Emory had symptomatic improvement, only 50 percent returned to work after surgery.

The evidence with regard to positive occupational rehabilitation as a result of CABG surgery is conflicting. Studies of patients in randomized trials show a lesser return to work for surgical patients than for medical patients (59). It seems that even if the procedure is successful, many patients seize the opportunity to retire, which is at that time socially acceptable and legitimate. Factors that influence this choice are the duration of postoperative recovery and the availability of compensation or retirement benefits.

Artificial Heart Recipients

Thus, we have several proxies on which to base estimates of probability of return to work after artificial heart implantation. The percentage of cardiac transplant patients who return to work is 20 to 25 percent (62). Because cardiac transplantation leaves the recipient prone to infections and rejection from the body's immune system, however, we believe that this percentage is lower than might be expected among recipients of an artificial heart.

Patients with coronary artery disease amenable to surgery are often in much better medical condition than those who would be receiving an artificial heart. Thus, we believe that the return-to-work figures for the coronary bypass group represent an upper limit. From the study by Rimm, et al. (65), we note a return-to-work percentage of 70 to 80 percent for CABG patients under age 55 and from so to 70 percent for CABG patients between age 55 and 65. We also note an approximate percentage of 60 percent of persons with advanced kidney disease on home dialysis who are able to maintain a normal working condition.

Thus, we would suggest as the overall percentage of previously employed artificial heart recipients who might return to work after surgery a lower limit of 20 percent (based on the experience of heart transplant patients) and an upper limit of 60 percent (based on the experience of CABG patients).

SOCIAL COSTS

A comparison of the costs of the artificial heart must include not only the charges to the consumer, but future economic effects on society as a whole. Below we discuss four prominent issues that arise in connection with proposed development of an artificial heart: 1) increased social expenditures, 2) distributional issues, 3) social costs of a nuclear device, and 4) opportunity costs.

Increased Social Expenditures

The extent of increased costs to society will depend on the quality of the artificial heart in clinical application. A highly effective device could increase the productivity of midcareer recipients and greatly benefit society. An inadequate device, however, would mean, in addition to losses in productivity, the loss to society of its investment in R&D, and charges for implantation, continuing medical care, welfare and rehabilitation programs.

The potential burden on social security and other retirement programs is related not only to the reliability and effectiveness of the artificial heart, but also to the quality of rehabilitation and the desire of recipients to return to active lives. The experience of cardiac transplant patients emphasizes the importance of psychosocial and economic motivation for complete rehabilitation. Likewise, the rapid diffusion of CABG surgery, with its disappointing return-to-work figures, suggests that considerable planning—with an eye toward comprehensive treatment, counseling and restricted development —should precede clinical application of the artificial heart to ensure the best possible results.

Given the large number of patients who might benefit from artificial heart surgery, the cost could run into the billions, as predicted by Sapolsky in 1978 (70). Yuki Nosé, of the Cleveland Clinic, has expressed the opinion that societal costs will equal those of present dialysis payments by medicare (which now exceed $1 billion).

From our own assumptions, if the average cost of artificial heart surgery is $28,000 and 33,600 implantations are done each year, the yearly aggregate cost for the surgery alone would be $941 million (see table 2). Added to the cost of surgery are continuing care costs—estimated at $2,000 per patient per year—which will increase incrementally as the number of procedures (and patients) accrues.

Using our figures (which are conservative estimates) for the cost of implantation and the pool of recipients, and applying these continuing care costs ($2,000 per patient per year) to the survival rates of heart transplant patients at Stanford (i.e., 70-percent survival for the first year and 5-percent attrition each succeeding year, or 50-percent survival through 5 years) yields the 5-year cost projections in table 13. As can be seen in that table, first year costs for 33,600 implantations at $28,000 per procedure would be about $941 million. Second year costs would be $941 million for another 33,600 implantations (at $28,000 per procedure) plus maintenance costs of about $47 million for the 23,520 survivors (at $2,000 per survivor), or a total of about $988 million. Third year costs would be $941 million for another 33,600 implantations plus maintenance costs of about $91 million for the survivors, or a total of about $1,032 million. Fourth and fifth year costs, calculated similarly, would be about $1,072 million and $1,109 million, respectively.

Even at these cost levels and projected patient pools, the artificial heart (when distributed on a large scale) will incur costs equivalent to present dialysis payments within 1 year. If the implantation turns out to be more costly, then the program will rapidly approach $2 billion annually. The decision to finance hemodialysis and the recent recommendation to finance cardiac transplants through medicare indicates that the costs of artificial heart implantation will probably be federally financed. If the experience of hemodialysis is typical of procedures supported by public funds, then we can expect a progression toward more relaxed patient selection criteria for and widespread availability of the artificial heart. Previously excluded candidates would thus be included. As the recipient group is expanded, and more resources are invested, the marginal quality-of-life improvements and longevity improvements will lessen.

Though the impact of the artificial heart on total population growth may be small, an increase in the proportion of older citizens may necessitate increased expenditures by social security and medicare to cover rehabilitation and early retirement. The present burden on social security due to our expanding elderly population is already well documented and of fiscal concern. The burden of increased social security expenditures will fall on all taxpayers. If recipients of the device are substantially more productive than they would have been without it, costs of the program maybe made up through increased tax revenue, as was predicted in the 1966 Hittman Report (35). Therefore, the development of a strong comprehensive rehabilitation program is crucial if the artificial heart is designed for large-scale distribution.

Table 13.—Projected 5-Year Sequence of Total National Expenditures on Artificial Heart Implantation and Patient Maintenance (dollars in millions)

	First year	Second year	Third year	Fourth year	Fifth year
Implantation charges	$940.80	$940.80	$ 940.80	$ 940.80	$ 940.80
Maintenance					
Year 1	—	47.04	47.04	47.04	47.04
Year2	—	—	43.68	43.68	43.68
Year3	—	—	—	40.32	40.32
Year4	—	—	—		36.96
Total costs	$940.80	$987.84	$1,031.52	$1,071.84	$1,108.80

SOURCE: D. Lubeck and J. P. Bunker, 19S0. See text for assumptions.

Distributional Issues

In the experimental years of the artificial heart program, strict patient selection criteria (similar to those for cardiac transplantation) would limit distribution and reimbursement problems. However, as the procedure becomes established for therapy, and medical criteria are relaxed, there will be fewer clinical reasons to deny the artificial heart to an individual able to benefit from it. Thus, financial considerations will gain in significance.

Even the most conservative estimates of the cost of the artificial heart project an amount that would be a severe burden on many families. Insurance companies, particularly in the early years of the artificial heart's availability, maybe unwilling to shoulder the high costs of such an innovative treatment, just as they have been in the case of cardiac transplants. Yet, in recent years, Americans more and more have come to see access to available modes of health care as a basic right that should not depend on one's ability to pay. The decision to cover hemodialysis under medicare is the most notable illustration. In the case of the artificial heart, the demand for public financing would be strengthened by the fact that the device came into existence only because citizens' tax dollars financed its development.

If artificial hearts do become available, the Federal Government will be faced with a serious dilemma—either to deny many citizens access to a device sponsored by a Government research program or to embark on a subsidization plan that could run into billions of dollars annually. Patient selection criteria and the mode of reimbursement will be the policy components that establish the scope and equity of artificial heart distribution. The challenge will be to design economically realistic financing and allocation arrangements that will not ration life on the basis of the value of individual members to society.

Social Costs of a Nuclear Device

The social cost of a plutonium-fueled artificial heart relates to the associated environmental and social hazards. Plutonium is an extremely toxic material. Each capsule (containing about 50 g of Pu-238) is the equivalent of many millions of lethal doses to a human being. From manufacture through transportation and storage to implantation, the materials would have to be protected from accidents and thefts that might result in breach of the capsule and release of the Pu-238 into the environment. After a patient's death, the material would have to be quickly recovered and returned to the Government. Since the basic premise of developing a device is that the device will be widely distributed, it follows that the safeguards associated with a nuclear power source would also be widely applied. The problems that could arise under conditions of unexpected use, theft, terrorism, or accident are dramatized by the estimate (with a very wide range of variability) that if the 50 g of Pu-238 in the artificial heart were to be distributed as an ideally aerosolized particle, that particle would be the equivalent of 1.7 billion doses of, lung cancer (26).

In addition to these risks, another consideration is the capital costs. At the current price of Pu-238 ($1,000 per g), each device (containing 50 g of Pu-238) would cost $50,000 for fuel alone. At 50,000 devices per year, the initial costs for fuel alone would be $2.5 billion. If this were financed at lo-percent simple interest per year, the finance charge would be $250 million per year. These costs would be added on to the other costs previously mentioned.

Opportunity Costs

In considering the costs of the artificial heart program, one must also take into account potential gains that might have accrued from other social expenditures precluded by the primacy of artificial heart development. Although spending on one project does not automatically preclude spending on another program, the development and promotion of an artificial heart is likely to reemphasize the importance of alternative approaches to the treatment of heart disease, as well as increase social costs.

As noted earlier, distribution of the artificial heart may proportionately raise social expenditures financed through medicare and social secu-