28 percent died, 50 percent resumed work, and 22 percent did not return to work. We adjusted these figures by reducing the case fatality rate for these cases from 28 to 10 percent and proportionately increasing the other two categories a total of 18 percent to reflect this decreased case fatality rate.

[17] Those *Campylobacter*-associated patients with GBS who died are assumed to incur the same costs as the surviving patients in their ventilation category. Rehabilitation costs after hospitalization were not included due to data limitations.

Table 2—Estimated annual U.S. medical costs of *Campylobacter*-associated Guillain-Barré syndrome, by mechanical ventilation category, 1995

Severity category	Base rate per item	Treatment per day	Rate per patient	Low # patients	High # patients	Low costs	High costs
	$	*#*	*$*	*#*	*#*	*$ million*	
Nonventilated patients							
Immunoglobulin	5,700	1	5,871	156	1,134	0.9	6.7
Plasma exchange	5,000	1.1	5,500	299	2,175	1.6	12.0
ICU room	1,956	6	11,736	421	3,064	4.9	36.0
ICU fees	1,924	6	11,544	421	3,064	4.9	35.4
Hospital room	978	13.1	12,812	421	3,064	5.4	39.3
Other medical fees	962	13.1	12,602	421	3,064	5.3	38.6
Sub-total	n.a.	n.a.	n.a.	421	3,064	23.1	167.8
Ventilated patients							
Immunoglobulin	5,700	1	5,871	39	283	0.2	1.7
Plasma exchange	5,000	1.1	5,500	75	544	0.4	3.0
ICU room	1,956	68.4	133,790	105	766	14.0	102.5
ICU fees	1,924	68.4	131,602	105	766	13.8	100.8
Hospital room	978	30.1	29,438	105	766	3.1	22.5
Other medical fees	962	30.1	28,956	105	766	3.0	22.2
Sub-total	n.a.	n.a.	n.a.	105	766	34.6	252.7
Total	n.a	n.a.	n.a.	526	3,830	57.7	420.5

n.a. means not applicable. Item means days or treatments, as appropriate. Figures may not total due to rounding. Total fees for physician care, laboratory tests, and other medical items are assumed to be equal to hospital room costs but are updated with the physician's consumer price index (CPI) instead of the hospital CPI. It is assumed that an intensive care unit hospital room costs double the cost of a regular room per day.

patient and by the number of patients with GBS receiving that treatment.

IVIG

Thornton and Griggs (1994) estimate that the cost of intravenous gamma globulin or immunoglobulin is $5,000 to $12,000 per 2 gm/kg course.[18] To obtain better cost estimates, we surveyed five neurologists on the medical advisory board of the Guillain-Barré Syndrome Foundation International (1994) and found the average cost of one IVIG treatment to be $5,700. Patients with GBS were found to require an average of 1.03 treatments, so in this analysis, the estimated cost of IVIG per GBS patient receiving IVIG is $5,871 (table 2). Assuming that 37 percent (also from the informal survey of neurologists) of all patients with GBS require IVIG, the estimated total annual cost of IVIG for all patients with GBS ranged from $1.1 million to $8.4 million a year.

Plasma Exchange

Thornton and Griggs (1994) estimate the cost of plasma exchange (PE) per course of 5 treatments ranges from $6,000 to $12,000 (p. 263).[19] Our survey indicated that the average cost of one course of plasma exchange is $5,000 and that patients with GBS require an average of 1.1 courses. Assuming that 71 percent (from the informal survey of neurologists) of all patients with GBS require plasma exchange, the estimated cost of plasma exchange for all patients with GBS ranges from $2.0 million to $15.0 million a year (table 2).

[18] A 1990 Dutch study (van der Meché *et al.*, 1992) found that intravenous immunoglobulin treatments (IVIG) appear to be at least equally effective as plasma exchange for patients with GBS after 4 weeks of treatment. However, this may not be the same in the United States because the Dutch patients with GBS who were treated with plasma exchange fared poorly when compared with patients in the United States.

[19] One course of plasma exchange usually lasts 2 to 3 hours and requires special equipment typically found only in larger medical centers and hospitals. Not all patients respond to plasma exchange and technical difficulties periodically interrupt treatment (Thornton and Griggs, 1994, p. 263).

Regular and ICU Hospital Room

The average length of hospital stay for patients with GBS varied between studies but was typically longer for those patients with GBS who required ventilation (Ropper *et al.* 1991, p. 264). For the 3,611 nonventilated patients with GBS in Health Care Finance Administration (HCFA)'s 1992 Medicare data, the mean length of stay was 15.6 days. For the 371 mechanically ventilated patients with GBS in the Medicare database, the average length of stay was 36.4 days. Sunderrajan and Davenport (1985, p. 334) found that nonventilated patients with GBS were hospitalized 19.1 (+/- 4.6) days and ventilated patients with GBS stayed in the hospital an average of 98.5 (+/- 30.5) days. In the current study, all patients with *Campylobacter*-associated GBS were assumed to require hospitalization and we adopt Sunderrajan and Davenport's figures.

Mechanical ventilation is typically administered in ICU. Therefore, those patients with *Campylobacter*-associated GBS who were mechanically ventilated were assumed to spend the same number of days in an ICU as they spend on mechanical ventilation (68.4 days), with the remainder (30.1 days) spent in regular hospital rooms. For those not mechanically ventilated, we assume one-third of the 19.1 days spent in the hospital were spent in ICU (6 days).

Our estimate of the average daily hospitalization cost was $978 per patient per day.[20] We assumed that the daily cost of an ICU hospital room is double that of a regular hospital room (approx. $1,956/day). The estimated total annual cost of regular hospital rooms for patients with *Campylobacter*-associated GBS ranged from $8.5 million to $61.8 million. ICU hospital rooms were estimated at $18.9 million to $138.5 million.

Other Medical Fees Associated With Regular and ICU Hospital Rooms

The above hospital room costs do not include physician fees, pharmacy costs, and medical treatments such as mechanical ventilation. Charges for those items associated with a regular hospital room were assumed to be the same as the regular hospital room rate, but were updated with the consumer price index (CPI) for physician services instead of the hospital room CPI.[21] Similarly, the fees for the items associated with the ICU room are the same as the ICU room rate, but we updated these fees with the physician services CPI. ICU care requires more specialized equipment than does care in a regular hospital room and therefore fees associated with ICU care are greater. For example, the cost of mechanical ventilation is assumed to be incorporated in the fees associated with the ICU hospital room because patients under mechanical ventilation are in ICU.[22] Estimated daily fees associated with a regular hospital room were $962 and estimated daily fees associated with an ICU room were $1,924. The estimated total annual cost of fees associated with regular hospital rooms for patients with *Campylobacter*-associated GBS ranges from $8.3 million to $60.8 million; for ICU fees, $18.7 million to $136.2 million (table 2).

Overall, the estimated total medical costs for the 526 to 3,830 patients with *Campylobacter*-associated GBS ranged from $57.7 million and $420.5 million a year. The largest costs for ventilated patients with GBS was for ICU rooms and for nonventilated patients, regular hospital rooms.

HCFA Medicare data were used to validate our primary estimates. Of the 3,982 Medicare patients with GBS in 1992, 371 were on mechanical ventilation during their hospital stay and 3,611 were not.[23] HCFA's medical charge per patient with GBS who required mechanical ventilation was (in 1992 dollars) $103,693; the average per patient with GBS who did

[20] In 1992, the daily hospitalization cost per person in community hospitals was estimated at $820 per patient (American Hospital Association in *Statistical Abstract of the United States 1994*, table 182). This estimate was updated to 1995 dollars using the change in the hospital room CPI (1992 CPI from the *Statistical Abstract of the United States 1994*, table 163; and the 1995 hospital room CPI from personal correspondence with BLS in March 1996).

[21] As before, we used the 1992 hospital cost of $820 per day, but we updated this cost with the physician services CPI (1992 CPI from *Statistical Abstract of the United States 1994*, table 163; 1995 CPI from personal communication with BLS in March 1996).

[22] Personnel at a major midwestern hospital estimated that the average daily cost of mechanical ventilation was $117. We assume that this cost is indirectly covered by the fees associated with the ICU hospital room.

[23] For the Medicare data, whether or not a GBS patient had mechanical ventilation was determined by the presence of an ICD-9 code for the surgical procedure #967. The number of GBS patients on mechanical ventilation could be an underestimate if other relevant ICD-9 surgical procedure codes should have been included in the analysis. In our analysis, an estimated 20 percent of patients with GBS required mechanical ventilation, whereas only 9.3 percent of the 3,982 Medicare patients with GBS required mechanical ventilation.

Table 3—Short-stay hospital use by Medicare beneficiaries with diagnosis 357.0, by age

Age	Discharges	Charges	Payments	Days care	Per discharge Charge	Per discharge Payment
		----------$1,000----------			*-----1992 dollars----*	
All beneficiaries with GBS						
Total	3,982	120,647	49,619	70,057	30,298	12,461
<65	520	13,258	5,345	7,556	25,496	10,279
65-69	978	32,722	13,249	18,107	33,458	13,547
70-74	907	28,392	11,394	17,118	31,303	12,562
75-79	882	28,570	11,797	15,959	32,392	13,375
80-84	450	11,893	5,416	7,551	26,429	12,036
85+	245	5,812	2,418	3,766	23,721	9,869
All beneficiaries with GBS that required mechanical ventilation						
Total	371	38,470	13,741	13,518	103,693	37,037
<65	40	3,965	1,367	1,260	99,125	34,179
65-69	108	11,659	4,178	3,983	107,950	38,682
70-74	94	9,707	3,311	3,729	103,263	35,227
75-79	79	7,962	2,872	2,696	100,790	36,351
80-84	37	3,857	1,575	1,606	104,233	42,572
85+	13	1,321	438	344	101,604	33,670
All beneficiaries with GBS that did not require mechanical ventilation						
Total	3,611	82,176	35,878	56,439	22,757	9,936
<65	480	9,293	3,978	6,296	19,360	8,287
65-69	970	21,064	9,071	14,124	24,211	10,426
70-74	813	18,685	8,083	13,389	22,983	9,942
75-79	803	20,608	8,925	13,263	25,663	11,114
80-84	413	8,036	3,841	5,945	19,458	9,301
85+	232	4,491	1,980	3,422	19,357	8,535

Source: Charlie Helbing, Health Care Finance Administration, 1994.
Guillain-Barré syndrome (GBS) as diagnosed with ICD-9 code 357.0
Ventilation requirement was identified for those patients requiring surgical procedure 96.7

not require mechanical ventilation was $22,757 (table 3).[24] After updating to 1995 dollars, these Medicare estimates are roughly 38 percent of the average total medical costs estimated in this analysis for ventilated patients ($329,860) and 50 percent of the costs for patients not requiring mechanical ventilation ($54,770). This difference may be due to Medicare cost limits; the expenditures by other health agencies may be substantially higher. Also, Medicare patients are older, on average, than all patients with GBS, and are more likely to die, which would cap total medical costs.

Annual Productivity Losses

Annual productivity losses were estimated for each of the six categories of patients with GBS in this study (2 ventilation categories times 3 outcome categories)(table 4). For patients who returned to work, productivity losses per patient were approximated by multiplying the baseline daily income by the average number of days of work missed. The value of an hour of time was assumed to be the same for patients

[24] This translates to $124,809 and $27,391, respectively, in 1995 dollars after updating with the hospital room CPI (1992 from *Statistical Abstract of the United States 1994*, table 163; 1995 CPI from personal communication with BLS in March 1996).

Table 4—Estimated annual U.S. productivity losses from *Campylobacter*-associated Guillain-Barré syndrome, by mechanical ventilation category, 1995

Severity category	Average daily income	Days work missed	Pay missed per patient	Low # patients	High # patients	Low costs	High costs
	$	*#*	*$*	*#*	*#*	*$ million*	
Nonventilated patients							
Resumed work[1]	115	41	4,707	341	2,482	1.6	11.7
Could not work	n.a.	n.a.	1,809,959	80	582	144.8	1,053.4
Died	n.a.	n.a.	1,809,959	0	0	0	0
Ventilated patients							
Resumed work[1]	148	211	31,239	66	483	2.1	15.1
Could not work	n.a.	n.a.	1,054,788	28	207	29.5	218.3
Died	n.a.	n.a.	1,054,788	11	76	11.6	80.2
Total	n.a.	n.a.	n.a.	526	3,830	189.6	1,378.7

n.a. means not applicable. Figures may not total due to rounding.

[1] Analysis assumes that for each day spent in the hospital, two days are spent at home recuperating before returning to work.

of any race, gender, or geographical location in the United States. The baseline daily income was derived from the usual weekly earnings by adjusting for nonsalary benefits, the labor force participation rate, and weekends. We used the average of "usual weekly earnings of employed full-time and part-time wage and salary workers" reported by the U.S. Bureau of Labor Statistics.[25] The 1995 average weekly earnings were $490 for a worker aged 25-34 and $650 for a worker aged 45-54 (BLS, 1996). To this, 40 percent of weekly earnings was added as an estimate of all nonsalary benefits (e.g., health, vacation, and retirement benefits).[26] Averaged across gender, the labor force participation rate was 83.8 percent for those aged 25-34 and 81.4 percent for those aged 45-54 (U.S. Dept. Commerce, BLS, 1996). These two participation rates were used for the two representative age groups in this study (30- and 47-year-old patients with GBS). The usual weekly earnings were divided by 5 work days to adjust for weekends. After adjusting for nonsalary benefits, labor force participation rates, and weekends, the estimated average daily productivity loss per person is roughly $115 for a worker 30 years of age. For a 47-year-old worker, the daily loss of productivity is $148.

In addition to work days missed while in the hospital, this analysis assumed that for every day spent in the hospital, twice as many days were spent at home recuperating before the patient could return to work (if at all). After adjusting for weekends, the average number of days missed from work was 41 days for a nonventilated patient with *Campylobacter*-associated GBS (19.1 days in hospital times 3 times 5/7 workdays per week) and 211 days for a ventilated patient with *Campylobacter*-associated GBS (98.5 days in hospital times 3 times 5/7). Recovery rates and illness duration are likely to vary widely but there are few published data on the rate of recovery. Sunderrajan and Davenport's (1985) estimate of the number of days hospitalized was used here because their study most concisely reported recovery rates for ventilated and nonventilated patients with GBS. This study errs on the side of conservatism. Because of the seriousness of paralysis and the propensity of patients with GBS to have lingering symptoms, the

[25] To avoid double-counting of income, the Government's lost tax revenue and transfer payments such as pension or relief payments are usually omitted (Cooper and Rice, 1976). Double-counting would occur if tax losses were combined with losses in earnings and it would be triple-counting if these taxes were used to pay for the medical care of GBS patients (Cooper and Rice, 1976).

[26] Personal conversation with BLS in Dec. 1995 provided the March 1994 employer costs for employee compensation per hour worked, divided into wage/salary ($12.25) and all nonsalary benefit ($4.85) components. Using these estimates, all nonsalary benefits are roughly 40 percent of wage/salary earnings. Therefore, total compensation is roughly 1.4 times the wage/salary earnings.

Table 5—Estimated annual U.S. medical, productivity, and total costs of *Campylobacter*-associated Guillain-Barré syndrome and of foodborne *Campylobacter*-associated Guillain-Barré syndrome, 1995

Source category	Patients	Deaths	Medical costs		Productivity costs		Total costs	
			Low	High	Low	High	Low	High
	Number		*$ million*					
All[1]	526-3,830	11-76	57.7	420.5	189.6	1,378.7	247.3	1,799.2
55% foodborne	289-2,107	6-42	31.7	231.3	104.3	758.3	136.0	989.6
70% foodborne	368-2,681	8-53	40.3	294.3	132.7	965.1	173.1	1,259.4

[1] Includes GBS associated with *Campylobacter* infections from all sources (e.g., food, water). Figures may not total due to rounding.

mean duration of illness is probably longer than the values used here. Kennedy *et al.* (1978, p. 98) found that recovery ranged "from 1 to 59 weeks after the onset."

Lost productivity for the 341 to 2,482 nonventilated patients who were able to return to work is estimated at $1.6 million to $11.7 million per year. For the 66 to 483 ventilated patients, estimated lost productivity ranges from $2.1 million to $15.1 million. The estimated annual total cost of lost productivity of all patients with *Campylobacter*-associated GBS who were able to return to work ranged from $3.7 million to $26.8 million.

To obtain the cost of lost productivity for those patients who died or did not return to work, Landefeld and Seskin's (LS)(1982, p. 563) estimates of the present value of adjusted productivity losses were used, after averaging across gender for each age category and updating to 1995 dollars.[27]

After updating to 1995 dollars, the LS estimate for a 30-year-old (nonventilated) individual is roughly $1,809,959 and the LS estimate for a 47-year-old (ventilated) individual is roughly $1,054,788. The estimated total cost of lost productivity for patients with *Campylobacter*-associated GBS who survive their illness yet do not return to work ranges from $174.3 million to $1,271.7 million. This includes $144.8 million to $1,053.4 million for the 80 to 582 nonventilated patients and $29.5 million to $218.3 million for the 28 to 207 ventilated patients.

Following Sunderrajan and Davenport (1985), it is estimated that none of the nonventilated patients died, and of the 105 to 766 patients who were on mechanical ventilation, 11 to 76 died. Using the 1995 LS estimates, the estimated total annual productivity loss for those patients with GBS who died ranges from $11.6 million to $80.2 million. Across all six categories of patients with *Campylobacter*-associated GBS, the estimated total annual productivity losses from *Campylobacter*-associated GBS in the United States ranges from $189.6 million to $1,378.7 million.

Total Cost Estimates

On average, the cost of lost productivity was over three times larger than the medical costs (table 5). Estimated total annual medical costs from *Campylobacter*-associated GBS in the United States range from $57.7 million to $420.5 million a year and estimated total annual productivity losses range from $189.6 million to $1,378.7 million. Medical costs and productivity losses together equal total annual costs of $0.25 billion to $1.8 billion per year. These estimates do not include costs of campylobacteriosis.

Sensitivity Analyses

Some of the estimates used in this study to calculate medical costs and the costs of lost productivity are subject to wide variation and controversy. Sensitivity analyses were performed to handle variations in two

[27] The BLS data series on usual weekly earnings did not have early enough data so we used another BLS average weekly earnings series (for nonsupervisory, nonagricultural positions; BLS, 1996) to update the LS numbers from 1977 to 1983 dollars. We then updated these 1983 numbers to 1995 dollars.

Table 6—Sensitivity analyses under alternate value of a statistical life assumptions

Adjusted productivity loss used[1]	Medical costs		Productivity costs		Total costs	
	Low	High	Low	High	Low	High
			$ million			
Baseline	57.7	420.5	189.6	1,378.7	247.3	1,799.2
VOSL = $3.6 mil.	57.7	420.5	432.1	3,140.8	489.8	3,561.3
VOSL = $5.0 mil.	57.7	420.5	598.7	4,351.8	656.4	4,772.3
VOSL = $8.4 mil.	57.7	420.5	1,003.3	7,292.8	1,061.0	7,713.3

[1] "Baseline" category uses Landefeld and Seskin's (1982) estimates of adjusted productivity losses. "VOSL=$3.6 mil." is when the LS estimate is replaced by Viscusi's lower value of a statistical life (VOSL) estimate. "VOSL=$5 mil." is when the LS estimate is replaced by the Department of Health and Human Service's standard VOSL estimate. "VOSL=$8.4 mil." is when the LS estimate is replaced by Viscusi's upper VOSL estimate. Viscusi's estimates have been updated so estimates are in 1995 dollars.

key estimates: adjusted productivity losses for those who die or are unable to return to work because of their illness, and the probability that patients with *Campylobacter*-associated GBS receive mechanical ventilation.[28]

Sensitivity Analysis - Value of Adjusted Productivity Losses

The Landefeld and Seskin (1982) estimates used in this study to represent adjusted productivity losses are relatively low when compared with other, more comprehensive valuations. Viscusi (1993) found that most VOSL estimates ranged between $3 million and $7 million in 1990 dollars (p. 1942).[29] In 1995 dollars, Viscusi's range becomes $3.6 million to $8.4 million.[30] The U.S. Department of Health and Human Services uses a standard $5 million per statistical life (Williams, 1995). In our sensitivity analysis, we replaced the LS estimates with these three values in 1995 dollars. This sensitivity analysis was particularly crucial to obtain defensible cost-of-illness estimates because the costs of lost productivity from *Campylobacter*-associated GBS constitute the bulk of the cost-of-illness estimates. When the baseline LS estimates of adjusted productivity losses are replaced with VOSL estimates of $3.6, $5.0, and $8.4 million, estimated costs increase dramatically (table 6).

Sensitivity Analysis - Probability of Receiving Mechanical Ventilation

The baseline analysis assumed that 20 percent of all patients with GBS required mechanical ventilation. Yet, higher probabilities are likely. After adjusting for different sample sizes in 12 separate studies, 30 percent of patients with GBS, on average, were put on a ventilator (app. table 2). The average was even higher for the four American studies (36.5 percent). In contrast, the 1992 U.S. Medicare Statistical Support data revealed that 9.3 percent of the 3,982 patients with GBS required mechanical ventilation (table 3)(Helbing, 1994). This sensitivity analysis considered the impacts on costs of a 9-percent and a 37-percent mechanical ventilation rate for patients with GBS.

Table 7 provides cost estimates for using both a low mechanical ventilation requirement rate (9 percent) and a high mechanical ventilation requirement rate (37 percent) in the baseline analysis (LS estimates) and in the scenario where the adjusted productivity loss per person is set at $5.0 million. The estimated number of deaths changed along with the new estimated range of ventilated patients for each scenario. For the low (9 percent) mechanical ventilation rate, 4

[28] To account for uncertainty of the data, three other sensitivity analyses were also performed: (1) the share treated with IVIG was halved from 37 percent to 18.5 percent, (2) the share treated with plasma exchange was halved from 71 percent to 35.5 percent, and (3) the average number of days GBS patients were on mechanical ventilation was reduced from 68.4 days to 41.5 days (adjusted average from five GBS studies). In these sensitivity analyses, results were altered by less than 2.5 percent.

[29] Fisher *et al.* (1989) found that the most defensible empirical estimates for a VOSL range from $1.6 million to $8.5 million (in 1986 dollars).

[30] Updated using average of the usual weekly earnings of employed part-time and full-time wage and salary workers (BLS, 1995).

Table 7—Sensitivity analyses on the share of patients with Guillain-Barré syndrome that are mechanically ventilated[1]

Medical scenario:	Type	Productivity loss scenario: Landefeld and Seskin Low	Landefeld and Seskin High	$5 million Low	$5 million High
			$ million		
Low (9%) mechanical ventilation	Annual medical cost	41.7	304.7	41.7	304.7
	Annual productivity loss	185.4	1,352.3	542.8	3,965.1
	Total annual cost	227.1	1,657.0	584.5	4,269.8
High (37%) mechanical ventilation	Annual medical cost	82.5	599.6	82.5	599.6
	Annual productivity loss	195.0	1,418.7	680.1	4,947.1
	Total annual cost	277.5	2,018.3	762.6	5,546.7

[1] For each mechanical ventilation requirement rate scenario, table 7 provides both low and high estimates of the medical costs, costs of lost productivity, and total costs to reflect the range of patients with GBS in each category. The two paired columns of numbers distinguish between the two productivity loss scenarios. The first column presents cost estimates using the Landefeld and Seskin (1982) estimates (which varies by age) of adjusted productivity losses. The second column presents cost estimates when the LS estimates are replaced with a $5.0 million estimate for every individual who cannot return to work or dies prematurely because of their illness, regardless of age.

to 34 patients died as compared with 19 to 141 in the high (37 percent) mechanical ventilation rate.

Under both productivity loss scenarios, the low rate reduced total estimated annual medical costs to between $41.7 million and $304.7 million (table 7). Estimated productivity losses also changed because the number of patients with *Campylobacter*-associated GBS in each outcome category was tied to the number of patients in the two ventilation categories. Under the low mechanical ventilation assumption, estimated productivity losses and total cost decreased. Estimated total annual costs under the LS scenario dropped to between $227.1 million and $1,657.0 million, $584.5 million to $4,269.8 million under the $5.0 million adjusted productivity loss scenario.

The high mechanical ventilation rate (37 percent) increased total estimated annual medical costs to between $82.5 million and $599.6 million. Estimated productivity losses and total costs increased with the higher rate of mechanical ventilation. Estimated total costs under the LS/high mechanical ventilation rate increased to between $277.5 million and $2,018.3 million, $762.6 million to $5,546.7 million under the $5.0 million VOSL scenario.

Foodborne *Campylobacter*-Associated Guillain-Barré Syndrome

Based on the findings of the Seattle-King County Department of Public Health (1984) and Deming *et al.* (1987), we assumed that 55 percent to 70 percent of all *Campylobacter* infections are foodborne. At 55 percent, an estimated 289 to 2,107 cases of GBS are caused by foodborne *Campylobacter* infections each year, including 6 to 42 deaths (table 5). Estimated annual medical costs range between $31.7 million and $231.3 million and estimated annual productivity losses range from $104.3 million to $758.3 million. Estimated annual total costs range from $136.0 million to $989.6 million.

Assuming that 70 percent of all *Campylobacter*-associated GBS has foodborne origins, an estimated 368 to 2,681 cases (8 to 53 deaths) incur medical costs between $40.3 million and $294.3 million and productivity losses from $132.7 million to $965.1 million. Estimated total annual costs range from $173.1 million to $1,259.4 million.

Thus, assuming that 55 percent to 70 percent of all *Campylobacter* infections and associated GBS illnesses are from food sources, annual costs of *Campylobacter*-associated GBS linked to food is $136.0 million to $1,259.4 million. These estimates

Table 8—Estimated U.S. costs of foodborne illness from select pathogens

Pathogen	Estimated costs	
	Low	High
	$ billion (1995)	
Campylobacter jejuni or *coli* [1] (including related GBS costs)	0.8	5.6
Clostridium perfringens	0.1	0.1
Escherichia coli O157:H7	0.3	0.7
Listeria monocytogenes [2]	0.1	0.3
Salmonella (non-typhoid)	0.9	3.5
Staphylococcus aureus	1.2	1.2
Toxoplasma gondii [3]	3.2	3.2
Total	6.6	14.6

[1] Campylobacteriosis accounts for $0.7-$4.3 billion (Buzby and Roberts, 1996) and *Campylobacter*-associated GBS accounts for $0.1-$1.3 billion (current study), combined the costs are $0.8 to $5.6 billion.

[2] Due to data limitations, this estimate only includes patients who were hospitalized.

[3] Includes congenital cases only. Immunocompromised patients such as patients with Acquired Immunodeficiency Disease Syndrome (AIDS) also face high risks from this parasite.
Source: Buzby and Roberts (1996). These estimates used Landefeld and Seskin's estimates of adjusted productivity losses.

can be compared against the costs of reducing *Campylobacter* in the U.S. food supply.

Conclusions

Buzby and Roberts (1996) provide cost-of-illness estimates for seven common foodborne pathogens (*Salmonella, Campylobacter, E. coli* O157:H7, *Listeria monocytogenes, Clostridium perfringens, Staphylococcus aureus, Toxoplasma gondii*) in 1995 dollars. They estimate that foodborne *Campylobacter* costs society $0.7 billion to $4.3 billion each year in 1995 dollars. This range increases to $0.8 billion to $5.6 billion when the estimated cost of GBS caused by *Campylobacter*-associated infections attributed to food sources is added (table 8).

When looking at the low cost estimates for these seven pathogens, *Campylobacter* is the third most costly of the pathogens, after *Toxoplasma gondii* and *Salmonella*. When looking at the high cost estimates, *Campylobacter* is the most costly of the seven pathogens. Although comparing estimates between different cost-of-illness studies should not be analyzed cardinally because of the different assumptions involved, comparisons can pinpoint those pathogens that may need extra attention by policymakers and members of the food industry.

In our primary analysis, which used the LS estimates, the estimated total annual cost of *Campylobacter*-associated GBS from all sources ranges between $247.3 million and $1,799.2 million. LS estimates of adjusted productivity losses are relatively low compared with the VOSL estimates, so our baseline estimates tend to be conservative. As with other cost-of-illness estimates, the COI estimates for *Campylobacter*-associated GBS understate true values because they do not include components such as pain and suffering, lost leisure time, the cost of preventive actions, travel costs, resources spent on research, and lawsuits (table 9). The estimates are also conservative in that they do not reflect the productivity losses of those patients with GBS who returned to work but had to take a lower paying job because of their illness.

The portion of the estimated annual human illness costs of *Campylobacter*-associated Guillain-Barré syndrome attributed to preventable foodborne campylobacteriosis cases can be weighed against the costs of implementing improvements for preventing these foodborne illness cases to determine net societal benefits. Currently, cost estimates specific to the prevention of *Campylobacter* alone have not been developed. However, cost estimates of implementing USDA's HACCP rule for meat and poultry are available (Federal Register, July 25, 1996). HACCP, when implemented, will likely reduce contamination of meat and poultry by many pathogens, including *Campylobacter*. Therefore, the estimated human illness costs from *Campylobacter*-associated Guillain-

Table 9—Social costs of foodborne illness

Costs to Individuals/Households[1]

Human Illness Costs:
- Medical costs:
  - Physician visits
  - Laboratory costs
  - Hospitalization or nursing home
  - Drugs and other medications
  - Ambulance or other travel costs
- Income or productivity loss for:
  - Ill person or person dying
  - Caregiver for ill person
- Other illness costs:
  - Travel costs to visit ill person
  - Home modifications
  - Vocational/physical rehabilitation
  - Child care costs
  - Special educational programs
  - Institutional care
  - Lost leisure time
- Psychological costs:
  - Pain and other psychological costs
  - Risk aversion

Averting behavior costs:
- Extra cleaning/cooking time costs
- Extra cost of refrigerator, freezer, etc.
- Flavor changes from traditional recipes (especially meat, milk, egg dishes)
- Increased food cost when more expensive but safer foods are purchased
- Altruism (willingness-to-pay for others to avoid illness)

Industry Costs

Impact of pathogens on animal production costs:
- Morbidity and mortality of animals on farms
- Reduced growth rate/feed efficiency and increased time to market
- Costs of disposal of contaminated animals on farm and at slaughterhouse
- Increased trimming or reworking at slaughterhouse and processing plant
- Illness among workers because of handling contaminated animals or products
- Increased meat product spoilage due to pathogen contamination

Control costs for pathogens at all links in the food chain:[2]
- New farm practices (age segregated housing, sterilized feed, etc.)
- Altered animal transport and marketing patterns (animal i.d., feeding/watering)
- New slaughterhouse procedures (hide wash, knife sterilization, carcass sterilizing)
- New processing procedures (pathogen tests, contract purchasing requirements)
- Altered product transport (increased use of time/temperature indicators)
- New wholesale/retail practices (pathogen tests, employee training, procedures)
- Risk assessment modelling by industry for all links in the food chain
- Price incentives for pathogen-reduced product at each link in the food chain

Outbreak costs:
- Herd slaughter/product recall
- Plant closings and cleanup
- Regulatory fines
- Product liability suits from consumers and other firms[3]
- Reduced product demand because of outbreak:
  - Generic animal product - all firms affected
  - Reduction for specific firm at wholesale or retail level
- Increased advertising or consumer assurances following outbreak
- Impact of outbreaks on tourism industry

Regulatory and Public Health Sector Costs for Foodborne Pathogens

Disease surveillance costs to:
- Monitor incidence/severity of human disease by foodborne pathogens
- Monitor pathogen incidence in the food chain
- Develop integrated database from farm to table for foodborne pathogens

Research to:
- Identify new foodborne pathogens for acute and chronic human illnesses
- Establish high-risk products and production and consumption practices
- Identify which consumers are at high-risk for which pathogens
- Develop cheaper and faster pathogen tests
- Risk assessment modelling for all links in the food chain

Outbreak costs:
- Costs of investigating outbreak
- Testing to contain an outbreak (for example, serum testing and administration of IVIG in persons exposed to Hepatitis A)
- Costs of cleanup
- Legal suits to enforce regulations that may have been violated[3]

Other considerations:
- Distributional effects in different regions, industries, etc.
- Equity considerations, such as special concern for children

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1 Willingness-to-pay estimates for reducing risks of foodborne disease is a comprehensive estimate of all these categories (assuming that the individual has included employer-funded sick leave and medical programs in their estimates). The estimate is comprehensive and covers reduced risks for everyone—those who will become ill as well as those who will not.

2 Some industry costs may fall with better pathogen control, such as reduced product spoilage, possible increases in product shelf-life, and extended shelf-life permitting shipment to more distant markets or lowering shipment costs to nearby markets.

3 In adding up costs, care must be taken to assure that product liability costs to firms are not already counted in the estimated pain and suffering cost to individuals. However, the legal and court expenses incurred by all parties are social costs.

Barré syndrome could be added to the HACCP's benefits of reducing *Campylobacter* to get an improved estimate of the true benefits of USDA's HACCP rule.

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Appendix: Guillain-Barré Syndrome

Characterization of the Disease

GBS is believed to be an autoimmune reaction and has been associated with various prior events including infection, trauma, or immunization (see box). Although GBS is relatively rare, it is a severe illness. Ropper *et al.* (1991, p. 128) state that GBS "is usually a monophasic illness, with a rapid initial onset, progressive weakness over one to four weeks, and recovery over subsequent months." GBS is characterized by inflammation and damage to the myelin, which is the insulation surrounding the central conducting core or axon of the peripheral nerves (i.e., those extending out from the spinal cord). In severe cases, there can be complete paralysis of the axial, respiratory, cranial, and peripheral muscles whereby the patient, though alert, can only communicate by eye movements (Parry, 1993, p. 12).

Final GBS outcomes range considerably. Although most patients with GBS recover with only minor residual symptoms, others are permanently bedridden, wheelchair-bound, or beset by fatal complications. Other potential lingering disabilities include abnormalities in the autonomic nerves and changes in heart rate, blood pressure, vision, and body temperature (GBS Foundation, 1990, p. 7). Most patients with GBS are hospitalized because of paralysis and some have relapses. Hughes (1990, p. 173) states that the prognosis of GBS varies and "up to 13 percent die and a further 20 percent are left significantly disabled" (e.g., unable to work after a year).

A common cause of death among patients with GBS is cardiac arrhythmias secondary to autonomic nervous system dysfunction. In 15 separate studies of

Triggers for Guillain-Barré Syndrome

As with other autoimmune diseases, GBS has several precipitating factors. Triggering factors other than *Campylobacter* include viral infections, surgery, systemic illnesses, and vaccinations (Parry, 1993, p. 116). Some women get GBS during pregnancy and may be paralyzed during childbirth. There have been reported outbreaks in Jordan in 1978 upon exposure to polluted water and in Finland after a national oral poliovirus vaccination (GBS Foundation, 1990, p. 5).

Another outbreak occurred in 1976 and 1977 following the U.S. Government sponsored mass inoculation using the A/New Jersey/1976/H1N1 (swine) influenza vaccine. This National Influenza Immunization Program was discontinued on December 16, 1976 and the Centers for Disease Control and Prevention (CDC) launched a national surveillance program for those patients with GBS whose disease onset occurred between October 1, 1976 and January 31, 1977 to determine if there was an association between the vaccination and GBS (Breman and Hayner, 1984, p. 881). The national surveillance program relied primarily on reports from neurologists and other clinicians gathered by State epidemiologists and was supplemented by a CDC hospital discharge study performed in cooperation with the Michigan Department of Public Health (Breman and Hayner, 1984, p. 880). The Michigan study conclusively found that the swine flu vaccination increased the risk of GBS and that the risk was elevated for only 6 weeks after the immunization (Breman and Hayner, 1984, p. 886).

Although the A/New Jersey strain is no longer used, its connection with the upsurge in patients with GBS raised the possibility that vaccination is a precipitating factor for GBS. Roscelli *et al.*'s (1991) retrospective study of active duty soldiers vaccinated between 1980 and 1988 found no association between the vaccinations and the 289 army patients diagnosed with GBS (p. 955). Yet, Roscelli *et al.* recommend continued surveillance with future vaccine formulations because the swine flu episode suggests that the risk from GBS may vary with different vaccines (p. 955).

Appendix table 1—Case fatality rates of Guillain-Barré syndrome patients in recent studies

Study (year)	Nationality	Patients	Deaths	Death rate
		- - - - - *Number* - - - - -		*Percent*
Löffel *et al.* (1977)	Swiss	123	3	2.4
Moore and James (1981)	Australian	33	1	3.0
Andersson and Sidén (1982)	Swiss	60	4	6.7
Beghi *et al.* (1985)[1]	American	48	2	4.2
GBS Study Group (1985)	American/Canadian	245	7	2.9
Sunderrajan and Davenport (1985)	American	40	5	12.5
Winer *et al.* (1985)	English	71	8	11.3
French Coop. Group (1987)	French/Swiss	220	14	6.4
Singh *et al.* (1987)	Indian	24	2	8.3
Halls *et al.* (1988)	Danish	34	0	0.0
Storey *et al.* (1989)	Australian	110	5	4.5
de Jager and Minderhoud (1991)	Dutch	63	5	7.9
Koobatian *et al.* (1991)	American	51	4	7.8
van der Meché *et al.* (1992)	Dutch	147	3	2.0
Winner and Evans (1993)	English	72	4	5.6
Total		1,368	67	——[2]

[1] Kennedy *et al.* (1978) used the same Olmstead County data.

[2] After adjusting for sample size, the average death rate in these studies is 4.9 percent and the average for the four U.S. studies is 4.7 percent.

case fatality rates associated with GBS, 12.5 percent of patients is the highest percentage that died (appendix table 1). The simple average of the case fatality rate over these 15 studies is 5.0 percent, and when each study is weighted by its sample size, the case fatality rate becomes 4.9 percent. The adjusted average case fatality rates for the four American studies is slightly lower (4.7 percent), perhaps reflecting differences in case severity or medical treatment. Several participants of the 1995 American Neurology Association meeting suggested that the overall case fatality rate for patients with GBS has decreased and is currently around 2 percent.

Patients with GBS who are mechanically ventilated are more likely to die than those who do not require mechanical ventilation (roughly 20-30 percent are mechanically ventilated). In Sunderrajan and Davenport's (1985) sample of 40 patients with GBS, 28 percent of the mechanically ventilated patients died, with no deaths among those not on mechanical ventilation.

Up to 65 percent of patients with GBS report neurological pain (Beghi *et al.*, 1985). One patient's pain persisted for more than 1 year (Andersson and Sidén, 1982). Muscle cramping, foot drag, and minor sensory abnormalities such as tingling and pain commonly persist in otherwise recovered patients with GBS.[1]

The rates of recovery following GBS vary between studies. This may be due to the subjective definition of "recovery" or to the lack of followup outcome data. Parry (1993, p. 89) states that 85 percent of patients with GBS achieve a "complete functional recovery" while Ropper *et al.* (1991, p. 265) state that 75 percent of patients with GBS recover enough to return to normal life within 6-12 months. Functional recovery may not mean a complete recovery but rather a return to participation in normal daily activities. Neurologic symptoms may linger and prevent a complete recovery. In one study, less than 15 percent had "absolutely no residual symptoms" (Ropper *et al.*, 1991, p. 265). Potential barriers to regaining a normal lifestyle and resuming work are the pain, tingling, muscle aches, and physical exhaus-

[1] Foot drag refers to a condition in which patients require braces or specialized shoes to help keep their toes up while walking to prevent accidental falls.

tion that may follow a certain amount of activity (GBS Foundation, 1990, p. 26). Excessive exercise can lead to temporary relapses (GBS Foundation, 1990, p. 26).

The incidence of GBS does not vary according to race, seasonal variability, or region of the United States. Although there may appear to be "pockets" of higher GBS incidence in some parts of the United States, this is likely due to differences in reporting systems and varying medical awareness of GBS.

Most of the studies reviewed for this analysis had samples with more male patients than females, (e.g., Andersson and Sidén, 1982; Beghi *et al.*, 1985; Kennedy *et al.*, 1978; Koobatian *et al.*, 1991; Löffel *et al.*, 1977; Singh *et al.*, 1987; Storey *et al.*, 1989; Rantala *et al.*, 1991). A few studies had more females than males (e.g., Moore and James, 1981; Winner and Evans, 1993). This study does not segregate outcome categories for patients with GBS by gender because the dollar value of one day of lost productivity due to GBS is assumed to be equal for both genders.

GBS can affect people of all ages. Patients with GBS range in age from 9 months to 97 years. It appears that there is an increasing incidence of GBS with age (Kennedy *et al.*, 1978; Koobatian *et al.*, 1991).[2] Beghi *et al.* (1985) found that people over the age of 60 have higher GBS age-adjusted incidence rates than people under 18 years old (p. 1054). Other studies showed bimodal or biphasic distributions (e.g., Halls *et al.*, 1988, p. 118; Moore and James, 1981; Storey *et al.*, 1989). In general, these studies showed an initial peak of GBS incidence for people in their twenties, a lower incidence for people in their thirties and forties, and the largest peak for people older than 50. Older patients with GBS are more likely than younger patients to have a poor prognosis.[3]

Common Medical Procedures for Treating Patients with GBS

Between 6.3 and 50 percent of all patients with GBS are mechanically ventilated to assist breathing during some portion of their hospital stay (appendix table 2). After adjusting each of these studies for sample size, 30 percent of patients with *Campylobacter*-associated GBS are on mechanical ventilation. In the most recent studies, approximately 20 percent of all patients with GBS required mechanical ventilation. This is the value assumed in the baseline analysis in this study. The adjusted average percent of mechanically ventilated patients in the four American studies is higher (36.5 percent).

Charles Helbing of the Health Care Finance Administration (HCFA) provided 1992 Medicare Statistical Support data for short hospital stays by Medicare beneficiaries (those over 65 years old). Out of 3,982 Medicare patients with GBS in 1992, only 9.3 percent required mechanical ventilation. Sunderrajan and Davenport (1985) found that the probability that patients with GBS will be put on mechanical ventilation increases with age, that the average age of those patients with GBS requiring mechanical ventilation was 47.0 +/- 5.6 years, and that the average age of those patients with GBS who did not require ventilation was 30.1 +/- 4.3 years.

After weighting each study by its proportion of patients with GBS relative to the total for the five studies, the adjusted average number of days a patient with GBS is on a ventilator is 41.5 days (app. table 3). Older patients with GBS are more likely to spend more time on mechanical ventilation than younger patients with GBS. Sunderrajan and Davenport (1985) found that patients under 46 years old were on mechanical ventilation for an average of 21.4 days and those older than 46 were on mechanical ventilation for an average of 98.3 days.

[2] In Northern China, a variant of GBS associated with *C. jejuni*, Acute Motor Axonal Neuropathy (AMAN), strikes mostly children and young adults and damages the nerve fibers themselves instead of the myelin insulation (GBS Foundation, 1990, p. 4). This variant is believed to be connected with chicken droppings.

[3] McKhann *et al.* (1988) assessed the relationship between outcome of the disease and age as a continuous variable. They found that outcomes were less favorable with age. Winner and Evans (1993, p. 164) compared clinical features in patients with GBS age 20-59 with those 60 or older. They found "no significant differences between old and young in: occurrence or type of preceding illness; site of symptoms at onset; severity of maximal neurological impairment....requirement for artificial ventilation; case fatality rate..."

Appendix table 2—Probabilities surrounding patients with Guillain-Barré syndrome who were mechanically ventilated

Study (year)	Nationality	Patients	Deaths	Percent on mechanical ventilation
		- - - Number - - -		*Percent*
Löffel *et al.* (1977)	Swiss	123	18	14.6
Moore and James (1981)	Australian	33	9	27.3
Andersson and Sidén (1982)	Swiss	60	10	16.7
Beghi *et al.* (1985)[1]	American	48	3	6.3
GBS Study Group (1985)	American/Canadian	245	109	44.5
Sunderrajan and Davenport (1985)	American	40	18	45.0
French Coop. Group (1987)	French/Swiss	220	82	37.3
Halls *et al.* (1988)	Danish	34	5	14.7
Chevrolet and Deléamont (1991)	Swiss	10	5	50.0
Koobatian *et al.* (1991)	American	51	10	19.6
Rantala *et al.* (1991)	Finish	27	5	18.5
Winner and Evans (1993)	English	72	15	20.8
Total		963	289	——[2]

[1] This Olmstead County data is updated every few years and was also used by Kennedy *et al.* (1978).

[2] After adjusting for sample size, the average probability of a GBS patient requiring mechanical ventilation in the studies listed above is 30 percent and the average for the four U.S. studies is 36.5 percent.

Appendix table 3—Average number of days patients with Guillain-Barré syndrome were on mechanical ventilation (MV)

Study (year)[1]	Nationality	Patients in study	Patients on MV	Average days on MV
			- - - - - - - - Number - - - - - - - -	
Moore and James (1981)	Australian	33	9	63
Andersson and Sidén (1982)	Swiss	60	10	30
Sunderrajan and Davenport (1985)[2]	American	40	18	68.4
Chevrolet and Deléamont (1991)	Swiss	10	5	24.9
Winner and Evans (1993)	English	72	15	28.6
Total		215	57	——[3]

[1] We did not include Halls *et al.* (1988) because the paper had a typographical error. They stated that the duration of mechanical ventilation for their "five" patients was "10, 19, 19, 19, 64, and 215" days.

[2] Sunderrajan and Davenport (1985) found that their non-ventilated patients averaged 19.1 days in hospital.

[3] The simple average number of days a GBS patient is on a ventilator is 43 days and after weighting each study by its sample size, the adjusted average number of days a GBS patient is on a ventilator is 41.5 days.

The current standard of care for treating patients with GBS includes plasma exchange (plasmapheresis)(PE) and/or intravenous immunoglobulin (IVIG) treatments.[4] Nerve growth hormones may be another promising treatment for GBS. These hormones are proteins that are injected directly into nerves and are currently being tested for other diseases.

Estimates of Cases

The National Center for Health Statistics[5] provided three sources of data regarding the number of GBS cases occurring in the United States each year: (1) 1990 National Ambulatory Medical Care Survey data, (2) 1990 National Mortality Follow-back Survey data, and (3) 1979-93 National Hospital Discharge Survey data. All three surveys incorporated International Code of Diseases classification system (ICD-9) codes, thus maintaining consistency across samples.[6]

The 1990 National Ambulatory Medical Care (NAMC) survey lists the diagnoses for each patient made by office-based physicians in randomly chosen regions or counties in the United States.[7] In the NAMC survey, no outpatients were diagnosed with GBS using the ICD-9 code for GBS.[8] This may reflect the severity of GBS whereby most patients are hospitalized. The National Mortality Follow-back Survey (NMFS) data indicated that 402 patients with GBS died in 1990 and that 203 of these patients had GBS listed as the primary illness.

The National Hospital Discharge Survey (NHDS) provides information on the duration of hospital stays for 10 percent of all non-Federal short-stay hospitals in the United States. Up to seven diagnoses are assigned to each patient, with the first diagnosis representing the primary illness.[9] The NHDS annual average of 9,575 patients with GBS (for 1979-93, as 1 of 7 diagnosed illnesses) suggests an incidence rate of 3.64 in 100,000 for the same population (appendix table 4).

The NHDS incidence rate is high when compared with rates found in most GBS studies where 1 to 2 cases occur per 100,000 people (e.g., Mishu and Blaser, 1993; Beghi *et al.*, 1985; Hughes, 1990; Ropper, 1992). For example, in a 42-year epidemiological and clinical study in Olmstead County, Minnesota, the mean annual incidence of GBS was 1.7 in 100,000 people (Kennedy *et al.*, 1978).[10] We spoke to several neurologists at the 1995 Annual Meeting of the American Neurological Association who told us that an incidence rate for GBS of 1 in

Appendix table 4—Estimated number of patients with Guillain-Barré syndrome who were discharged from U.S. hospitals by year[1]

Year	Patients with GBS
1979	6,618
1980	8,677
1981	9,185
1982	13,323
1983	9,061
1984	7,061
1985	11,341
1986	9,736
1987	11,805
1988	11,969
1989	6,996
1990	7,706
1991	7,168
1992	7,562
1993	15,417

[1] These data include Guillain-Barré syndrome (GBS) caused from all factors. The average is 9,575 patients with GBS per year.

Source: National Hospital Discharge Survey data, 1979-93.

[4] In PE, "blood is removed from the patient, plasma is separated from blood cells and discarded, and blood cells are suspended in colloid solution and reinfused" (Thornton and Griggs, 1994, p. 262). Thornton and Griggs (p. 260) state "it is likely that plasma exchange acts by removing pathogenic antibodies" and they offer seven possible explanations of how IVIG works, which is less understood. IVIG is where pooled human IgG (a plasma protein) is intravenously administered.

[5] The National Center for Health Statistics is part of U.S. Department of Health and Human Services' Centers for Disease Control and Prevention.

[6] The ICD-9 code for GBS is 357.0.

[7] The most accepted guidelines for diagnosing GBS are provided by the ad hoc National Institute of Neurological and Communicative Disorders and Stroke (NINCDS) committee.

[8] Diagnosis of GBS typically relies on obtaining spinal cord fluid to detect elevated cerebrospinal fluid protein and on nerve conduction velocity-electromyography (NCV-EMG) to detect nerve conduction blocks or slowing.

[9] The NHDS estimates of the number of GBS patients are conservative because they include only those patients diagnosed with GBS, and like other illnesses, GBS is under-reported (e.g., diagnoses may be classified as miscellaneous).

[10] The Olmstead County data are updated every few years. Kennedy *et al.* (1978) is one of many papers that use these data.

Appendix table 5—Estimated annual incidence of *Campylobacter* infections, Guillain-Barré syndrome (GBS), and *Campylobacter*-associated GBS in the United States

Disease	Annual incidence (patients/100,000 pop.)		Total patients/year	
Campylobacter infection	1,000[2]		2,627,550[1,6]	
Patients with GBS	Low	High	Low	High
All GBS	1.0[3]	3.64[1,4]	2,628[1,3]	9,575[4]
GBS associated with *Campylobacter* infection	0.20[1,5]	1.46[1,5]	526[5]	3,830[5]

[1] Based on estimated 1995 U.S. population of 262,755,000 people (U.S. Bureau of the Census, 1995).

[2] Tauxe, 1992.

[3] Low estimate from Mishu and Blaser (1993) and Hughes (1990, p. 101) and from advice from neurologists at the 1995 Annual Meeting of the American Neurological Association.

[4] National Center for Health Statistics' National Hospital Discharge Survey (NHDS) data, average 1979-1993.

[5] Estimated at 20 percent to 40 percent of all patients with GBS. 526 patients is 20 percent of the estimate of 2,628 patients with GBS per year. 3,830 patients is 40 percent of the NHDS estimate of 9,575 patients with GBS per year. Here we consider *Campylobacter* infections from all sources, not just foodborne.

[6] For every 100,000 people that have *Campylobacter* infections each year, 20 to 146 develop GBS. This estimate of the number of *Campylobacter* infections uses the same procedure as Tauxe (1988) but is applied to a larger population.

100,000 people was a reasonable low estimate for our analysis. This rate translates into 2,628 new patients with GBS in the United States annually for a 1995 population of roughly 262.8 million people (U.S. Bureau of the Census, 1995).[11] Here, we use a range of 2,628 to 9,575 patients with GBS per year to reflect the uncertainty about the true number of patients with GBS per year (appendix table 5).

Guillain-Barré Syndrome Attributed to Food

Since the first report of *Campylobacter* infection complicated by GBS was published in 1982 (Rhodes and Tattersfield, 1982), evidence has accumulated that these infections may be an important trigger of GBS. Serologic and cultural studies all over the world have confirmed that 20-40 percent or more of patients with GBS had infection with *C. jejuni* in the 1-3 weeks prior to the onset of neurologic symptoms (Mishu and Blaser, 1993; Kuroki *et al.*, 1993; Rees *et al.*, 1995). In 50 to 75 percent of all patients with GBS, onset is preceded 1 to 3 weeks by an acute infectious illness of the gastrointestinal or respiratory tract (Mishu and Blaser, 1993, p. 104). Although respiratory symptoms are reported most frequently, gastrointestinal symptoms are common and precede GBS in 10 to 30 percent of cases.

Kuroki *et al.* (1993) isolated *Campylobacter* from stools of patients with GBS and used serological evidence to conclude that 41 percent of patients with GBS were linked to *Campylobacter* infection. Not all patients with GBS in whom *Campylobacter* is cultured report gastrointestinal symptoms, meaning that the immune system's production of antibodies to *Campylobacter* has stopped the intestinal infection, but the antibodies have already triggered GBS. Asymptomatic *Campylobacter* infections are not uncommon; up to 50 percent of persons with culture-proven *Campylobacter* infections may be asymptomatic (Riordan, 1988). *Campylobacter* infections may trigger GBS even in the absence of gastrointestinal symptoms. In Kuroki *et al.* (1993), 26 percent of *Campylobacter*-infected patients with GBS had no preceding gastrointestinal symptoms.

Campylobacter may be the most common bacterial foodborne pathogen in the United States. Dairy products are the most common cause of reported outbreaks of *Campylobacter* infections, whereas poultry is the most common source for sporadic *Campylobacter* infections. Contaminated water and all undercooked meats are other common vehicles of transmission of *Campylobacter*. The CDC estimate

[11] For this analysis, incidence is defined as the number of new cases that develop in 1 year per 100,000 people.

that roughly 1 in 100 people are diagnosed with symptoms of *Campylobacter* infections in the United States each year (Tauxe 1992, p. 3). Tauxe (1988) estimated that of 2.5 million people ill with campylobacteriosis in the United States each year, 200 to 730 die because of their illness.

Assuming that 20 to 40 percent of all patients with GBS are caused by antecedent *Campylobacter* infections (Mishu and Blaser, 1993), there are an estimated 526 to 3,830 new patients diagnosed with *Campylobacter*-associated GBS each year in the United States.[12] The current study focuses on this range of cases.

The current study estimates annual costs for all patients with GBS who had antecedent *Campylobacter* infections, regardless of the source of *Campylobacter* infection (i.e., foodborne, waterborne, etc.). The study then estimates the annual costs of GBS caused by foodborne *Campylobacter*, assuming that 55 to 70 percent of all *Campylobacter* infections are foodborne.[13] Although some studies suggest that *Campylobacter*-associated GBS is more severe than GBS caused by other factors (Molnar *et al.*, 1982; Rhodes and Tattersfield, 1982; Constant *et al.*, 1983), this distinction is not made in this study because of data limitations.

[12] 526 patients with GBS is equal to 20 percent multiplied by the low estimate of 2,628 patients with GBS per year. 3,830 patients with GBS is equal to 40 percent multiplied by the NHDS estimate of 9,575 patients with GBS per year.

[13] Buzby and Roberts (1996) assumed 55 to 70 percent of *Campylobacter* infections were foodborne and estimated that annual medical costs and productivity losses for campylobacteriosis from food sources range from $0.7 billion to $4.3 billion in 1995 dollars.