Economic Evaluation of Maternal Screening to Prevent Congenital Syphilis

BABILL STRAY-PEDERSEN, MD

From the Department of Gynecology and Obstetrics, Aker Hospital, University of Oslo; and the National Institute of Public Health and Norwegian Defense Microbiological Laboratory, Oslo, Norway

Benefit-cost analysis was applied to a model of first-trimester screening for syphilis where approximately ten new cases of early infections are identified and treated per 50,000 pregnancies. The cost of the screening is estimated to be $4.60 (U. S.) per participating woman, while the benefit-cost ratio was 3.8; thus the economic benefits are nearly four times the cost of the program. Furthermore, there are many other beneficial factors that cannot be evaluated in terms of money. The validity of the results varies with discount rates, frequencies of syphilitic infection, and rates of transmission to the fetus. If the incidence of maternal syphilis is 0.005%, the benefits equal the costs of the prevention program. In Norway, prenatal screening has been obligatory for 30 years. This represents a net benefit, or a total savings, of $8.6 million (U. S.; 1979). From an economic point of view, the first-trimester serologic screening should continue unabridged, whereas an extended preventive program, including premarital screening or additional third-trimester serologic tests, may not be advisable in Norway.

CONGENITAL SYPHILIS is a serious but preventable disease. *Treponema pallidum* may be transmitted from an infected pregnant woman to her fetus as early as the ninth week of gestation, but transmission usually takes place after the 18th week of pregnancy and occurs, in particular, when the woman suffers from early syphilis in the primary, secondary, or latent stages.[1] If the maternal infection is adequately treated during the first months of pregnancy, the risk to the infant is minimal.[2,3]

Serologic screening of pregnant women for syphilis has been required by law in Norway since 1948. Since World War II, however, the annual frequency of acquired syphilis has decreased markedly and is today as low as one notified case per 15,000 inhabitants.[4] Syphilis, therefore, can now be considered as a less serious health problem than in the past, and this change naturally raises the question of whether the obligatory screening ought to be discontinued.

This paper presents an analysis of the benefits and costs of the Norwegian prenatal program for prevention of congenital syphilis. The analysis employs a model requiring the identification of a detailed list of factors and the assignment of the actual dollar values to the different items concerned. The calculations refer to Norway, but the model can be applied for evaluation of similar preventive programs elsewhere.

The Model

Epidemiology

Each year about 50,000 women in Norway are pregnant. Serologic tests done during the first-trimester uncover about ten previously undiagnosed cases of early syphilis annually; thus the incidence of maternal syphilis is 0.02%.[5] If the maternal infection remains untreated until the fourth month of gestation and if the rate of transmission to the fetus is 60%, the outcomes of these pregnancies will be as follows: delivery at term of an uninfected infant, 20%; premature delivery, 20%; spontaneous abortion, intrauterine, or neonatal death, 20%; or delivery of a congenitally infected infant who will be more or less handicapped because of damage to the bones, eyes, ears, or brain, 40% (fig. 1).[2,3] In this analysis it is assumed that the premature children will develop normally, whereas half of the infected children surviving the neonatal period will need institutional care for life, while the other half will need special education and training (fig. 1).

The Preventive Program

The procedures for the prenatal serologic screening are as follows. The blood samples routinely collected at the first antenatal visit are tested by the standard tests for syphilis: the Wassermann CF test, the VDRL (Venereal Disease Research Laboratory, Atlanta, Ga.) flocculation

I am indebted to K. Loe, M.D., and A. Løkken, M.A.B., for providing data, and to I. Helliesen for comments and advice.

Reprint requests: Dr. Med. Babill Stray-Pedersen, Vallegt 16a, Oslo 4, Norway.

Received for publication on January 26, 1983, and in revised form on April 13, 1983.

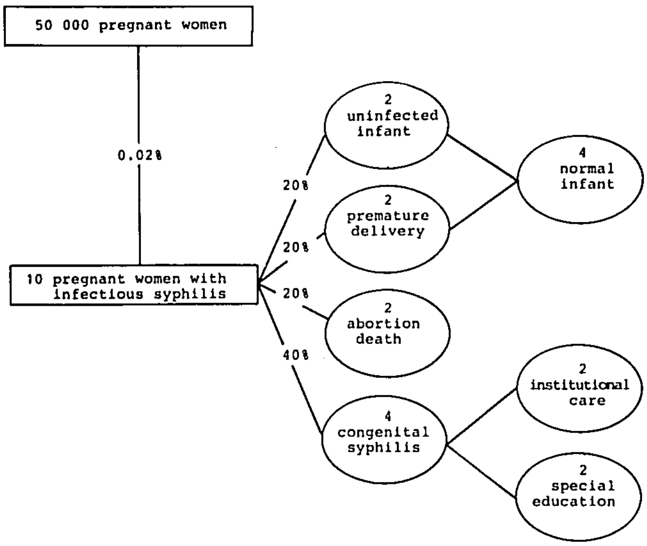

Fig. 1. Projected outcomes of pregnancy and prognoses of offspring of women with untreated syphilis.

test, and the Meinicke flocculation test.[4,5] Since these tests measure the reagins and are nonspecific, as many as 0.5% of the total samples yield positive or dubious results[5] and have to be retested by specific treponemal tests, such as the *T. pallidum* immobilization test (TPI) and the fluorescent treponemal antibody–absorption (FTA-Abs) test. In selected cases (0.3%), new blood samples have to be collected and checked for the presence of biologically false-positive reactions. After repeated testing, 0.1% of the pregnant women (50 cases) can be expected to show serologic evidence of syphilitic infection,[5] indicating a sensitivity of the standard syphilis tests of 100% and a specificity of 99.6%. In the majority (40) of the infected women, however, the disease has been recognized earlier and adequate treatment has been provided, while in ten cases new infectious syphilis is detected. These at-risk patients have to be treated with penicillin, and their infants are obliged to undergo repeated clinical, ophthalmologic, radiologic, and serologic examinations during their first months of life.

The cost of the preventive program includes the cost of the prenatal screening and the cost of the treatment and follow-up program for newly infected mothers and their children. The average cost of the serologic tests is calculated from the laboratory expenses by assessment of the cost of every item used in the performance of the tests and the share of the salaries (including benefits) of the medical and technical staff. To this figure is added a further 40% to cover administration and expenditures for electricity, fuel, and housing. The 1979 currency exchange rate of $1.00 (U. S.) equals 5.00 *Norwegian crowns (Nkr)* is applied in these calculations, which show that the cost of the screening tests is $4.00, while the total cost of the different tests to confirm syphilis is $48.00 (including the fee to the medical doctor).

The cost of medical consultations, special examinations, and specimen collections is calculated from the specific rates of payment obtained from the Norwegian Medical Association. The costs of treatment include the retail price of the drugs.

The Effects of the Preventive Program

In Norway the effectiveness of detection and treatment of maternal syphilis is observed to be 100%, a fact implying that the at-risk pregnancies develop normally, and the at-risk children are born uninfected. The economic benefits of the preventive program comprise the reduction in the use of health resources and the gains in economic output resulting from the prevention of congenital syphilis.[6] The costs associated with congenital syphilis are split into two components: the direct cost and the indirect cost.[7]

The direct cost equals the costs of long-term institutional or medical care as well as special education and special rehabilitation of children with physical deformities or mental retardation.[8] Since the specific costs may be incurred at various times over the years, all costs are adjusted to their present value, i.e., the year of the prenatal screening or the birth-year of the child.[9] The adjustment is made by discounting future expenditure at a fixed average rate of 7% per year.[10]

The model follows a person for a lifetime.[7,10] The present value of the total cost for a care or rehabilitation service is estimated as

$$\sum_{t_1}^{t_2} \frac{C_t}{(1 + x)t} ,$$

where t ranges from the year of the start of the special service (year t_1) to the year when the service is no longer needed (year t_2). C is the annual cost at the age t, and x is the discount rate. The duration and the total costs of the different special services are shown in table 1.

The indirect cost equals the value of productivity lost because of disability or death and is estimated as the loss of income for a presumed number of working years. It is assumed that an institutionalized person remains incapacitated for life, while a person receiving special education will achieve 70% working capacity at the age of 25 after a training period of five years, during which the working capacity is 50%. The present (birth-year) value of the lifetime income is calculated as

$$\sum_{t_1}^{t_2} I_t O_t F_t \alpha_t \frac{(1 + i)^t}{(1 + x)^t} ,$$

TABLE 1. Lifetime Costs of Special Services and Expected Lifetime Incomes Adjusted to Birth-year (1979) Values Using a Discount Rate of 7%

Service Required	Duration (Years of age)	Cost of Service	Total Cost per Child (U. S. $)
Institutional care	4–50	\$18,200/year × 46 years	203,400
Special education*	7–20	\$27,400/year × 13 years	159,600
Ordinary school	7–24		10,880
Total expected lifetime income of a normal person working from 16–70 years of age			45,800
Total expected lifetime income of a handicapped person with a 70% working capacity after special training			28,800

* Includes teaching and boarding in special school.

where I_t is the expected income of a normal person at the age t. The 1979 average age- and sex-specific income is employed; a discount rate (x) of 7% and an increase of wages (i) of 1% per annum are assumed. Unemployment and the value of domestic work are not taken into account. O_t is the probability of a person being alive at age t, while F_t is the probability (%) of being employed at a certain age. This last figure is based on the labor force surveys of the total population. For a handicapped person, α_t expresses the degree (%) of working capacity.

The total expected lifetime income of a normal person working from age 16 to age 70 and the total expected lifetime earnings of a handicapped person after special education are given in table 1.

Results

Estimated Benefits of the Preventive Program

The information given in fig. 1 and table 1 provide the data for calculating the direct and indirect costs associated with congenital syphilis. If the preventive program is not applied, the disease will remain unrecognized in ten infected pregnant women. These women will give birth to four congenitally infected (live) children, of whom two will require institutional care for life and two will need special training.

The benefit in direct cost is obtained by subtracting the cost of the ordinary educational program for normal children (born after the preventive program is applied) from the cost of the special care and training program for infected children (born when the program is not applied). As shown in table 2, this benefit amounts to approximately \$660,000.

The benefit in indirect cost represents the reduction in the loss of future income (gain in economic output), i.e., the difference between the assumed future economic productivity of children born with and without the preventive program. This benefit amounts to \$220,000.

The total economic benefits are the sum of the benefits of the direct and indirect costs and approximate \$880,000. The benefits of preventing one risk case is thus \$88,000 (table 2).

Estimated Costs of the Preventive Program

The costs of the prenatal screening and of the treatment and follow-up examinations of the infected women and their children are outlined in table 3. These costs total \$230,000 for 50,000 women or \$4.60 per participating woman. The physician's fee associated with the collection of the initial blood sample is omitted from the calculations since the screening is assumed to be performed on the samples collected during the routine medical visit for determination of blood groups and isoagglutinins.

Comparison of Benefits and Costs

By comparing the costs of the preventive program with the benefits obtained from its application, the benefit-cost ratio is calculated to be 3.8. Principally, this ratio may be considered as a constant value independent of the size of the population screened. However, the total savings to society, or the overall effect of the preventive

TABLE 2. Economic Benefits (\$ U. S.) of a Prenatal Screening Program for Congenital Syphilis (Assuming Ten At-risk Cases among 50,000 Women and 1979 Dollar Values)

Direct costs (\$ U. S.)		
Without program (fig. 1)		
Institutional care of 2 infected infants	406,800	
Special education of 2 infected infants	319,200	
Ordinary school of 4 uninfected infants	43,520	
With program		
Ordinary school of 10 uninfected infants	108,800	
Benefit in direct cost of preventive program		660,720
Indirect costs (\$ U. S.)		
With program:		
Lifetime income of 10 uninfected infants	458,000	
Without program:		
Lifetime income of 4 uninfected infants	183,200	
Lifetime income of 2 infected specially trained infants	57,600	
Benefit in indirect cost of preventive program		217,200
Total benefits of preventive program		877,920
Total benefits of preventing one case		87,792

TABLE 3. Costs ($ U. S.) of a Prenatal Screening Program for Congenital Syphilis (Assuming Ten At-risk Cases among 50,000 Women and 1979 Dollar Values)

First-trimester serologic screening		
Collection of blood samples (included in the regular antenatal control)	0	
Cost of initial screening test (standard syphilis tests for 50,000 pregnant women)	200,000	
Cost of specific *Tremponema pallidum* tests (0.5% of the women)	12,000	
Cost of retesting (physician's fee and serologic testing, 0.3% of the women)	10,380	
Total cost of prenatal screening		222,380
Treatment and Follow-up of At-risk cases		
Costs for infected mothers (including physician's fee, serologic testing, and treatment)	2,968	
Costs for at-risk infants (including special medical examinations and serologic testing)	3,668	
Total cost of treatment and follow-up		6,636
Total cost of preventive program		229,016
Total cost per participating woman		4.60

policy, may also be calculated as the net benefit (benefit minus cost), which is directly dependent on the number of participants. In Norway, with an annual pregnant population of 50,000 women, this value approximates $650,000 yearly. The prophylactic program has now been in operation for 30 years; thus the total benefit is $8.6 million.

Discussion

The results of the present analysis indicate clearly that the performance of a first-trimester screening program for syphilis is economically beneficial to society. The program applied to 50,000 women yields a benefit-cost ratio of 3.8 and an annual net benefit of $650,000. Admittedly, the value of some parameters employed in the calculations could not be estimated precisely. Generally, therefore, the costs of the different elements of the screening were set at maximal levels, whereas estimates of the costs of the medical and social care of the affected children were as low as possible in order to avoid overassessment of the economic attractiveness of the program. The most uncertain values probably are those connected to the indirect cost, i.e., the economic value of the lost productivity of a physically handicapped or a mentally retarded person. However, if the indirect cost is completely excluded from the analysis, the program still gives a favorable benefit-cost ratio of 2.9 and a net benefit of $430,000.

Special attention should be called to four parameters that were assumed as constants in the present calculations but that should be considered as variables: (*1*) the discount rate, (*2*) the incidence of maternal infection, (*3*) the rate of transmission of the infection to the fetus, and (*4*) the efficacy of the screening tests.

The discount rate turns out to be the most important quantitative factor, since minor changes will cause considerable alterations in the benefit-cost ratio. In this analysis, a value of 7% was employed, in accord with the recommendations from the Norwegian Ministry of Finance. If the discount rate were raised to 10%, the benefit-cost ratio would decrease to 2.4.

The current incidence of maternal syphilis was assumed to be 0.02%, which is comparable to the frequency reported from Denmark[11] and the United States.[12] In Norway, the observed incidence during the past 15 years has been 0.01–0.03%.[5] As illustrated in fig. 2, this incidence range corresponds to a benefit-cost ratio of 1.9–5.7. When the incidence is as low as 0.005%, the cost of the program equals the economic benefits.

The rate of transmission to the fetus depends on the stage of disease in the mother. The value employed (60%) refers to the early latent stages of maternal syphilis,[3] which may be assumed to constitute the largest group of the cases detected in the screening. Fig. 2 shows that this transmission rate also gives the highest economic benefit. At a transmission rate of 20%, which may be observed in cases where the infection was acquired as long as ten years before the actual pregnancy,[2] the benefit would be equal to the costs of the program. On the other hand, those types of syphilitic infections showing a transmission rate of >60% will also give a lower benefit as a consequence of the increased fetal mortality observed in these cases.[3] As many as 80–100% of the offspring of mothers with early primary and secondary syphilis may be infected, but approximately half of those will die either in utero or within weeks after delivery.[3,4] The sensitivity and specificity of the standard tests for syphilis may vary. After specific treponemal testing by the TPI and FTA-Abs tests, 0.4% of the results obtained in the initial prenatal screening were classified as dubious or falsely positive. Usually the frequency of falsely positive reactions in the standard tests for syphilis are reported to be <0.4%,[5] thus indicating a higher specificity than the value (99.6%) used in the present calculation. Use of a specificity of 100% for the standard tests would increase the benefit-cost ratio to 4.2 and the net benefit to $670,000 per year. On the other hand, further investigation of persons with falsely positive reactions in the standard tests may give additional, uncalculated benefits resulting from the early detection of certain autoimmune diseases.[4]

The current prenatal screening is confined to the first trimester, i.e., women who become infected later in pregnancy will not be identified. The risk of acquiring a syphilitic infection during the second and third trimester is about 0.04 per 1,000,[5,7] which corresponds to two cases per year in Norway. In order to detect these additional cases, a third-trimester serologic screening would have to be included in the prophylactic program. The total costs of this program for 50,000 women would be $620,000 ($12.40 per woman), and the total benefits would be $1.05 million; these figures give a benefit-cost ratio of 1.7 (fig. 2). However, an economic evaluation of the third-trimester screening itself would give a benefit-cost ratio of <1, which means that it cannot be considered as economically beneficial to society. The performance of repeated serologic testing in the last trimester should thus be restricted to those women who may be assumed to be at a high risk of acquiring syphilis.

A premarital screening for syphilis is carried out in some states in the United States.[12] This program obviously detects acquired cases of syphilis and helps to prevent disease transmission to sex partners. As for those women who have no testing performed during pregnancy, this premarital screening provides the only opportunity for detection of syphilis and prevention of congenital infection. In Norway, however, the rate of participation in the gestational screening is nearly 100%, indicating that all cases of maternal syphilis will be diagnosed in pregnancy. In addition, the premarital program would cost about $16 per participant, or approximately four times the cost of the first-trimester screening, mainly because of additional expenditures in the collection of blood samples. Thus in Norway the costs of both premarital and gestational screening would exceed the benefits (fig. 2) and should not be recommended as long as the first-trimester screening is so effective.

In this cost-benefit analysis only the cost to society has been taken into account; the psychological and emotional factors have been disregarded since these factors cannot be evaluated in terms of money. An infected child may represent a financial burden for his family because of the increased cost of the family's social and medical care and/or because the effort required to care for the child may reduce the working capacity of his parents. Moreover, recognition of the infection has to be regarded as a benefit for the affected woman. Without the serologic screening, her infection might enter the late stage and cause serious sequelae necessitating medical or institutional care or causing a reduced working capacity.[13] Finally, an unrecognized case of syphilis must be considered as a danger to public health, since it represents a source of the spread of the infection. The preventive program provides systematic tracing of asymptomatic cases and their contacts and thus guarantees against epidemic outbreaks of the disease.

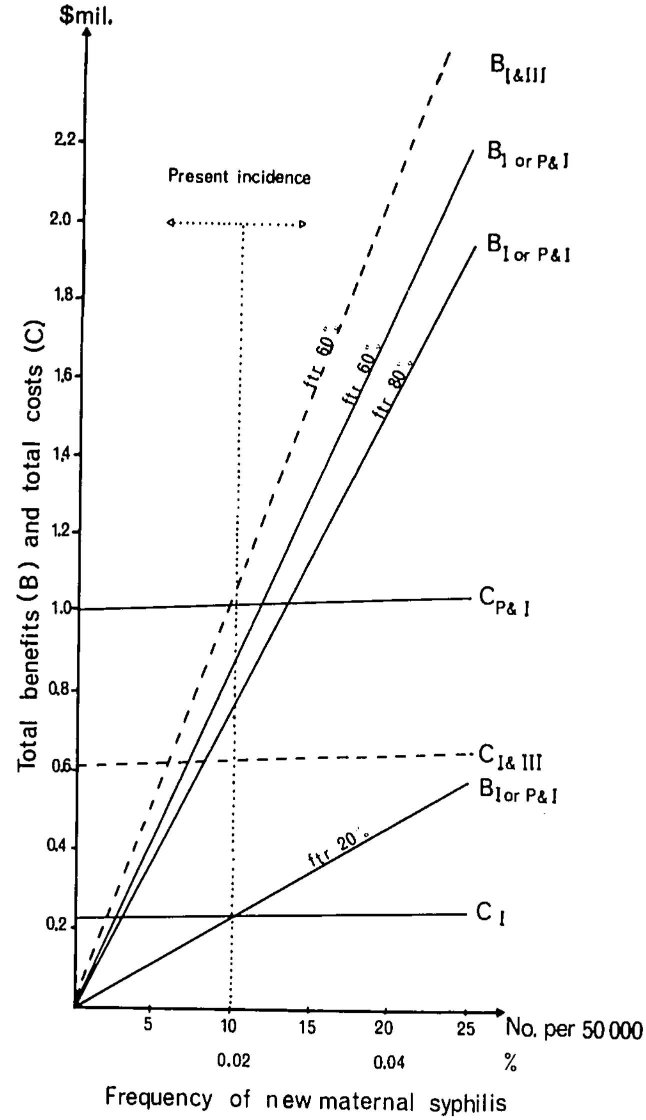

Fig. 2. Benefit-cost analysis of various programs for prevention of congenital syphilis. The screening applies to 50,000 women, and the results refer to different frequencies of maternal syphilis and different rates of transmission to the fetus (ftr). (——) = results of first-trimester screening (I) or combined premarital and first-trimester screening (P & I). (– – –) = results of combined first- and third-trimester screenings (I & III).

In conclusion, the greatest benefits of the serologic screening program for detection of syphilis are enjoyed by the few women whose at-risk pregnancies are detected and who consequently may avoid deliveries of children with severe malformations and handicaps. Congenitally infected infants may be effectively treated in utero, which means that a therapeutic abortion is not necessary and consequently that the program does not involve problems of an ethical nature. The present study shows that the first-trimester screening program gives a favorable benefit-cost ratio and results in a net saving of money for society. Thus continued support of the program is warranted.

References

1. Harter CA, Benirschke K. Fetal syphilis in the first trimester. Am J Obstet Gynecol 1976; 124:705–11.
2. Ingall D, Norins L. Syphilis. In: Remington JS, Klein JO, eds. Infectious diseases of the fetus and the newborn infant. Philadelphia: W.B. Saunders Company, 1976:414–63.
3. Krugman S, Katz SL. Syphilis. In: Krugman S, Katz SL, eds. Infectious diseases of children. St Louis: C. V. Mosby, 1981:390–408.
4. Storm-Mathisen A. Syphilis. In: Vinken PJ, Bruhn GW, eds. Handbook of clinical neurology. Infections of the nervous system. Amsterdam: North-Holland, 1978; 33:337–94.
5. Skarpaas T, Loe K. Positive serologic syphilis reactions among pregnant women in Norway, 1964–1978. Tidsskr Nor Laegeforen 1980; 100:1840-3.
6. Klarman HE. Syphilis control programs. In: Dorfman R, ed. Measuring benefits of government investments. Washington, D.C.: Brookings Institution, 1965:367–414.
7. Schoenbaum SC, Hyde JN, Bartoshesky L, Crampton K. Benefit-cost analysis of rubella vaccination policy. N Engl J Med 1976; 294:306–10.
8. Steiner KC, Smith HA. Application of cost-benefit analysis to a PKU screening program. Inquiry 1970; 10:34–40.
9. McCarthy NJ. Benefit-cost and cost-effectiveness analysis: Theory and application. In: Developments in biological standardization. Vol 43. Basel: S Karger 1979; 43:403–17.
10. Norwegian Ministry of Finance. Programanalyse, R-505. Oslo: Tannum-Norli A/S 1979:156.
11. Nilsen HA. WR-rutineprøver og cost-benefit. Ugeskr Laeger 1977; 139:3011–2.
12. Feldman YM. Should premarital syphilis serologies continue to be mandated by law. JAMA 1978; 240:459–60.
13. Braun P, Sherman H, Komaroff AL. Urethritis in men: Benefits, risks, and costs of alternative strategies of management. Sex Transm Dis 1982; 9:188–99.