Health Care Technology as a Policy Issue ,

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The rapidly rising costs of health care became the most important health policy issue in many countries during the 1980s and early 1990s. These costs are now threatening the prospects for providing higher quality services to broader population groups, especially in the United States. The reasons for rising costs clearly include the aging of the population, with associated increasing rates of chronic diseases and disabling conditions. Another critical factor is the rate at which resources are used in health care-which in turn is linked with the rapidity of technological change.

Apart from inflation and its effects on wages and the costs of goods, the increase in resource use is the primary reason for rising health care costs. Nations seeking to control these costs must control the growth and/or use of resources—an effort that inevitably has involved trying to control the processes by which health care technologies are developed, evaluated, adopted, and used.

Yet even without rising costs, controlling technology seems necessary. Choices among technologies have to be made—this occurs at different levels of health care systems. Some choices are made at the national or regional policy level, as when laws and regulations prevent the purchase of equipment or the provision of certain services. Most choices, however, are at the operational level of clinical practice: made by hospital administrators, heads of clinical departments, and health care providers working day to day. The ability to influence these choices, and the means through which that influence is exerted, are prominent health policy issues.

One means of positively influencing choice is through the application of health care technology assessment. Now about 20 years old, the assessment field developed as a tool for policy-

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Country	Population (millions)	GDP per capita ($US)[a]	'/o GDP on health care	'/o public spending[b]	Spending per capita[c]($ US)
Australia	17.3	17,038	8.6	67.8	1,409
Canada	27.0	21,537	10.0	72.2	1,915
France	56.4	21,022	9.1	73.9	1,605
Germany	78.0[d]	24,585	8.5	71,8	1,659
Netherlands	14.9	19,298	8.3	73,1	1,360
Sweden	8.5	27,498	8.6	78.0	1,443
United Kingdom	57.5	17,596	6.6	83.3	1,035
United States	251.4	22,204	13.4	43.8	2,867

TABLE 1-1: Population, GDP Per Capita, and Health Care Spending in Eight Countries

[a] **Average** GDP per **capita** for Organisation for Economic Co-operation and Development countries $US20,305

b percentage **of** health spending from public Sources

[c] Made comparable through purchasing power parity, in $US

[d] Germany West, 61 3; Germany East, 16.7

SOURCE Organasation for Economic Co-operation and Development, OECD Health Data A Software Package for the International Comparison of Health Care Systems (Paris, France Organsation for Economic Cooperation and Development, 1993)

makers to help shape the course of technological change in health care. One major focus of this report is the relationship between policy and operational levels and the field of health care technology assessment.

THE DIFFUSION OF HEALTH CARE TECHNOLOGY

Influencing technological change in health care means developing policies that affect basic research, applied research, clinical investigation and testing, and diffusion of technologies. *Basic research* produces new knowledge about the biological mechanisms underlying the normal functioning of the human body and its malfunctions in disease. Public policies definitely can affect this stage of technological change, as public funds support most of the world's health-related basic research. However, basic research is rather far from clinical technology. The paths by which technology develops are not well understood. Interventions at the basic research stage that might change the course of knowledge development would have unknown effects on later technology development. For these reasons, intervening in basic research has not been very promising as a policy tool.

Applied research uses information from basic research and other sources to generate new solutions to problems of disease prevention, treat-

ment, or cure. Policy interventions at this stage could have greater effects on technological change; however, little is known about these processes. Attempts to direct the course of technological change by undertaking applied research are hampered by the fact that such research related to pharmaceuticals and equipment is carried out by industry, which means that much of the information concerning both these processes and their results cannot be easily obtained. Governments at various levels can, of course, fund applied research aimed at certain ends, but governments have been reluctant to invest heavily in applied research.

Clinical investigation and testing involves testing new health care technologies in human subjects. This stage encompasses a range of activities, from first human use to large-scale clinical trials and demonstration projects to determine efficacy and effectiveness (i.e., health benefit) and safety. Many of these activities are closely associated with technology assessment, as they form an essential part of the evidentiary basis for the field.

Diffsion is the stage of adoption and use of technology. As a new technology appears to be of value, clinicians begin to use it and patients begin to ask for it. Diffusion may culminate with the technology's attainment of an appropriate level of use or with the technology's abandonment, either

TABLE 1-2: Total Health Care Expenditures as Percentages of GDP (by year)				
Country	1981	1988	1990	1991
Australia	7,5	8.0	8.2	8.6
Canada	7,5	8.8	9.5	10.0
France	79	8.5	8.8	9,1
Germany	8.7	8.6	8.3	8.5
Netherlands	8.2	8.1	8.2	8.3
Sweden	9.5	8.5	8.6	8.6
United Kingdom	6.1	6.1	6.2	6.6
United States	9.6	10,8	12.4	13.4

SOURCE Organisation for Economic Co-operation and Development, OECD Health Data A Software Package for the International Comparison of Health Care Systems (Pans, France Organisation for Economic Cooperation and Development, 1993)

because it was of no value or because a more effective technology has been developed. The technology also may be used too much or too little, as often seems to be the case.

In recent years a great deal of attention has been paid to the possibility of assessing the benefits, risks, and costs of technologies before they come into general use and employing the results of these assessments to guide technology adoption and use. The way in which such technology assessments have developed in eight countries is the major theme of this report.

For various reasons the effect of technology assessment has been limited in these nations, especially when the forces of the health care system lead to behavior that differs from what is seemingly desirable. Consider the powerful incentives embodied in payment for health care. Physicians may be paid highly for doing endoscopies, and studies showing that endoscopy is overused will probably have little effect on practice as long as use is well rewarded. This situation underlines the importance of the structure of the health care system and the nature of policies on technology adoption and use. These factors are discussed in the chapters that follow.

CONTENT OF THIS REPORT

Industrialized countries have begun to intervene with mechanisms to influence the development,

diffusion, and use of health care technologies. The general and specific public policies that affect these processes in eight industrialized countries are discussed in chapters two through nine of this volume, which cover Australia, Canada, France, Germany, the Netherlands, Sweden, the United Kingdom, and the United States. Each chapter also presents that country's experience with a number of specific technologies: treatment for coronary artery disease (mainly coronary artery bypass grafting and percutaneous transluminal coronary angioplasty); medical imaging; laparoscopic surgery; treatment of end-stage renal disease (including dialysis, renal transplant, and erythropoietin); neonatal intensive care (including extracorporeal membrane oxygenation); and screening for breast cancer.

The eight countries are all at similar levels of socioeconomic development. Their populations vary from 8.5 million to 251 million and their gross domestic product per capita varies from about $17,000 to about $27,000 (table 1-1). In 1991, the percentage of Gross Domestic Product (GDP) going to health care ranged from 6.6 in the United Kingdom to 13.4 in the United States (table 1-2). The health levels of the selected countries are generally similar (tables 1-3 and 1-4). One must be aware, however, that health status is related to many factors besides health care and health care technology (88).

TABLE 1-3: Infant Mortality Rate (infant deaths per 1,000 live births) Selected Years, 1981–91				
Country	1981	1986	1990	1991
Australia	10.0	8.8	8.2	7.1
Canada	9.6	7.9	6.8	—
France	9.6	8.0	7.2	8.3
Germany	11.6	8.7	7.1	—
Netherlands	8.3	7.8	7.1	6.5
Sweden	6.9	5.9	6.0	6.1
United Kingdom	11.2	9.5	7.9	7,4
United States	11.9	10,4	9.1	8.9

SOURCE Organisation for Economic Co-operation and Development, OECD Health Data A Software Package for the International Comparison of Health Care Systems (Paris, France Organisation for Economic Cooperation and Development, 1993)

TABLE 1-4: Life Expectancy at Birth, Selected Years, 1981–91								
	1981		1986		1990		1991	
Country	Women	Men	Women	Men	Women	Men	Women	Men
Australia	78,4	71,4	79,2	72.9	80.0	73.9	NA	NA
Canada	79.1	71.9	79,7	73.0	80.4	73.8	NA	NA
France	78.5	70,4	79.7	71.5	80.9	72.7	81,1	73,0
Germany	76.9	70.2	78.4	71.8	NA	NA	NA	NA
Netherlands	79.3	72.7	79.6	73,1	80.1	73.8	80.3	74,0
Sweden	79,1	73.1	80.0	74.0	80.4	74.8	NA	NA
United Kingdom	76,8	70,8	77.6	71,9	78.5	73.0	78.6	72.0
United States	77.8	70.4	78.3	71.3	78.9	72.0	NA	NA

NOTES 1990 and 1991 figures for US and UK are not confirmed: NA = not available

SOURCE Organisation for Economic Co-operation and Development, OECD Health Data. A Software Package for the International Comparison of Health Care Systems (Pares France Organisation for Economic Cooperation and Development, 1993)

Each of these chapters introduces the country's form of government and economy and then describes the country's health care system. Policies concerning research and development (R&D), evaluation, diffusion, regulation, and payment for technologies are discussed, and the chapters end with the case studies mentioned above showing how these policies have been applied.

The final chapter of the report draws general lessons from the eight countries. As background for the policy discussions in the remaining chapters of this volume, the technologies featured in the case studies are defined below and their uses, efficacy, and costs briefly described.

Case studies

TREATMENTS FOR CORONARY ARTERY DISEASE-CABG AND PTCA

Coronary artery disease, the most frequent cause of death in the industrialized world, is caused by narrowing and blocking of one or more of the arteries that supply blood to the heart. Coronary artery bypass grafting (CABG) is a surgical procedure in which a grafted vessel is placed between the aorta and a coronary artery to bypass a contracted portion of the artery, improving blood supply to the heart muscle.

A number of surgical procedures were tried in the past to improve the blood supply to the heart, but CABG is now the standard procedure. The American surgeon Michael DeBakey performed the first CABG in 1964, using a vein from the patient leg as a graft to bypass the occlusion in the coronary artery. After its introduction CABG spread rapidly into practice. In 1991 more than 400,000 CABG procedures were done in the eight countries discussed in this report.

The first randomized clinical trials to evaluate CABG took place in the early 1970s. It was clear early on that the operation effectively relieved angina pain, but the impact on survival was less clear. A recent overview of the trials, in which CABG was compared with medical therapy, shows the following results (93): significantly improved survival in patients with left main coronary artery disease, and in patients with single- or double-vessel disease; a non significant trend toward improved survival at five years, but no difference at 10 years (68).

During the 1960s and 1970s, the use of a catheter to dilate arterial stenosis (narrowing) was investigated. In 1964 Dotter and Judkins (22)

al vascular system, noting substantial improve-ment in health status and avoidance of amputation of the limbs when used for peripheral blockage. This technique continues to be used in Europe but never gained adherents in America (40).

In 1974 Gruentzig and his colleagues (36) used a catheter with a modified distensible tip to dilate renal and peripheral arteries. Two years later a similar but smaller tip was used to dilate coronary arteries in animals, and the technique was then used in humans. This procedure, percutaneous transluminal coronary angioplasty (PTCA), is now the standard noninvasive (minimally inva-sive) procedure for cardiovascular disease. PTCA is done under local anesthesia and does not require an operating room, although emergency backup is necessary in case of cardiac arrest or other life-threatening complications.

PTCA involves penetrating the skin (percuta-neous), crossing the inner space of the blood ves-sel (transluminal), and affecting the vessel constriction (angioplasty). It uses a guide catheter that can travel to the constricted area and a balloon threaded by wire through the catheter and across the stenosis. When the balloon is in the appropri-ate location, it is inflated repeatedly with a mix-ture of saline and contrast material. As the balloon presses against the artery wall, fluid is expelled from the plaque, which then splits at its weakest point. Over time, healing occurs. Immediate suc-cess rates for stenosis are above 90 percent, de-pending on the characteristics of the stenosis, the patient's clinical status, and the skill of the clini-cians (39,48). Success rates for total blockage are considerably lower. PTCA is particularly indi-cated for short, segmental, and high-grade (more than 50 percent) blockages. Although restenosis occurs in 25 to 35 percent of patients, usually within six months of the procedure (46), PTCA has excellent later results, with few recurrences af-ter six months.

PTCA was not tested in randomized controlled trials in its early diffusion. Trials comparing PTCA and CABG are only now underway in both the United States and Europe.

The evaluation of outcomes in the case of pro-cedures on the coronary arteries is difficult. Cure cannot be expected. The patient generally contin-ues to have the disease, and symptoms are often progressive. Cardiologists favor PTCA primarily because it delays the need for CABG, a much more invasive procedure. An issue of increasingly visibility in the United States and some other countries is the possible inappropriate use of CABG and PTCA (92).

In recent years a number of new technologies have come into development, including laser treatment, stents, rotary devices, and others (89). In general these have not proved (yet) to have bet-ter results that PTCA (74). One prominent alterna-tive used increasingly in a number of countries is excimer laser angioplasty (6). Excimer laser an-gioplasty is being tested in a randomized clinical trial in the Netherlands.

The cost-effectiveness of PTCA versus CABG has been analyzed, but results the are not entirely convincing because of the lack of definitive in-formation on the effectiveness of the procedures. Comparing PTCA with CABG (without a pre-vious attempt at PTCA), the costs for a year of care (in 1984) averaged $US11,472 for PTCA and $US13,262 for CABG (70). A major expense in the PTCA group was the treatment of restenosis, seen in 33 percent of patients. These U.S. results might not necessary transfer readily to other coun-tries.

Comparing 100 patients with PTCA for at least two vessels to a matched group of controls under-going CABG, in one year of followup, one repeat PTCA was required in 10 patients, two were re-peated in one patient, and three PTCA patients un-derwent a CABG. The average costs for a year of care in this case were $US11,100 for the PTCA group and $US22,862 for the CABG patients (in the mid-1980s) (9). More recently, RAND Corp., using data from the Framingham heart study and expert judgment, estimated five-year costs at about $US33,000 for PTCA and $US40,000 for CABG (50).

A 1991 study estimated the cost per quality adjusted life year (QALY) for CABG in patients with left main disease with severe angina pectoris at 2,090 British pounds, compared to 18,830 pounds for patients with one-vessel disease with moderate angina pectoris.

MEDICAL IMAGING (CT AND MRI)

Medical imaging was born with the discovery of x-rays in 1895 by Roentgen in Germany. By 1900, x-rays were being used to diagnose fractures, gallstones and kidney stones, foreign objects in the body, and lung disease. Bismuth was used beginning in 1896 to allow x-ray pictures of the gastrointestinal tract (71).

The innovation of x-rays forced changes in health care organization in all countries. Departments of radiology were established in the early decades of this century, and they expanded rapidly in the 1920s (79,80). The specialty of radiology was formally established in the 1930s. Physicians thereby gained complete control of the medical uses of x-rays.

Medical imaging remained relatively unchanged until the computed tomography (CT) scanner was introduced to the market by the EMI Co. in 1972. The CT scanner is a diagnostic device that combines x-ray equipment with a computer and a cathode-ray tube (a television-1ike device) to produce images of cross-sections of the human body. The principle of CT scanning was developed by the English physicist Hounsfield; he succeeded in producing the first scan of an object in 1967, and in 1971 he was able to scan the head of a live patient. Commercialization of the CT scanner in 1972 initiated a revolution in the field of diagnostic imaging (86). The first machines were "head scanners," designed to produce images of abnormalities within the skull (e.g., brain tumors). "Body scanners" able to scan the entire body were then developed.

CT scanning was rapidly and enthusiastically accepted by the medical community. Despite concerns about its high cost—up to and more than **$US1 million—it** diffused extraordinarily rapidly and came into widespread use throughout the world. A number of companies developed CT scanners; the international market is now dominated by such companies as General Electric, Philips, and Siemens. Although no randomized studies of the value of CT scanning were done in its early years, clinical experience gradually accumulated that indicated its usefulness in many conditions. It is now a fully accepted diagnostic technology.

Magnetic resonance imaging (MRI) is a more recent innovation in the field of medical imaging, based on nuclear magnetic resonance (NMR). NMR images are formed without the use of ionizing radiation and reflect the proton density of the tissues being imaged, as well as the velocity with which fluid is flowing through the structures being imaged and the rate at which tissue hydrogen atoms return to their equilibrium states after being excited by radiofrequency energy. The first NMR image was published by Lauterbur of the State University of New York in 1973 (49). Prototype MRI units were developed in the United States, England, and the Netherlands in the late 1970s (87).

MRI produces images of cross-sections of the human body similar to those produced by CT scanning (86), with some important differences. A CT scanner depicts the x-ray opacity of body structure. MRI images depict the density or even the chemical environment of hydrogen atoms (42). These various properties are not necessarily correlated.

MRI has several advantages. It gives a high-contrast sensitivity in its images, and it can distinguish between various normal and abnormal tissues. Blood flow, circulation of the cerebrospinal fluid, and contraction and relaxation of organs can be assessed. Tissues surrounded by bone can be represented. Also, MRI does not employ potentially dangerous ionizing radiation, as do CT scanning and other imaging methods. It is not necessary to inject toxic contrast agents, as is often done with CT scanning (although contrast agents are being used more and more frequently with MRI scanning). MRI allows for a choice of different imaging planes without moving the pa-

tient; CT scanning can produce an image of only one plane at a time, and some planes are not scannable. Finally, images can be obtained from areas of the body where CT scanning fails to produce clear images.

Despite its potential, the initial diffusion of MRI in most countries was less rapid than had been the case with CT scanners. Introduction and diffusion were slowed because of the economic recession in the early 1980s. At the same time health authorities were unwilling to invest heavily in MRI before any thorough evaluation had taken place. Questions such as these were asked: Is present MRI an advance in imaging technology as compared with CT scanning? Does it produce useful information at a reasonable cost? Does it produce diagnostic information not otherwise available?

MRI has been repeatedly and formally assessed since its introduction (1 ,24,35,45,60,61,62,82, 86). An early issue of the *International Journal of Technology Assessment in Health Care* examined many aspects of MRI (72). These assessments agree that MRI is a reliable diagnostic device that produces information that can be quite useful. However, evaluation of MRI scanning has been far from optimal. For example, a literature review published in 1988 (18) found that 54 evaluations did poorly when rated by commonly accepted scientific standards, such as use of a "gold standard" comparison of blinded readers of the images (i.e., the expert doing the reading does not know the status of the patient). Only one evaluation had a prospective design. Also, over the period examined there was no improvement in quality of research over time, and this problem continued in later years (44,45).

Literature shows that MRI is probably superior to CT, its main competitor, for detection and characterization of posterior fossa (brain) lesions and spinal cord myelopathies, imaging in multiple sclerosis, detecting lesions in patients with refractory partial seizures, and detailed display for guiding complex therapy, as for brain tumors (44,45). In other diseases the efficacy of MRI is similar to that of CT. In fact, the best designed study, carried out in a heterogeneous group of patients in neuro-

radiology studied in a matched pair design, found that the sensitivity and specificity of CT scanning were somewhat better than those of MRI (38).

As for the diagnostic or therapeutic impact, little information is available. Investigators in Norway found that 33 percent of patients had their main diagnosis changed by MRI scanning (67). Plans for surgery changed in 20 percent of the patients, and plans for radiotherapy changed in 8 percent.

Although most MRI scans are of the brain(11), a specific advantage of MRI lies in diagnosis of spinal cord problems, where MRI may replace myelography, an x-ray procedure involving injection of a potentially dangerous dye. In the spinal cord two studies have examined the relative accuracy of MRI in relation to myelography and CT (57,58). The studies found that MRI and CT were roughly equivalent in terms of true positive results but that both were superior to myelography. MRI is gradually replacing both CT scanning and myelography (8,58). In one study the percentage of physicians ordering myelography prior to MRI dropped from 15 percent to zero during the two-year study period (67).

Another area in which MRI could be quite useful is in imaging joints (19,53). A common problem is torn or damaged menisci (cartilages) of the knee. The standard diagnostic procedure is either arthroscopy by scope or arthrogram, an x-ray procedure. Both are invasive in that the scope must be inserted into the joint or a contrast material must be injected. MRI is not invasive. However, the advantage of arthroscopy is that a therapeutic procedure can be done if an abnormality is found. Another common problem for which MRI may eventually be useful is herniated nucleus palposis ("ruptured disc").

The capital cost of an MRI scanner varies greatly, depending particularly on the strength of the magnets. A basic unit costs at least $US1 million. Operating an MRI facility in the United States costs between $US840,000 and $US1, 115,000 per year in the mid-1980s (1 1,3 1). Only about one-third of this operating cost is accounted for by the capital investment in the scanner itself. Other expenses include space, personnel, equipment,

and maintenance. The cost per scan in one mid- 1980s study was between $US370 and $US550, and the fee paid for the scan was **$US500**. (The costs apparently do not include payment to the physician.) Other studies have demonstrated that the costs of an MRI scan are considerably more than those of a CT scan (45). With increased throughput, MRI units have done well financially (32).

MRI costs maybe offset by replacement of other diagnostic procedures, particularly myelography (1 1). Although myelography requires hospitalization of at least one day, MRI can be done on an outpatient basis. It does not appear to have replaced other modalities, such as CT scanning in the brain, except that it is used preferentially in suspected posterior fossa tumors (84). In general, however, replacement of other procedures by MRI has not been demonstrated. The result is a considerable increase in costs (7,66).

The basic issue with CT scanning and MRI scanning is that they provide similar information. It has been difficult to demonstrate much advantage with MRI.

LAPAROSCOPIC SURGERY

Laparoscopic surgery is part of what has become known as "minimally invasive therapy" (MIT) or "minimally invasive surgery," a new and rapidly growing area of medical treatment that causes substantially reduced trauma to patients. MIT is truly a new field in medical technology, depending in most cases on new, advanced technologies-specially endoscopes, vascular catheters, and imaging devices.

In some respects, however, MIT is not completely new. Physicians and surgeons have always used the orifices of the body to observe internal structures. The first workable endoscope was developed by Desorrneaux in 1853. The laryngoscope, which made it possible to look at the larynx and the vocal chords, was developed in 1857. The benefits of the ophthalmoscope and laryngoscope stimulated the development of devices to explore other body cavities, such as the vagina, rectum, and stomach (1860). Visual scopes, such as the

hysteroscope (1869) and the gastroscope (1870), came into use later; however, these procedures became truly widespread with the introduction of the flexible fiberoptic endoscope in the mid-1950s. Endoscopy then became a routine diagnostic tool. The movement toward surgery came as instruments were gradually incorporated into the scopes; they included miniature forceps, scissors, and (more recently) lasers, heat probes, electrocoagulation devices, and cryotherapy devices.

The first endoscopic examination of the abdominal cavity was carried out by Ott in 1901 in a procedure he named "ventroscopy." Kelling also carried out this procedure in 1901 and published a paper in which he described the entire procedure and its future possibilities (37). Nevertheless, the procedure was not often used, probably because of limitations of the technology. Introduction of the flexible fiberoptic endoscope in 1957 solved many of the technical problems and led to the widespread use of diagnostic laparoscopy.

The laparoscope was first used therapeutically in gynecology during the 1960s. The first International Symposium of Gynecological Endoscopy was held in 1964, and tubal sterilization by laparoscope was done with increasing frequency by 1969 (37). By 1974, a few treatments of endometriosis through the laparoscope by fulguration had already been reported (52).

Appendectomy is among the commonest surgical procedures in most countries. Appendectomy removes an inflamed appendix, which may perforate and spread infection. Appendectomy by laparoscope has now been done by Semm (73) in Germany for more than 10 years with good success. A gynecologist, Semm observed that during diagnostic laparoscopy for pelvic pain in young women, he sometimes found an unexpected inflamed appendix. He developed instruments to allow removal of the appendix through the laparoscope. The procedure is gradually gaining favor in the United States and Europe.

Laparoscopic cholecystectomy is the most dramatic case of laparoscopic surgery. Cholecystectomy, removal of the gallbladder, has been done since 1882. It is one of the most frequent surgical

procedures in industrialized societies. The standard treatment for symptomatic gallbladder disease (e.g., inflammation, stones) has been surgical removal, a procedure associated with ileus, pain, and a slow return to normal functioning (21) and a hospital stay averaging five days (90).

The first successful cholecystectomy via laparoscope was done by Mouret in France, in 1987. The procedure spread in France, and in 1988, particularly after publication of the experience of the group headed by Dubois (23), it began to spread internationally, particularly rapidly in North America (12). The first procedure was done in the United States in 1988 (69), but most of the spread has occured in the 1990s. In late 1990 more than two-thirds of 29 Canadian hospitals responding to a survey were already in the laparoscopic cholecystectomy business (13), Surgeons in the United States and elsewhere were skeptical initially, but patients began demanding the less invasive procedure and surgeons have acquiesced (5, 12).

Laparoscopic cholecystectomy was not evaluated initially by randomized controlled trials (5). In fact, evaluations of laparoscopic cholecystectomy played little part in its diffusion. Nonetheless, a number of uncontrolled studies give clear evidence of the superiority of this procedure in skilled hands (41 ,78). Other applications of laparoscopic surgery (in general surgery and gynecology) have not yet been well evaluated. These applications include hernia repair, bowel resection, treatment of colorectal cancer, removal of kidney stones, and a number of gynecological procedures, such as hysterectomy and removal of ovarian cysts (5).

Laparoscopic procedures are assumed to be more cost effective than the corresponding open surgeries, but few good analyses have been performed. The assumption of cost-effectiveness is based on a shorter length of hospital stay and an earlier return to normal activities. A comparative study of Australia and Canada estimated that the change to this procedure from open surgery could potentially reduce the health care costs of cholecystectomy in Canada from $C271 million to $C215 million and in Australia from $A124 million to $A1OO million (54). One can readily observe that the potential total savings from the 100 or so procedures included in MIT could be enormous. However, the number of cholecystectomies actually rose 15 to 20 percent after introduction of the laparoscopic technique in Canada and Australia (54). The actual health system savings achieved were only 56 percent of the potential savings in Canada and only 13 percent of those in Australia.

TREATMENTS FOR END-STAGE RENAL DISEASE (ESRD)

Hemodialysis and renal transplantation are two life-extending therapies developed in the early 1960s for victims of ESRD, a clinical condition reached when a person has such a degree of deterioration of kidney function that without treatment, he or she will soon die. In hemodialysis toxic waste products are removed from the blood by means of an artificial kidney. The first dialysis machine was built in the Netherlands by physician and bioengineer Kolff in 1943. His machine was the basis for dialysis treatment as provided today. In the beginning the dialysis machine could be used only for patients with acute renal failure because the cannulas inserted into the patient arteries caused serious damage and could be used only for a short time (a matter of days). This changed around 1960 when Scribner and Quinton invented a new shunt system linking an artery to a vein and making use of teflon and silicone rubber cannulas, which prevent blood clotting and damage to the arteries and allow the shunt to stay in place permanently. Since then, patients have been able to live on "chronic intermittent dialysis," usually about three times a week.

In renal transplantation a healthy kidney from a living person or from someone who has just died is substituted for an individual's nonfunctioning kidney. Kidneys were the first successfully transplanted organs and remain the prototypic transplant. The Russian surgeon Voronoy attempted the first kidney transplantation in a human being in 1933; however, this and other attempts inevitably ended in rejection of the organ and death of the patient.

After the Second World War, new attempts were undertaken. A great step forward was made through the work of Peter Medawar, an Oxford zoologist who studied the immune response and found ways to manipulate it and induce immunological tolerance. On the basis of this work, immunosuppressive therapy using different drugs was developed. Medawar's finding that the immune response was not present in closely related individuals gave doctors the courage to try kidney transplantation between identical twins. In December 1954 Murray performed the first successful kidney transplant in Boston between the twin brothers Richard and Ronald Herrick. Richard survived for eight years with a functioning donor organ.

In 1962 the first successful kidney transplantation using the kidney of a deceased, genetically unrelated donor took place, following the discovery of the effective immunosuppressive drug 6-mercaptopurine. In 1958 the French immunologist Dausset discovered the role of human leukocyte antigens in graft rejection, and this became the basis for tissue typing and matching, making possible the matching of organs from deceased unrelated donors to recipients. Kidney transplantation on a large scale thus became a reality.

Steroidal hormones were used in conjunction with antimetabolites beginning about 1962, producing better results. Antilymphocyte serum joined the other two types of drugs around 1966, further improving results. In the 1970s cyclosporin, a particularly effective drug that acts by suppressing certain T-lymphocytes, was discovered and began to be used clinically. (In addition to their benefits, these drugs have significant toxic effects.)

With these improvements, kidney transplantation spread into use around the world, beginning in the 1960s. Kidney transplants are performed for ESRD associated with all major causes—mostly in people under 65 years old but increasingly in elderly people as well. Transplants are considered a fully established medical intervention.

The current rate of kidney survival is about 65 percent survival for five years after one transplant and 45 percent after a second transplant (if the first one fails). The five-year rate of survival from live donors (about five percent of the total) is about 85 percent: for patients in the age group up to 45 years, it is about 95 percent, and in the age group 45 to 65, about 80 percent (34).

Kidney transplant and different forms of renal and peritoneal dialysis comprise the treatment mix of ESRD programs. Without dialysis, patients with ESRD would die if an organ did not become available in time. After irreversible rejection of a donor kidney, the patient would die without a second transplant or dialysis. In practice, kidney transplant is a substitute for dialysis; therefore, the effects of kidney transplant as well as financial costs must be considered in comparison with the outcomes of dialysis. In general, quality of life following kidney transplant is nearly equal to that of the general population and is considerably higher than that of people on dialysis treatment (29,43,77). (An increased number of kidney transplants does not lead to a gain in years of life because of the availability of dialysis, however.)

An exemplary study from the Netherlands illustrates the financial savings to be gained by transplant (20). The yearly cost of renal dialysis carried out in a dialysis center was found to be Dfl 77,000 (about $US40,000). Renal transplant was found to cost Dfl. 69,000 (about $US38,000) in the first year and Dfl. 6,000 (about $US3,300) in every succeeding year.

The cost per QALY has been estimated for different ESRD treatments (55). Hospital hemodialysis costs 21,970 British pounds per QALY, compared with 19,870 pounds for continuous ambulatory peritoneal dialysis, 17,260 pounds for home hemodialysis, and 4,710 pounds for kidney transplant.

A new technology frequently used as part of renal dialysis is erythropoietin (EPO), licensed in the United States in June 1989. EPO is a substance produced through biotechnology that stimulates the bone marrow to make red blood cells. The most frequent use of EPO is inpatients on chronic hemodialysis for ESRD, as such patients suffer from a depressed bone marrow leading to frequent blood transfusions. EPO can make transfusions

unnecessary or much less frequent. In clinical trials EPO has been found to reverse uncomplicated anemia of renal failure within months (16,47,91).

Several clinical trials have examined the efficacy of EPO. Evans and colleagues (30) examined the quality of life in 300 patients before and after treatment with EPO and found it was improved in various respects. Patients reported increased energy, activity levels, functional ability, sleep and eating behavior, disease symptoms, health status, satisfaction with health, sex life, wellbeing psychological affect, life satisfaction, and happiness. The Canadian EPO Group reported similar findings.

EPO is very expensive, however. In the United States, it costs about $US 10,000 per year per patient on chronic dialysis. Because patients apparently do not return to work, there is no financial offset for this expenditure, raising serious questions about the cost-effectiveness of EPO in the setting of chronic renal failure.

Maynard (55) found that the estimated cost per QALY gained by EPO for dialysis anemia, assuming a 10-percent reduction in mortality, was 54,380 British pounds. Assuming no increase in survival, the cost per QALY was 126,290 pounds. McNamee and colleagues (56) estimated that the cost per QALY gained at Df1374,000 (about $US210,000).

NEONATAL INTENSIVE CARE

Neonatal intensive care involves the constant and continuous care of the critically ill newborn. The origin of "modem" neonatal intensive care technology can be traced to the first incubators developed by the obstetrician Tarnier in Paris in 1880. He took the idea from a chicken incubator that he had seen at an agricultural fair. The scientific development of medical care for the premature child started with Pierre Budin, a pupil of Tarnier, who published a treatise on the care of the premature newborn in 1890. In the years up to 1950, the Tamier prototype was improved. The "Lion incubator," introduced in 1896 (at the Berlin World Exhibition) by Couney, had a metal

frame with glass doors, and air, temperature, and moisture could be regulated. Through Couney's promotional activities, specialized care for premature babies became established in the United States.

Another development was the Auvard incubator, a less sophisticated device made of wood in which hot-water bottles were placed. This machine became very widely used because it was relatively cheap. (Some hospitals used it up to the 1950s.) The most significant technological developments have occurred since World War II.

Most babies with severe problems weigh less than 2,500 grams at birth. During the late 1940s and 1950s, babies began regularly to be fed with indwelling tubes and to be given high concentrations of oxygen (15). Subsequently, the use of respirators, electronic monitoring, analysis of small blood samples, and the development of specialized staffs of highly trained nurses have become part of neonatal intensive care. Regional networks have been organized to coordinate services for obstetrical and newborn care in many countries. Regional tertiary-care centers have been developed to specialize in high-risk births and the care of sick infants.

Beginning about 1980, there has been concern about both the effectiveness and costs of neonatal intensive care. However, most studies (as in the case of prenatal care) consider the effectiveness (and/or costs) of a package of care given to high risk and very low weight infants, and it is difficult to isolate either the effective or the ineffective parts of this care (1 5).

There is evidence of falling mortality among populations of babies born weighing less than 1,500 g during the period of introduction of neonatal intensive care methods; evidence that low-weight babies born in institutions with neonatal intensive care units (NICUS) have a lower mortality rate than similar babies born in other institutions (65): and evidence in geographically based populations of better outcomes for low birth-weight babies with access to NICUS (4,33). The mprovements in outcome have been seen in the group weighing from 750 to 1.000 g (26).

More than 700 randomized controlled trials of aspects of neonatal care have been identified (59). These trials do not help much in gaining an impression of what works in NICU and what does not. They deal with quite varied subjects, such as the effect of supplementary feeding on neonatal jaundice or the value of red blood cell transfusion for infants with low hemoglobin levels. The numbers in these trials are generally small. For the most part, the trials give little guidance on best practice because of these problems and a general lack of relevance (59).

An increasing rate of handicap among the population might have been expected from the growth in NICUS, but it has not been seen (26). *(Numbers of handicapped children have, however, increased.)*

The most comprehensive evaluation of neonatal intensive care was carried out in Canada (10), in a study in which the economic aspects of neonatal intensive care of very -low-birthweight infants were evaluated using costs and outcomes before and after the introduction of a regional neonatal intensive care program. The two periods compared were 1964 to 1969 and 1973 to 1977. Information on health state was collected from parents and used to calculate outcomes in QALYs. The overall results show an apparently good outcome in the group weighing from 1,000 to 1,499 g as compared with the 500 to 999 g group. The economic cost per QALY gained in the first group is $Cl ,000, compared with $C17,500 for the other group (expressed in 1978 Canadian dollars). There seems little doubt that NICU, as a package, is effective. It is also an expensive intervention.

Technology development has been rapid in neonatal intensive care. This has resulted in a proliferation of untested technologies in a situation in which effectiveness already is not well understood (15). Although randomized trials of new interventions would be desirable, clinicians feel that they cannot withhold possibly effective treatments. The result is that "many interventions become part of the armamentarium of the practicing professional without ever having been proven to be effective" (15).

An example of such a technology is extracorporeal membrane oxygenation (ECMO), developed in the United States in the early 1970s. This technique is used to improve oxygenation and lower mortality in certain serious diseases (81). It is an expensive and invasive technique that is potentially both effective and hazardous. ECMO entails diverting part of the blood circulation through a device that permits gas exchange across a permeable membrane (51) and involves ligating (tying) the carotid artery of the infant (although a newer technique uses a catheter connecting two veins). Some feel that only a few infants could benefit from this treatment, as compared with conventional treatments such as supports for respiration and oxygen (3). Only one small randomized trial (19 babies) was done before widespread diffusion of ECMO in the United States (64) All other studies have been much less rigorous. Yet although ECMO is not proved to be of benefit, it has been stated that randomized trials are no longer possible in the United States (28). A multicenter randomized controlled trial is currently under way in the United Kingdom, coordinated by the National Perinatal Epidemiology Unit in Oxford. A trial using historical controls in the Netherlands, incorporating a cost-effectiveness analysis as part of the study, reported preliminary results in 1994 favoring ECMO over conventional treatment for neonates with severe respiratory distress (at a cost of DF153,500 per infant).

A recent development is the use of nitric oxide (NO) as an alternative to ECMO in the United States. The use of ECMO has begun to decline following experience with an apparently effective and less invasive modality. However, careful evaluations of NO have not yet been carried out.

SCREENING FOR BREAST CANCER

Screening for breast cancer was developed during the late 1960s and early 1970s. The key event in this case was a large, well-designed randomized trial carried out in the Health Insurance Plan (HIP) of Greater New York during the 1970s, showing clear benefits from routine screening in terms of

mortality from breast cancer in women over the age of 50 (75).

Two procedures are used in organized breast cancer screening programs (25): breast physical examination by a trained practitioner and x-ray mammography. Other methods, such as thermography, ultrasonography, CT, and photoluminescence, have also been proposed for screening, but have not proved effective. Breast self-examination has also been promoted and may be of benefit.

The HIP randomized trial offered the interventional group, approximately 31,000 women aged 40 to 64 years, four successive annual screenings with two-view mammography and breast physical examination. About 67 percent of the women accepted, and approximately 50 percent of those received at least three screenings (76). The trial showed a statistically significant reduction in mortality in women who were over 50 years of age at entry into the study. Five years after entry, the reduction in mortality was about 50 percent, falling to about *20* percent at 18 years after entry. For women 40 to 50 years of age at entry, the reduction in mortality was small (about 5 percent at five years, and not statistically significant) (17).

These studies have been followed up by two randomized studies in Sweden (2,83), one in the United Kingdom (85), and a number of nonrandomized studies. These studies in total seem to demonstrate benefit from screening but leave a number of unanswered questions. One problem is that each one has used a different screening regimen, so the independent contribution of the two methods of examination cannot be estimated. (Despite this, most articles reporting on the studies refer to "mammography screening.") Another problem is that the studies have been done at different times with different x-ray technologies; the question of the usefulness of modern technology cannot then be answered. Nonetheless, it is widely assumed that modern x-ray mammography screening alone is of benefit.

A contentious issue is the question of screening women under the age of 50 years. In the United States some groups do not recommend screening women under 50 years of age (25), but others do.

In Canada the Task Force on the Periodic Health Examination does not recommend screening younger women (14), but the province of British Columbia does support this practice.

A number of cost-effectiveness analyses of breast screening have been carried out. For illustrative purposes the results of one study from the United States will be presented. Using a number of assumptions, Eddy (25) estimated that a program that screened 25 percent of American women between the ages of 40 and 75 would cost $US4.2 billion for annual breast physical examination alone and $US15 billion for examination plus mammography. Using outcomes from the HIP study, the marginal cost of adding a year of life with both examination and mammography would be $US 134,081 in the age group from 40 to 50 years; $US83,830 in the age group from 55 to 65 years; and $US92,412 in the 65 to 75 year-old group. Other studies have found lower costs per year of life added with breast cancer screening. Typical figures range between $US13,2000 and $US28,000 per year of life saved (27). Maynard (55) found that the cost for a QALY gained through breast cancer screening was 5,780 British pounds. All of these analyses embody certain assumptions about benefit that might not be true.

INTERPRETATION OF THE CASES

Each country has dealt with these technologies, and information on their benefits and costs, in different ways that reveal various forces at work in technological diffusion. The chapters that follow will examine them from each country's perspective.

In chapter 10, these technologies are revisited. Differences and similarities in how they have been treated in each country are highlighted in that chapter.

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