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COST-BENEFIT ANALYSIS IN DECISION MAKING FOR DIAGNOSTIC RADIOLOGY[1,2]

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INTRODUCTION

Diagnostic medical radiation represents the largest source of man-made radiation exposure to the general population [1]. This paper reviews certain current concepts and methods relating to benefit-risk analysis, in terms of economic costs and radiation risks to health, in relation to the benefits from diagnostic radiology in clinical medicine. ¶Diagnostic radiological health programs are designed to prevent disease, improve health, and decrease costs resulting from illness, and thereby to contribute to efficiency of man's productive capabilities. Benefits of controlling disease may be assessed as the costs of the disease averted by the health program [2]. Such benefits, or averted costs, can be related to 3 broad cost categories: resource-use costs, eg, expenditures on medical or diagnostic radiological care; resource-loss costs, eg, estimated losses of human productivity; and resource-transfer costs, eg, payments for hidden costs transferred from the well to the sick. Such costs and the symmetrical "averted costs" may be summated as identifiable activities. Resource-use costs in diagnostic radiology include the direct capital and recurring costs of radiological care and services, eg, services of physicians, paramedical and technological personnel, hospital facilities, x-ray equipment, x-ray film, etc. Resource-loss costs are losses of productivity of individuals who are ill, who otherwise would be well and productive. These include: loss of earnings from loss of work for medical diagnosis and treatment, and to be rehabilitated to productive activity; and reduction in earnings because of illness which renders a person less productive or less employable. Transfers of resources are costs to givers transferred as benefits to the receivers; disease takes economic resources away from those who are well and have paid costs of the program, to those who are ill and receive benefits of the health program [3]. ¶Limited economic resources available to society has led to a social philosophy which takes into account such losses or gains, arising from changes in incidence of dis-

ability, disease or death, and costs of medical care services necessary to avert losses and to improve gains or benefits [4,7]. Analysis of saving life may be considered symmetrical with that of losing it. One common analysis of the loss of life is the net output method to calculate the economic worth of a person's life [5]. An initial step to estimate the value of the benefits of any program for saving life or reducing illness, thereby improving health is to determine what the average individual whose health is improved, or life is saved, would earn or produce over the rest of his life. ¶In any cost-benefit analysis of diagnostic radiological health programs, the traditional approach in health economics is: the purpose of the program is to save lives and reduce illness; death or illness avoided means that a loss of human productivity is avoided; problems center on valuing benefits per life saved or per illness avoided; the economic value of a life saved varies according to a variety of factors, including age, and can be determined; and the noneconomic value of a human life can be determined based on costs society will spend to save a life [6]. None of these factors, except possibly the last, takes into account the many variables entering into the effects of disability, debility and death, among the most important of which are risks leading to illness and death [7]. This latter approach to cost-benefit analysis establishes that various kinds of risk to health exist, and then decides how much to spend to reduce these risks. This implies that the individual and society can evaluate risk and reduction in risk. However, the primary purpose of this approach in diagnostic radiology where radiation risks exist is the same as the averted costs approach, viz, to save lives and reduce illness.

COST-BENEFIT-RISK ANALYSIS MODELS IN DIAGNOSTIC RADIOLOGY

Economic costs of diagnostic radiological services arise out of the impact of disease and injury upon utilization, distribution, and availability of economic resources in society. ¶1. RESOURCE-USE MODEL: Direct costs of health programs involve manpower and material resources required for prevention, diagnosis, treatment, rehabilitation, and research which are usually determined for each major disease and disability, such as cancer or heart disease. The part of the nation's manpower and goods and services produced (both public and private expenditures) devoted to health care has increased substantially during the past 50 years; in 1977, health and medical expenditures in the United States exceeded $140 billion (approaching 8.5% of the Gross National Product) or about $700 per capita. By 1980, this value approached $1,000 per individual. The resource-use costs of this total amount spent specifically for diagnostic radiological services are represented by financial outlays of public and private health insurance and other agencies, employers, and individuals and their families. These are sizeable costs and

include: services by radiologists and other physicians, hospitals, dentists, technologists, nurses, and other health personnel; complementary commodities, such as x-ray film, radiopharmaceuticals, chemicals, and other medical supplies; public and private health agency programs, mass x-ray screening and surveys for certain disease programs or socioeconomic groups; capital expenditures for construction, x-ray equipment, maintenance, radiological services and complementary radiological goods; costs of educating and training health personnel; and radiological research. ¶2. APPLICATION OF RESOURCE-USE MODEL: We do not know the exact extent of public and private expenditures for radiological care services. Some limited information is available. From the 1970 United States Public Health XES Study, approximately 210 million medical and dental x-ray and radioisotope examinations were performed in the United States. If the average cost per chest x-ray examination, the most frequent or more than 40% of all medical x-ray examinations, to the medical consumer was $30 in 1970, then the direct recurring expenditures for all 65 million chest x-ray examinations carried out in 1970 would be about $2 billion. For all diagnostic radiological services in 1970, the cost would be approximately $6 billion. If this represents two-thirds of the costs of all diagnostic radiological services, the remainder including the capital expenditures for construction, purchase, and maintenance of x-ray facilities used, and in production of complementary health goods, then an estimate of all direct costs or resource-use costs devoted to radiological services and supplies in 1970 would approach $9 billion. Today, this value well exceeds $20 billion, and represents a radiological health expenditure per person of approximately $100 annually or about 10% of the per capita expenditure for all medical services in the United States. ¶3. RESOURCE-LOSS MODEL: The loss or costs of human resources arising from illness results in a decrease of society's productivity [3]. This concept has been justified since resources available to society are limited, and without sickness and injury, health servies would b unnecessary so that available resources would be free for other productive uses. To quantitate the loss in economic terms, it is necessary to estimate the productive output foregone. If illness could be prevented, eliminated, or limited in time, it would be important to determine how much productive gain (benefits to society) those persons who are presently ill would have contributed to societal resources. ¶The effects of illness on human productivity may be considered as: debility, the loss of productive capacity of individuals while at work; disability, the loss of productive working time; and death, the loss of workers [3]. Based on this definition, various stages in achieving a calculation of the estimated previous output lost may be determined.

These stages assume that for any estimate of work lost due to disease, if it were not for the disease, those sick persons would have otherwise been well, and therefore productive. Estimates include costs of certain societal concomitants, such as unemployment, or loss of output due to debility. ¶4. APPLICATION *OF RESOURCE-LOSS MODEL: To assess benefits from diagnostic* radiology, one procedure would be to classify categories of x-ray examinations, eg, for immediate care of an injured patient, for mass x-ray screening for early detection of cancer for pre-employment or medicolegal examinations, etc. In each, it is then necessary to identify a particular health benefit to be balanced against a cost, either economic cost or radiation risk to health of the individual, or both. Here, the x-ray examination is part of resource-use of health resources necessary for prevention, diagnosis, treatment and rehabilitation of diseased persons who are temporarily or permanently lost from the human labor force during that year. As such, the x-ray examination may be evaluated by its beneficial effect on overall resource-loss costs. In other words, prevention of debility, disability or death is the benefit to the individual patient. In this cost benefit model, assumptions are made on the value or benefit of each x-ray examination and its influence on the effectiveness of management of the patient, affecting the medical outcome. ¶The benefit of the x-ray examination may be related to prevention of disease, and thus prevention of loss of productivity. There are two stages in estimating productivity lost: estimating loss in productive work-time, and assigning a value to productive output foregone that this lost work-time represents [8]. This yields a relative value which takes into account disability-prevention and includes lives saved or deaths prevented. This may then be converted to an economic value which represents the composite value of loss of output attributable to debility, disability, or death. Economic valuation represents only one form of calculating a relative value. The economic value may be used to represent a rough estimate of the expected increase in productive output that would occur if the loss of resources due to sickness were decreased or eliminated. The total dollar-value benefits from diagnostic radiology derived in the United States based on this model would require a complete knowledge of the value of all radiological examinations. Assumptions can be made on the distribution of such values for various categories of medical x-rays, but these concepts may not apply to dental x-rays or nuclear medicine examinations. ¶5. COSTS-RISK MODEL: A cost-risk model for diagnostic x-ray exposure can be developed in terms of somatic risks and genetic risks of low-level ionizing radiation. Knowledge of the distribution of diagnostic radiological examinations, the size of the populations examined, and the radiation dose to the

individual and to the population exposed would be necessary. The potential radiation risks of special concern are delayed or late health effects of low-dose radiation: carcinogenesis, ie, radiation-induced cancer; teratogenesis, ie, developmental abnormality in the newborn; and mutagenesis, ie, genetically-related ill-health. Here, the resource lost as a result of radiation-induced illness and death is human productivity; the model assesses the value of the loss by estimating the productive output foregone resulting from radiation-induced debility, disability, or death, as in the case of the benefits model. The somatic effects to be considered include primarily radiation-induced cancer in adults, neonatal developmental abnormalities and spontaneous abortions, and childhood cancer. For example, valuation of costs of potential somatic effects of antenatal radiography could be used to estimate the dollar-value costs resulting from such x-ray exposure. Information is required on frequency of obstetrical and pelvimetric x-ray examinations, their distribution, the radiation doses to the fetus, and birth rate. The model takes into account that fetuses or children who die or who are seriously disabled never enter the work-force, and the potential entire lifetime productivity is lost. ¶Application of the model to potential radiation-induced genetic effects requires a great deal of information on the genetic risks from radiation. Certain of the classes of genetic diseases and hereditary effects to be expected from radiation: precise data on expression, distribution, and incidence (morbidity and mortality) of these genetic diseases in the population; on birth and fertility rates in the irradiated population; on doubling doses of radiation for mutational effects in man; on distribution of x-ray examinations affecting the genetically significant dose; and on estimation of loss of productivity and direct costs of ill-health in society of future generations affected by the genetic disease, with appropriate future discounting. ¶6. REDUCTION-OF-RISK MODEL: The resource-loss model, which implies that a person's health and, therefore, life can be valued by his productive capacity, has 3 objections: it does not take into account different levels of valuation of more or less productive members of society; it assumes that society values an individual only in terms of his economic contribution; this would exclude children and the elderly; it does not take into account such intangible circumstances as pain, bereavement, and attempts to deter death [9]. ¶An approach to how society might value noneconomic losses or gains may be considered in terms of risk, and its avoidance. An extension of the resource-loss model can be applied to increased or reduced risk of injury, disease and death. The model is symmetrical; eg, an increased risk of disease and death is a recognized by-product of growth of an activity resulting from

an increased use of ionizing radiation, as in diagnostic radiology. A reduction in risk of disease and death can be a by-product of growth of an activity, as in immuno prophylaxis in preventive medicine. It is possible to decide how much to spend to reduce various kinds of risk. Societies, both in their public and private capacities, do incur costs to reduce risks to which they are exposed [10]. ¶7. APPLICATION OF REDUCTION-OF-RISK MODEL: The reduction-of-risk model assumes that reduction of the incidence of disease and death is an activity regarded as a collective societal good. A program of early diagnosis of disease, such as cancer of the breast, affecting a large population can be considered to save a certain number of lives annually. Mass x-ray screening programs lend themselves to this model. An example is that of the assessment of the benefits and the risks of mammography in mass x-ray screening for the early detection of breast cancer. The evidence for a radiation-induced excess of breast cancer in irradiated women is available chiefly from epidemiological studies [11]; in all these surveys, the dose-incidence relationship below a few hundred rad does not deviate significantly from linearity [12]. The incremental risk of breast cancer in women 35+ at exposure is about 3.5-7.5 excess cancer cases per million women exposed per year per rad to both breasts, beginning at the end of a 10-year latent period, and averaged over the subsequent duration of life [12]. The risks of a single 1-rad mammogram appear unlikely to outweigh its potential benefits in the individual woman aged 35+. On the other hand, based on such risk-benefit analysis, not including direct economic costs, it would not be sound public health policy to recommend yearly mass x-ray screening mammography of large numbers of asymptomatic women unless the predicted benefits would clearly outweigh the presumed risks, possibly in the case of selected high-risk populations, however small the presumed risks might seem to the individual [12]. Furthermore, because the natural incidence of breast cancer rises with age, while susceptibility to radiation-induced breast cancer decreases after about age 30, in general, the ratio between the likelihood of detecting the disease and the likelihood of producing it in the same x-ray procedure become more favorable with advancing years.

CONCLUSIONS 1. Benefit-risk-cost analysis can be carried out for decision-making in diagnostic radiology as it applies to large populations. Economic valuation should be used only as a relative value, but it does provide a method to relate all direct and indirect costs to the benefits accrued. 2. Efforts should be directed to improving the benefit-risk-cost ratio without limiting the benefits derived from modern radiological services to the individual and to society. 3. Careful benefit-risk analysis should be done prior to carrying out mass x-ray

screening programs of large populations. Such programs may involve potentially high radiation risks. They should be safe, reliable, provide early diagnosis specific for the disease, and result in a good yield of curable cases. 4. The benefit-risk ratio for medical radiation can be improved without loss of benefit, by decreasing the potential health risks--carcinogenesis, teratogenesis, and mutagenesis--through dose-reduction methods.

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