NMML OCCASIONAL PAPER

PERSPECTIVES IN INDIAN DEVELOPMENT

New Series
26

Medical Technology: Review and a test of perspectives

Indira Chakravarthi

Nehru Memorial Museum and Library
2014

Published by

Nehru Memorial Museum and Library
Teen Murti House
New Delhi-110011

e-mail : ddnehrumemorial@gmail.com

ISBN : 978-93-83650-18-7

Price Rs. 100/-; US $ 10

Page setting & Printed by : A.D. Print Studio, 1749 B/6, Govind Puri Extn. Kalkaji, New Delhi - 110019. E-mail : studio.adprint@gmail.com

Medical Technology: Review and a test of perspectives*

Indira Chakravarthi**

Introduction

Technical innovation is considered to have played an important role in the profound transformations that have taken place over the past century in medicine and in the delivery of medical care through hospital-based health systems and also by making available effective preventive, diagnostic and therapeutic tools. The most visible of these changes are the widespread use of instruments and equipment ranging from the simple to the very complex, the centering of medical care in hospitals and the rise of numerous specialties and sub-specialties—features commonly described as 'high-tech' or 'state-of-the-art' medicine.

Much of the influx of technology into medicine began in the industrialized countries of the West in the latter decades of the nineteenth century. It took firm roots by mid-twentieth century, and has since become an indistinguishable component of medical practice and health-care systems, and an important form of technology in modern society. Indeed, the term healthcare technology is used by many to denote medical technology. To a very large extent in the industrialized countries of the West, and much acclaimed and adopted in nearly all developing countries such as India, medical care is provided through complex hierarchical delivery systems, involving a lot of technology, and

---

* Revised version of the lecture delivered at the Nehru Memorial Museum and Library, New Delhi, 7 May 2013.

** Indira Chakravarthi is presently a Fellow with the Nehru Memorial Museum and Library, New Delhi.

numerous specialized personnel. The use of technology in medicine is accepted as natural and given, as an inevitable, desirable feature of medical practice and healthcare.

However, by the mid-twentieth century several problems with medical technology and medical practice started to be highlighted, such as the safety, efficacy, costs and effectiveness. There was a general consensus that medical technologies are expensive to acquire and maintain, and substantially contribute to increasing the costs of medical care in a number of ways. The high cost had come to be seen as a problem that needs a solution. Others considered that the root cause of the increasing healthcare costs lay in too much technology, which they felt should somehow be regulated.

Since the 1970s, modern medicine, especially 'high technology medicine' has also come to be described in a variety of negative terms—expensive, esoteric, mechanical, and inhumane, an expression of power, and so on. Illich propounded the idea of clinical iatrogenesis—pain, sickness and death result from provision of medical care—as a problem of industrialization of society, and industrialization of medicine.[1] In the mid-1980s it was pointed out that 'for some high-technology medicine is a blessing, a saviour, while to others it is a burden, a scapegoat; to some it is a milestone marking progress in medicine; to others it is a millstone holding back progress towards the millennium of preventive and holistic medicine…'.[2] In general, there is voluminous discourse and writing about medicine and its technology, about the nature, cost and effects of medical technology by a range of scholars, including medical professionals. As aptly put by Leo Marx,

> …advances in medicine and social hygiene are perhaps the most widely admired realm of science-based technological advances; nonetheless, it is often said today that those alleged advances are as much a curse as a blessing.[3]

---

1 Illich (1975)
2 Jennet (1984)
3 Marx (1994) p 239

Such analysis of technology has largely been swinging between the dichotomies of 'good'–'bad', between 'glorification'–'vilification', between 'utopia–resignation'. Despite much analyses and writing there seems to be no effective and meaningful resolution of the problems attributed to technology in modern societies, especially medical technology. Despite reservations and conflicts, mainstream medical practice remains dominated by technology, and continues to seek technological solutions to health problems. Despite their alleged role in pushing up costs of healthcare, promotion and widespread adoption of medical technologies continue.

In the four sections that follow, this paper reviews the approaches to study of technology and of medical technology respectively and applies the findings to evolve a critical, socially relevant approach to the understanding of the socially significant activities of science and technology, of modern medicine, public health and medical technology. The attempt is to provide a coherent social underpinning to the emergence of medical technology, and shed some light on at least some of these problems in the Western as well as in the Indian context. This analysis postulates that there is adequate information available on medical technologies to identify some patterns. It therefore attempts to synthesize available case studies, to address broad questions with larger units of analysis over longer time frames to reveal aspects not easily evident from case-studies and micro-studies. The review seeks to explicitly bring the social–cultural–economic–political issues into the analysis. It adopts an inter-disciplinary approach and uses insights from history of medicine and public health, sociological studies of medical innovations, and evaluation/policy studies. A significant point of departure of the present analysis from existing ones is that: (a) it views medical technologies as part of an interdependent system of medicine and public health, in an industrial capitalist society; (b) it delves into discourse within the medical profession on technology; and (c) it looks at production of technology, by drawing in information on the medical technology business and industry. These are dimensions largely neglected in studies of medical technology.

1
Approaches to Technology

Since World War II there has been a large amount of writing on science, technology, and medicine, respectively. Science and Technology Studies (STS) has since become an established discipline. Vessuri identifies two broad components in these studies of science and technology, and of a tension between these two streams. On one hand is the disciplinary approach, linked to the traditional academic disciplines of sociology, economics, history, anthropology and political science. The other is *the problem approach*, which is forced upon us by the very dynamic and impact of technical, scientific and social change. Such as writing by feminists on technology and medicine, especially on reproductive technologies and their impact on women's lives. According to Vessuri this approach is a rich source of inspiration —not only does it foster the renewal of research agendas, thus putting new demands upon the traditional disciplines. It also helps practitioners in this broad work front 'to participate in the political and social debate of the contemporary technological society in which we live and in which their transformations are not only a source of joy, but also of suffering'.[4]

1.1 *Technological Determinism*

Technological determinism (TD) is the single most influential theory regarding the relationship between technology and society—the dominant perspective guiding much of the studies of technology. This is the view that technological development occurs according to some naturally given logic; that technology is autonomous and that it impinges on society from outside. Further, it is believed that technology is the primary causal agent in social change; that changes in technology cause social changes—social structures evolve by adapting to technological change. In its strongest version, the theory claims that change in

[4] Vessuri (1996)

technology is the most important cause of change in society.[5] In other words, the proponents of technological determinism view technology (and science) as a-social institutions whose development is driven by the unfolding of their own internal logic. An associated view is that there is no distinction between science and technology: advances in science are considered to lead to its applications, namely that technology is nothing but 'applied science'. The traditional linear model of technical innovation and development in this TD perspective considers technologies as 'applied science' emerging through a sequential flow from basic science, through applied R & D, to commercial production and use/consumption. The invention–innovation–diffusion processes are conceived as separate stages in an essentially linear process. These established artifacts then diffuse through the marketplace to have 'impacts' upon society, work organization, production systems, and so on. All science and technology are looked upon as objective and neutral instruments of cultural, social and economic progress and development (the notion of scientism). In this view, therefore, the scientific and technological capacities are linked to the development and economic success of a country. It is argued rather constantly stressed, especially in 'developing' countries like India that science and technology be harnessed for the growth and development of the nation.

---

[5] Leo Marx discusses the transformation in the idea of technology, on one hand, and in the ideology of progress, on the other, over the nineteenth century, wherein technology is not just discrete, identifiable artifacts, but includes abstract, scientific and seemingly neutral systems of production and control (technocracy). At one time innovations in science and in the mechanic arts were regarded as necessary, yet necessarily insufficient means of achieving general progress, which was conceived as a more just, more peaceful and less hierarchical society based on the consent of the governed. This republican idea of progress got transformed over time, where progress came to be construed as improved technology; where improvements in technical means became an end in itself, became the basis and measure of progress in society, and there was a tendency to bypass moral and political goals. In other words, what is called as the *technocratic idea of progress, which is considered to be characteristic of corporate capitalism*. Within this idea there was a 'reification' of technology in the late nineteenth and early twentieth centuries, and technology came to be invested with a host of metaphysical properties and potencies, and as an autonomous agent of social change (Marx 1994).

Most studies of science and technology are conducted within this TD framework. So we have policy related studies as well as economic models and analysis of technical innovations and change, of science and technology (S & T) infrastructure and capacity, of research and development (R & D) capacities and expenditures relating it to economic concepts of productivity, performance and competitiveness, cost-benefit analysis of technologies, of transfer of technology from developed to developing countries and so on. Furthermore, studies have also tended to concentrate on the effects, on the impact of technology on society and descriptions of 'how technology has changed the way we do many things', namely *technology shaping society*.

In the aftermath of World War II, and especially during the Cold-War period and after the Vietnam War, there arose a lot of concern about developments in science and technology and their impact.[6] Socially, the 1950s–1960s was the period of social ferment and counter-culture movements, including the radical science movement. The dominant 'use-abuse' understanding of science and technology was found to be inadequate on many counts and there arose critiques from several quarters such as from the anti-war movement, the organised left and the women's health movement. Radical political critiques of science appeared in the 1960s and 1970s wherein the concept of neutrality of science was questioned; the role of science and technology

[6] In July 1955 the Russell-Einstein Manifesto, initiated by Bertrand Russell and Albert Einstein, and endorsed by several other scientists, drew attention to the threats posed to civilization by development of nuclear and hydrogen bombs, to 'the perils that have arisen as a result of the development of weapons of mass destruction…'. The scientists spoke as human beings, as 'members of the species Man', whose continued existence, they felt, was in doubt. They felt that the world then was full of conflicts; and overshadowing all minor conflicts was 'the titanic struggle' between Communism and anti-Communism, between the East and the West. (*www.pugwash.org/about/manifesto.htm*, last seen 3.9.13). This call led to the first Pugwash Conference on Science and World Affairs in 1957, at Pugwash, Canada. The offer of the then Prime Minister of India, Nehru, to host this Conference in Delhi was accepted; however it could not be held here (*http://www.pugwash.org/about/conference.htm*, last seen 3.9.13).

in imperialism, in exploitation of workers, in racism, in war and in oppression, became matters of central concern. There were also feminist critiques of science, and the women's health movement came up with critiques of medicine based upon their experiences. As pointed out by Martin, during that period 'a critique of science was seen as a part of a critique of society. The emphasis was on political economy, especially an analysis of capitalism'.[7] There were calls and movements for alternative technologies, such as for 'appropriate' technology and 'intermediate' technology. There was also questioning of ideologies of a 'technological imperative' which suggested that particular paths of technological change were inevitable.

Critiques of technological determinism have given rise to a large collection of studies and literature which can be broadly categorized as social shaping of technology (SST) that emerged in the 1970s and the social construction of technology (SCOT) of the 1980s. Together, SST and SCOT offer better insights into the complexities in the development of technology and its role in society. In these, technology is viewed not as existing outside or above society, but as a social product, subject to social forces and amenable to social analysis, and thus open to social intervention. They provide insights into the social processes of the conception, invention, design and development of technology all of which embody particular social relations. However, there are also significant differences between the two.

1.2 *Social Shaping of Technology*

The social shaping of technology perspective emerged in the 1970s from Marxist labour process debates about production. The question that it posed was: 'what has brought about the technology whose effects are being studied, are being experienced by society? What role does society play in the shaping of the technologies we have?' MacKenzie and Wajcman argued for 'at least equal time for the study of the "effect of society on technology"', to study this issue also more seriously and systematically.[8] The SST perspective as it was broadly referred to

[7] Martin (1993)
[8] MacKenzie and Wajcman (1985)

proposed that in the early stages of development of technologies choices could be made between alternative processes. The choices/final products are shaped by interests—economic, social and political—of individuals, groups and institutions involved. Essentially it implies that we view technology not as something that has suddenly 'appeared', but as something that has been developed and produced by certain individuals or groups of individuals, as a product of human relations and actions. Along with 'technical' considerations, a range of 'social' factors shape the outcome, thus influencing the content of technologies and their social implications. Our technology, like our economy or our political system, then becomes a social product, a characteristic of how we live; it ceases to be an independent factor, dropping out of the blue and making us accept it or reject it.

1.3 *Social Construction of Technology Perspective*

The social construction of technology perspective (SCOT) emerged in the 1980s as an extension of the sociology of scientific knowledge approach (SSK) from the sociology of science into the realm of technology (in other words to study the *social construction of facts and artifacts*).[9] It tries to explain how technological artifacts/ technologies are developed, are 'constructed' by social processes. A common feature of all the studies within SCOT is the emphasis on 'thick description', that is, looking carefully into what was considered as the 'black box of technology', to see what it contains. While social constructivist studies have been useful in conceptualizing technology development as a social process, they have been a-historical, highly empirical and focussed on micro contexts, an aspect that has drawn critical appraisal from several quarters.[10] Adequate attention is not given to the relations between these micro contexts and the larger

[9] The sociology of *scientific knowledge,* in turn was an extension of the sociology of knowledge to the study of the so-called 'hard sciences'. See Pinch and Bijker (1984).

[10] There have been several critiques of the constructivist approach in the sociology of science. Such a mode of analysis does not move beyond the micro-sociological level of analysis, and has contributed little to the understanding of the interface between science, technology and society. According to Baber one of the 'unintended consequences' of the

macro context and macro processes, which may not always be visible. Such as: the influence of the dominant cultural values of technocracy and of consumption of capitalist societies. They do not provide answers to why we chose these technologies to begin with, or to the question of dominance of technologies in areas such as medicine and public health.

The SST approach offers a more comprehensive framework that incorporates the specific with the larger context to address the many different levels, forms and processes by which social relations interact with and affect choice of technology and its expansion; to locate technology in the context of the larger social structures of production, as well as deployment and use. Studies in this genre looked at a range of social factors as well as 'technical' considerations that pattern and affect the design, direction of innovations and processes of implementation of technology. The idea of *technological systems* was used in some of these studies. It was argued that increasingly technologies were being made not as separate, isolated devices, but as part of a whole, as part of a system, such as the invention of the electric bulb by Edison.[11] Attention was also drawn to the important role of cultural values such as that of 'the culture of engineers' in which there is fascination with computers, and the most automated is seen to be the most 'advanced', and in which human factors (in production, in measurement) are seen as sources of human error to be eliminated.

---

proliferation of studies in this relativist/constructivist SSK genre has been a total neglect of 'the constitutive historical question of the sociology of science: what explains the origins of modern science in the seventeenth century and its ascendance in four centuries to a position of cognitive monopoly over certain spheres of decisions', neglect of the comparative historical and civilizational perspective pioneered by Joseph Needham (Baber 1998). Martin describes the developments in the sociology of science as 'the taming of science studies by its academic context'. Science studies has become the study of science as it is, as it is serving society; the radical critique and development of alternatives 'have been pushed to the wayside'. Studies of science have become less accessible to scientists and activists, more insular, more disconnected from the early concerns about the human impact of science and crucial social issues (Martin 1993).

[11] Hughes (1987)

Studies also illustrated how the requirements/considerations of capitalist production (such as those of economy, of efficiency, of profitability, of control over labour process, the growth of nuclear family), have shaped the outcome where choices in technology have existed.[12] With the example of nuclear power, Winner drew attention to the dynamics of large-scale socio-technical systems, and brought in the theory of technological politics that takes technical artifacts seriously, and identifies certain technologies as political phenomena in themselves. According to him,

> *The things we call 'technologies' are ways of building order in our world.... Consciously or not, deliberately or inadvertently, societies choose structures for technologies that influence how people are going to work, communicate, travel, consume, and so forth, over a very long time.... In that sense technological innovations are similar to legislative acts of political foundings that establish a framework for public order that will endure over many generations. For that reason, the same careful attention one would give to the rules, roles, and relationships of politics must also be given to such things as the building of highways, the creation of television networks, and the tailoring of seemingly insignificant features on new machines.*[13]

Yearley broadened the sociological vision to examining the role of science and technology in the underdeveloped world, located within the broader academic concepts of underdevelopment.[14] It has also been proposed that the social processes producing technologies should be situated in an established framework—that provided by a broadly Marxist form of radical social analysis.[15] There is also need to understand the contexts, the specific domain, in which the objects are deployed—the study of specific technical systems and their history helps understand which technologies and which contexts have become

[12] See MacKenzie and Wajcman (1985) for these studies.
[13] Winner (1980) pp. 127–28, (1986)
[14] Yearley (1988)
[15] Russell (1986)

important to us and why. For instance, an important dimension to understanding medical technology is to locate it in the context of the overall medical and healthcare system, the ideas and values regarding health and disease, of what keeps populations healthy, role of medicine and of medical practitioners, how to provide medical care, and so on. It has also been argued that there is need for a theoretical perspective in which technical and economic activities are embedded in and interact with a more complex social structure; need of a perspective that draws both on sociology and on economics; it is not enough to join together bits and pieces taken from the two.[16]

Over the 1990s, Feenberg has renewed the potential of technology studies by articulating a theoretical–philosophical approach to technology in the context of modernity. He concedes that while cultural studies and constructivist sociology and history had shed new light on technology, however, they have so 'disaggregated the question of technology as to deprive it of any philosophical significance'.[17] They have become a matter of specialized research and have been unproductive because they remain at an abstract level. They do not have any implications for technological development, the actual foundation of modernity. They minimize or ignore the top–down control of technical rationalization such as by corporations. Feenberg sees no distinction between technology and culture in modernity; he puts forth a 'critical theory of technology' to bridge technology studies with modernity theories, and to develop a theory of democratic technological change that would allow reshaping of modern technological society. According to him 'The poverty of actual techno-culture must be traced not to the essence of technology but to other dimensions of our society, such as the economic forces that dominate technical development, design and the media'. The design that a given technology takes is shaped by social actors not all of whom have the same amount of influence in this process. Those groups whose worldview determines what is normal and real and rational have a greater say in the designs of technology than those of non-dominant ones. As a result, the technologies/designs that one actually sees are not necessarily the single

---

[16] Blume (1992)
[17] Feenberg (2003)

most efficient and rational ones, but those which are from among a group of potential designs, best reflect the hegemonic beliefs and values of the dominant group; which Feenberg calls *technical codes*. The invisibility of these technical codes makes them appear as normal even though they are not. Further, technology in modern societies has become a legislative political institution and therefore should be controlled democratically; rather than be left to a few privileged groups. Lastly, Feinberg's critical theory suggests that 'the starting points of a new path are not to be sought in speculative fantasies but among marginal elements of the existing system…technologies corresponding to different civilizations co-exist uneasily within our society'.[18]

2
Medical Technology

Over the twentieth century the term 'technology' has come to represent simultaneously an artifact/device/machine, a specialised form of theoretical knowledge or expertise, a distinctive mental style and a unique set of skills and practices. In fact it is felt that technology is identified less closely with the material or artifactual aspect, and is much more an abstract, inclusive concept denoting the inter-penetration of the machine with certain kinds of knowledge, practices and organisational styles.[19] In keeping with this concept of technology, the term medical technology denotes a set of procedures, techniques, drugs, devices, equipment and facilities used by healthcare professionals in delivery of medical care; it includes the organisational and supportive systems within which such care is delivered.[20] Medical technology is also used to refer simply to the instruments and equipment used by medical professionals in providing medical care. One also comes across terms such as 'hard' and 'soft' technologies, where 'hard' technology

[18] Feenberg explores the inter-penetration of technology, economics, politics, and culture, the relationship between technology, rationality and democracy in modern societies, and makes a strong case for the radical democratization of technological societies. See Feenberg (2002).
[19] See note 5.
[20] This commonly used definition, or characterization, of medical technology, is that of the Office of Technology Assessment, USA.

refers to equipment-embodied technology, such as instruments, machines and devices, while ‘soft’ technology refers to organizational and financing mechanisms. Working definitions have been formulated in Europe and the US largely for regulatory purposes and are more specific and limiting.

2.1 *Technology in Medicine*

There is voluminous literature describing the history of developments in modern medicine and medical technology. Reiser’s historical account of the introduction of several technologies in the ‘art and practice of medicine’ during the past four centuries in Europe and North America and the responses of the medical profession is a seminal work. He provides detailed descriptions of the origin and development of some instruments and techniques (such as the stethoscope, thermometer, microscope, sphygmomanometer, and clinical laboratory tests) and on the processes by which a technical innovation got accepted or rejected by the medical profession.[21]

The deterministic notion about technology prevails in the field of medicine too, in the views regarding medical technology. For instance: in a colloquium in 1980 on medicine and technology it was argued that there was a *technological imperative in medicine*. ‘What began as simple tools and purely effective extensions of the physician’s personal approach to the patient have, especially in the last 80–100 years, become intrinsic, self-propagating, requisite and almost autonomous elements of today’s biomedicine’. The colloquium concluded ‘I would guess that by 1990 we will be proceeding in a more rational way in the practice of medicine and the distribution of healthcare’.[22] However, despite a lot being written about the economic and social impact of medical technology, it is said that nothing clearly emerges about the nature of the problems regarding medical technology, nor how they can be resolved; that no country had yet succeeded in developing a coherent system for assessing healthcare technology.[23]

---

[21] Reiser (1978)
[22] Both quotes cited in Hofman (2002)
[23] Banta and Luce (1993)

Perusal of medical literature reveals that there are debates about and concerns within the medical profession about the tendency for (over) dependence on technology, over its possible gains and losses to medicine. Reiser's work reveals that the routine practice and organisation of early twentieth century medicine was slow and cautious in changing and in accommodating the new ways of representing and understanding disease that were becoming possible. Beginning in the seventeenth century, the introduction and acceptance of medical technologies has been a long-drawn out process, marked by tension/ contestation between the proponents and opponents of the concerned technique/technology. The delegation of responsibility for diagnosis to technical experts raised basic moral problems for twentieth-century medicine. According to Reiser, in the late-nineteenth and early-twentieth centuries (by which time technologies like the x-ray and the clinical laboratory had started becoming widespread) two movements developed within the medical profession which raised important questions about the uncritical reliance of medicine on technologically generated facts. One attempted to reverse the growing neglect of the patients' views, their history and description of symptoms, and emphasized that these symptoms constituted important evidence and should be carefully considered by the doctor in evaluating illness. The other emphasized that all techniques used to gather and evaluate medical evidence, including those based on technology, were liable to significant error. They also urged physicians to explore their own attitudes towards illness and ways of reaching medical judgments. It was pointed out that 'facts obtained from the laboratory are in one sense no more objective that those collected at the bedside—both types of evidence must be interpreted by the human mind. Instruments are only powerful transmitters. Essentially all data are subjective: in all observations an opinion is registered at the same time that a fact is recorded'.[24] The writings of medical professionals such as Cochrane raised considerable doubts about the efficacy of many medical procedures in general.[25]

---

[24] Reiser (1978) p 183
[25] Cochrane (1972)

2.2 *Limits of Technological Determinism: Technology Assessment, Denial of Choice*

Given the pervasive influence of the technological determinism perspective, it is not surprising that it has been taken for given that there will be 'advances' in medicine and medical technologies and also that complex, advanced technologies will be expensive. It is as if a technology has somehow suddenly appeared and then adopted into medical practice, and started having certain effects, desirable or undesirable.

The evaluation, largely of costs or of organizational changes to adapt to the technology or to make efficient use of it, is taken up well after the technologies have diffused into medical practice and have become 'standard procedure'. In fact the dominant paradigm assumes that technological assessment can take place only after the prototype technology has been developed, and subsequently, after it has diffused in the healthcare system.

Availability of technologies and their widespread adoption and use in North America and Europe, especially the extremely rapid diffusion of the CT-scanner in the mid-1970s, triggered off questions in policy circles about costs of technology and gave rise to national policies and legislation to regulate the cost, development and diffusion of technologies. Medical technology assessment emerged as a policy area. There is extensive documentation of impact of medical technology in the industrialized countries of the West a large proportion of it on the impact on cost of healthcare and on regulatory mechanisms. These provide several critical insights. The limited usefulness of conventional economic evaluations for medical procedures was one such issue. It emerged that technology assessment was not a simple matter of putting together data on cost-effectiveness and making a 'once and for all' decision in the light of evidence. It also emerged that development of technologies does not always follow a neat, systematic process where it is possible to distinguish clear stages of development, adoption and regular use. Technologies were adopted even before they had been fully evaluated for their usefulness and effectiveness.

Technology Assessment (TA) addresses the problems that arise *after* the technology has become well established, which is of limited value. Firstly, it is unable to reverse the damage that can be caused by its use such as those of x-rays and pharmaceutical drug. Secondly, by the time evaluations are taken up the technology is often already locked into particular organizational structures and patterns of use. It is seen that once a technology diffuses into practice, it sets off a chain of events such as: institutional changes, attitudinal changes among doctors, and changes among patients' attitudes. It becomes next to impossible to reverse these events, no matter what the results of the evaluations. In promoting their cause, advocates of a new technology dwell on/highlight the defects or disadvantages of older or alternative methods, and it becomes difficult (if not impossible) to maintain earlier skills or even test out or refine the alternatives.

Another crucial fall-out of this deterministic approach is that it implicitly denies any possibility of choice in technological development. In this view therefore, the purpose and scope of study of technology, and of public policy is limited to (1) forecasting and/or monitoring the progress of technology along its inevitable trajectory, (2) to find ways of increasing the pace of innovations, their diffusion, etc., by making available the required resources, removing the obstacles, modifying the policy, and (3) promoting the smooth adaptation of concerned organizations and society, in general, to the changes it demands. The problems associated with a technology are viewed in relation to use of a specific technology and/or as arising from some aspect of the healthcare system, such as shortage of resources for healthcare or use of excess personnel or the mode of payment for healthcare, or inappropriate use, and so on. This is of limited use if at all; as it assumes that the technology is desirable and so has to be made available to the people. Hence they need to be managed or regulated by use of some economic or legal instruments, or by adjustments in society (impose limits on hospital budgets, laws to curb malpractice, or to prevent use of technology for a particular purpose, change in attitude/behaviour, limit population size, and so on). The problems and dilemmas that arise are viewed as incapable of resolution, as a price that one has to pay for the putative advances or benefits from the technology. Questions such as whether there can be other technologies or other ways of treating diseases even within the biomedical model are either not posed at all or tend to be ignored.

Much of the sociological discourse on medical technology has been in the framework of technological determinism (TD) or social essentialism. They have either over-estimated or under-estimated the technologies. All the topics traditionally of interest to sociologists have been projected on to medical technology, but what is typical or unique about medical technology has not been adequately explored.[26] Criticisms of medical technology have also emerged from women's groups, disabled persons' groups and feminists, which largely view it as an instrument of control and hegemony by the medical profession.

Hence, while case-studies abound of what happens when a technology gets adopted into medical practice, there has been no attempt to systematically address the issue of why there is widespread adoption and misuse, despite their supposed role in pushing up cost of medical care, and despite lack of formal evaluation of effectiveness of many technologies. There is hardly any attempt to synthesize these studies, or to get a larger picture of the landscape of medical technology. There is a narrowness of analysis that tends to view the issue of expense and proliferation of technologies, especially of high technology, in medicine as separate from that of the culture, practice and organization of medicine and medical care itself. Despite a large number of micro-studies and so much scholarship on medical technology, one finds that there is no attention to organization of medical care and healthcare policies.

Scant attention has been paid to actual development and production of technologies. Existing studies do not address the question of how innovations actually develop; why we have only these particular technologies and not something less expensive, or less complex, or free of the problems that have been identified. They do not also take into account the social context of the use and deployment of medical technologies, at the larger reality of the organization of medical care and healthcare.

---

[26] Timmermans and Berg (2003)

This is so despite observations such as the inadequacy of professional dominance theory in explaining adoption of medical technologies,[27] the references to influence of commercial forces in the manufacture, marketing and use of medical technologies, and observations on role of the State in development and promotion of technologies.

2.3 *Development and Production*

Within the conventional definition of medical technology, production of vaccines and therapeutic drugs and pharmaceuticals has received a lot of attention**.** There is substantial work on the emergence and activities of this industry—on research and development of new drugs, on pricing mechanisms, international trade, interaction of the pharmaceutical industry with the medical profession, its influence on policy, pricing, and regulations, and on the political economy of the industry. Liebnau's business history account reveals the interaction of technology, business and medicine in the evolution of the pharmaceutical industry in the late nineteenth–early twentieth century.[28] The work sheds much useful light on the producers and manipulators of medical technologies namely industry, scientists and physicians. According to Liebnau the medical industry must be viewed, together with the hospital, as a major source of medical technology. Davis's study of production of pharmaceuticals as a dynamic network of relationships among the individual (patient/consumer), the doctor, the state, the media and the industry, concludes that from a policy perspective the fundamental dynamics are provided by the economic actors, namely the industry, the State, third-party payers, professional organizations, and even

[27] Greer's study to examine the participation of physicians in actual technology decisions reveals that the traditional views/hypotheses of hospital domination by concerns of clinical medicine are greatly complicated by concerns with the fiscal-managerial management of the growth and development of the institution (Greer 1984). There are different reasons for acquisition of technology by hospitals, depending on the objectives of the hospitals and their ownership pattern, whether it is a government or teaching hospital, and so on.

[28] Liebnau (1987)

consumer and user organizations. Even within this network of economic relationships it is the industry that plays the formative and most strategic role. The fundamental axes are: profit generation and competitive survival within the industry, fiscal balance and macroeconomic management for the state, risk management and budgetary viability among provider organizations and financial access for the consumers. Driven by the constant search for profit and survival, it enters into a dynamic set of relationships with other actors. The major fallout of this preoccupation with profitability is that the growth of the industry has not been in consonance with the needs of the people.[29]

With the emergence of the social constructivist approach the development of medical technology has received some attention. For instance, Yoxen's study of formation of medical consensus around value of images brings out the influence of the culture of scientism and of professional socialization of doctors and engineers on the development of medical ultrasonography.[30] Blume's study of several imaging technologies (x-ray, CT scanning, ultrasonography and MRI) details the co-operation and mutual dependency among scientists, doctors and industry in the processes of innovation and adoption, the importance of these interactions as also the support of the government. He argues that 'the structure of relations that have developed between radiologists and the firms supplying instruments to them is in some sense vital to innovation processes in diagnostic imaging'; and that 'not the structure of production alone, but the structure of use as well, and the relations between the two exert crucial influence on the innovation process'.[31]

3
Development and Diffusion of Medical Innovations: Findings from case studies of some widely used technologies

The proponents and promoters of existing and new medical technologies argue that these technologies are the best possible ones

[29] Davis (1997)
[30] Yoxen (1987)
[31] See Blume (1992) p 54 and p 261 respectively.

from the viewpoint of modern medicine and that a technology becomes 'standard practice' and 'routine' only after it has been thoroughly tested for its efficacy, effectiveness and safety, based on objective scientific criteria. They are widely adopted also because they are better than existing ones. An analysis of development and diffusion of some widely used medical innovations provides important insights about the considerations and criteria that lie behind development and promotion of medical technologies, and raises doubts about the above claims by their proponents of being rational and the best. It also sheds light on the emergence of the medical equipment industry in the mid-twentieth century, on the significant role of industry in the adoption/ diffusion of technologies, on the role of State and its policies, and on the interaction between users of technology (the medical profession) and business.[32]

3.1 *Interests in Development and Promotion of Medical Technologies*

- As already mentioned, by the early twentieth century, use of technologies for diagnosis and treatment was considered to be an integral aspect of the practice of 'scientific medicine'.[33] By the 1970s there existed the notion of 'technological imperative' in medicine. Prior to and in the early decades of the twentieth century, innovations had emerged out of the work of individual

[32] This and subsequent sections are drawn from the author's doctoral research on medical technology, in which these case studies have been described and discussed in detail. See Chakravarthi (2009).

[33] Discussion of the origins over the mid-19th to early 20th century of the intense relation of technology and medicine in the name of scientific medicine is beyond the scope of this paper. While the concrete scientific developments of the period led to the application of scientific thought and investigation to problems of disease, and were adopted by the reformers of medicine as an essential component of the medical reform and professionalization process, scientific medicine had equally important economic and social origins. It succeeded also because it gained the support of dominant sections of the society in the west. See Brown (1979) and White (1991). See also Note 59.

researchers who pursued certain areas of investigation due to a general interest in the science, and hence depended upon chance, and chance encounters between individual researchers and entrepreneurs/manufacturers. Engineers and physicists, largely university based, or as small entrepreneurs, provided design skills and ideas to medical practitioners who provided clinical inputs and more importantly, had access to patients. In general, for a long time much of the research and development was being performed in non-industry settings, in hospitals and universities. Many individuals and small entrepreneurial companies played a significant role in developing much of today's creative and glamorous technologies, with or without co-operation from clinicians in hospital settings. The manufacturing industry, especially big established ones entered the scenario only when they saw the market potential. By and large, they undertook product refinement and introduced newer models, rendering older ones 'obsolete'. Thus, there began the association of the medical profession with manufacturing of technology—and with business.

- The process of innovation and development of medical technologies became different in post-World War II period. Following the two World Wars there was a search for new uses of skills and knowledge acquired during the war; search for medical applications of technologies and interests of clinicians, rather than genuine clinical/public health needs and problems became an impetus for development of technologies. At the larger level changes in the political and socioeconomic sphere, as well as the cultural impact of X-ray technology were such that there was a shift from notion of hygiene and social improvement to 'miracle technologies' as the basis of health. Hence there was a favourable climate for development of technologies, towards 'applying every new discovery in science to health', and so on. Innovations and developments in the immediate post-War period can be looked upon as systematic attempts to redeploy/apply to medicine skills, technologies and knowledge developed during the war or from defence research institutions. Engineers, scientists, and physicians in several countries now pursued the possibility of applying several technologies for clinical/medical purposes.[34]

- Scientific research and the development of technology (science and technology 'S&T') now became more organized. An important development was that governments started taking interest in S&T, in facilitating and influencing such activities through funding and other support mechanisms. A 'strong' S&T base was considered as an important input for economic growth and development of a country. Strengthening and expansion of the medical technology industry was made a priority in innovation policy in a number of countries.[35] In certain instances, interaction between the industrial manufacturer and the medical profession was mediated directly by the State. Further, regulations and policies as well as the mechanisms by which governments provided healthcare had their impact upon development of technologies and the medical equipment industry. Government regulatory policies with respect to application and diffusion were influenced by the interest of national industries.[36]

- There existed a variety of ideas and resources regarding how to get information about the body (investigative mechanisms for process, direct observation of morphology, and measurement of body parameters such as temperature). Of these only some prevailed and got established into medical practice— x-ray and radiology dominated, while others such as thermography got marginalized. For instance, mammography

[34] For example: the experience in World War II of use of sonar and radar technologies for spatial location of objects (based on ultrasound), and of lasers had a significant influence on development of diagnostic ultrasound and of medical lasers respectively. Similarly, with infrared thermal imaging, and of use of lithium batteries developed for use in space were used in pacemakers, and so on.
[35] Blume (1985)
[36] Groot (1988)

was promoted over ultrasound and thermal imaging for breast cancer screening and detection.[37] Several questions arise: How much are the 'failures' of some technologies attributable to solely technical limitations? Was enough research conducted before they were shown to be technically not feasible or inappropriate for clinical use? What about the role of professional and commercial interests in the choice of areas to be pursued, in their acceptance as viable or plausible areas for research and development, and in the ultimate 'failure' and 'success' of medical innovations?

- The development and diffusion of the CT scanner illustrates the considerations guiding the process of medical innovations. This technology is well known for its extremely rapid diffusion in the early 1970s, and the first instance of commercialisation of a medical technology. After the initial work at EMI, government support became critical for further development and testing of prototypes. There was planned, organised interaction by the UK government between the manufacturer and radiologists, with the government permitting testing of the prototypes in its hospitals, as also committing funds for initial development and purchase of prototypes. During the development phase itself, a strong commercial dynamic was created among the radiology profession. No established names in X-ray manufacturing then, (and currently the major manufacturers of CT-equipment) were involved in the initial phase of development. In fact they did not want to license CT technology initially; but licensed it only when the development was complete and there was a booming market for it. It brings out the power of the big players in the X-ray industry to capitalise on their substantial resources and their established relationship with the radiological profession.[38] The industry did

[37] See Blume (1992).

[38] The CT scanner was developed over the late 1960s by an engineer working with the English firm Electric & Musical Industries (EMI), a pioneer in making electric records and other home entertainment equipment, which had made huge profits from sales of the Beatles' records. It had

not take any risks, so to say. While planning and organisation in development of technologies are needed, the problem is with the objectives. In this case they were driven clearly by the industry's questions and concerns regarding how to support its development, manufacture, and marketing. This reality of development of innovations raises questions about the justification of patenting by big industry who work on the premise that 'advanced technology' needs substantial R & D input, and therefore will be expensive.[39]

- It also indicates that the 'success' of a technology, or what will ultimately prevails, depends on numerous factors such as the ease with which it can be accommodated in the existing structures, or on the ability of its proponents to mobilise the resources needed for its development. Berggren invokes the idea of an organizational structure of which modern technologies are critical components; this structure 'selects' and then promotes interesting technologies. CT-scanning received the backing and resources from an established 'socio-technical system of radiology' that contributed to its immense

no experience in medical equipment. The then established manufacturers of x-ray equipment, such as Philips, Siemens, General Electric, entered the market only after EMI had carried out the development work with state support, thereby reducing the risk to them, and when the work was more to do with product refinement. The big advantage they had, which manufacturers like EMI lacked, was contact with the radiology profession and established marketing organisations in the x-ray sector. (see Blume 1992).

[39] In the late 19th–early 20th century there were debates (in USA) over the ethics of patenting of products meant for medical care. Universities and academic researchers then resisted patenting innovations for several reasons —such as free flow of scientific knowledge, and how to allocate the profits of the final result because of the interconnectedness, the group nature of scientific research. The situation posed a genuine dilemma especially in bio-medicine—often physician-inventors found that commercial organizations exploited remedies based on their work, which went against their traditional professional ethic of not profiting from patients (see Weiner, 1987, Foote 1992 p. 30).

'success'.[40] The components of this socio-technical structure are the professional specialty of radiology, and the well-entrenched and resource rich x-ray manufacturing industry, with its firm linkages with the radiology profession. CT-scanning attracted early support from public agencies. Being based on x-ray technology, it found immediate acceptance in radiology, which by then was well established and occupied a central place in diagnosis. Together and independently, the radiology profession and the x-ray industry had well-established channels for disseminating information on developments in CT-scanning at all levels, from the local to the international. In a system as well developed as this and encompassing many common values, the emphasis in technology development and research is on established fields. Fields outside to it tend to get inadequate attention and resources. Blume also points to the centrality of the inter-organizational field of radiology and x-ray industry in development of innovations. Subsequently the x-ray manufacturing industry also took over the manufacture of ultrasonography equipment, and this modality has now become part of the diagnostic imaging 'armamentarium'.

- With regard to this selection of 'interesting technologies' the 'culture of engineers' needs to be given due consideration, in which the most automated is presumed to be the most advanced, the best, and in which there is a fascination with computers and the most automated techniques. In this culture human factors (such as in measurement) are construed as sources of error that need to be eliminated. This is a value strongly held by the dominant sections of the professional class of engineers, scientists, doctors, managers, and technocrats in general. To what extent such factors too contributed to the immense 'success' and glamour of CT-scanning, MRI, and other imaging technologies, rather than just their usefulness in diagnosis and management of the disease remains unexplored. The current trend in diagnostic equipment is increasingly in favour of complex imaging systems and scanners dependent

[40] Berggren (1985)

on computer processing, which cost upto tens of lakhs of rupees, which are being manufactured by only a few multinationals, and are very aggressively promoted and marketed.

- It also emerges from these case studies that to understand how and why we now have certain kinds of technologies, we need to look at the history of all innovations/ideas that co-existed, but 'failed' to become part of modern medicine, or were not as well-accepted as some others were, or were not adequately worked upon or developed.

- In absence of resources/funds, or where there are controls/ regulations, doctors/health institutions are not easily able to acquire a technology. In such cases non-state agencies with different interests/motivations (not always commercial) have stepped in and aided procurement of technologies, in the name of charity and public interest—as in the case of charities and other non-governmental organisations aiding purchase of CT scanners in UK and of the lithotripter in Germany.

3.2 *Lack of Rigor in Assessment of Technologies*

- It is assumed that complex, expensive equipment such as CT, MRI, PET scanners, cardiac care units, would be evaluated and tested rigorously before huge financial outlays are made on them; that such an investment would be based on evidence of considerable gains for medicine, actual and potential. However, the diffusion of CT scanners took place without formal and detailed proof of their efficacy. It was very expensive by any standards, and yet it was purchased without sufficient information regarding its applications, safety and effectiveness. The evidence regarding accuracy and usefulness was based on clinical experience, and there was no information available on therapy planning and patient outcome.[41] A commentary on the 'battle for the x-ray scanner market', notes that while several

[41] Creditor and Garrett (1977)

> major manufacturers of radiological equipment including EMI, were targeting the lucrative market in North America, all were lacking in one attribute essential for medical equipment, namely, clinical evidence of their capabilities.[42] The situation was such that most of the manufacturers had placed at least one machine in a US hospital, and it was expected that within a year they would have some experience to call upon. Yet another shortcoming of this glamorous technology was the lack of attention to radiation dosage levels delivered to the patients. The acceptance of the new technology was so rapid that operating regulations for permissible x-ray levels had not been drawn up; existing ones for use of conventional x-rays were being loosely applied to CT-scanners. The adoption and diffusion of MRI also shows a similar pattern. Similarly, Coronary Care Units (CCUs) grew rapidly in the USA, in late 1960s-early 1970s despite lack of controlled studies showing effectiveness.[43] At a conference in 1968, sponsored by government agencies, greater development and support of CCUs were advocated, despite clear statements in the conference that their effectiveness had not been demonstrated.

It follows from the above that indications for use of a technology are not sufficiently established before their adoption; the studies made on the effectiveness of technologies such as the imaging technologies and their safety, have been quite small in number and were extremely uncritical. Formal evaluation and the usefulness of such high-cost equipment remain to be established, even though a lot of resources and institutions are committed to them. There is widespread adoption, and we find that currently many of the users of such inadequately evaluated equipment are outside teaching hospitals and established clinical research centres, concentrated largely in private hospitals and diagnostic centres. It appears therefore that adoption of technologies in medical practice takes place despite the inadequacy of empirical support for their efficacy and usefulness, and despite lack of information on safety and indications for their use.

---

[42] Kehoe (1976)

[43] Waitzkin (1979)

- The conflict regarding clinical utility of ultrasound, thermography and mammography in breast cancer reveals lack of rigorous standards in the medical profession for evaluating usefulness of innovations. Several issues regarding mammography were unresolved, especially that of safety. Yet, it was advocated and promoted over thermography for screening and detection of breast cancer.

- Yet another issue is that regarding the concept of 'invasive' and 'non-invasive technologies/techniques'. On one hand, sections of the medical profession are always making a case for innovations that are non-invasive or minimally invasive. Much of the development of technology within medicine has been aimed at outlining structures inside the body without having to cut the skin, and therefore without pain (non-invasive or minimally invasive technologies). X-rays were the first of these, followed by the use of CT-scanning, and ultrasound, which was promoted and used in situations where x-rays were likely to be harmful, especially in pregnant women. The fact that these radiations are potentially harmful to the body has been completely ignored, and these technologies continue to be perceived as 'non-invasive'. Similarly, the potential of alternative techniques like thermography (infra red imaging) for breast cancer detection, which involve measurement/observation of physiological parameters (such as temperature) as against mammography was not fully pursued, and was actually marginalized, on basis of assessments by the radiology specialty. Instead we have development and promotion of imaging technologies that are promoted as non-invasive, but actually subject the human body to x-rays, ultrasound and strong magnetic fields, simply on the presumption that no harmful effects have been observed in their use. This is an issue that has significant implications for the concept of safe technologies.[44]

[44] A technology can be safe to begin with, or it may be unsafe, but built in a way where it has to be used cautiously to avoid harm. Dyson's description of a project to design and build nuclear reactors for civilian use illuminates this concept of 'engineered safety' and 'inherent safety'

- Safety of technologies does not get the attention that it should in a profession associated with healing and health. There are controversies and unresolved issues regarding the safety of the imaging technologies— conventional x-ray, CT-scanning, and ultrasonography. Such as: in case of CT-scanning no attention was paid to radiation dosage levels delivered to the patients, especially to children. Till 2000 none of the CT manufacturers paid much attention to reducing radiation dosage levels associated with the CT equipment**.** The tremendous increase in CT usage has only now led to concerns about the long-term consequences of such exposures. Use of CT for mass screening of asymptomatic individuals (such as for lung cancer, cardiac disease, whole-body scanning) is a recent innovation, driven partly by the increased availability of CT-machines. While there is no consensus yet about their efficacy, there is significant exposure to x-ray involved, and indications are that radiation risk to lungs may be significant. Yet only now concerns are surfacing about long-term consequences of such exposures. Sections of radiologists hold that it is desirable to reduce CT-usage as long as patient care is not compromised, that CT-doses can be also reduced.[45] Only now dosage-reducing programmes are being introduced. Physicians and radiologists are only now talking of the importance of education to increase awareness of the hazards of radiation dose associated with paediatric CT, and of minimizing the dose by reducing or eliminating non-indicated CT scans.[46]

- Similarly, ultrasonography became part of routine antenatal practice in USA and Europe without formal evaluation of its benefits or even its need, and continues to remain 'routine' despite evidence of lack of benefit. Routine scans in pregnancies

---

of a technology—meaning that *its safety was guaranteed by the laws of nature and not merely by the details of its engineering.* A group of scientists and engineers worked on the physics of the safe reactor and the chemistry of its fuel rods, and succeeded in building a safe, working reactor in 1959 (Dyson 1979 p 102).

[45] Hall and Brenner (2008)

[46] See Miglioretti et al (2013)

are of low benefit, and may actually present a risk for certain foetal examinations, depending on the exposure conditions chosen, and the training, skills and awareness of the ultrasonographer.[47] Despite findings showing potentially adverse effects of ultrasound and uncertainties, it continues to be said that the clinical use is safe. The rider is that its use has a 'good' efficacy and safety record only when used in a proper clinical setting, according to well-laid-out standards of medical practice, by skilled and well-trained people.[48] As in the case of CT, only since the past few years are medical professionals calling for caution and rigorous education and training in use of ultrasonography. Despite use of x-rays and ultrasonography for several decades now, and despite knowledge of the effects of these radiations on tissues, safety remains a neglected issue, and is set aside as a technique becomes 'routine practice'. Though reservations regarding such unsafe practices exist, however, these are only among small sections of the medical profession.

So we find that within the domain of scientific medicine there is scepticism and conflict among the medical professionals. These are different approaches different ways of thinking about a disease, its diagnosis and treatment. Yet we see that only some technologies, some specialties, like the x-ray and the associated specialty of radiology dominate, are looked upon as the best, while others are marginalized, have 'failed'. Similarly, the field of coronary care is marked by differences regarding management, as indicated by the debates over invasive and non-invasive care.

It is striking that in a field such as modern medicine, which claims a scientific basis and is also associated with healing and curing, many of the dominant and so-called 'standard' practices are based upon *a belief* in efficacy and effectiveness of a technology, rather than adequate evidence based on well designed clinical trials. There is lack of rigorous standards among the medical profession over evaluating usefulness of

[47] Filly and Crane (2002)
[48] Barnett (2003)

innovations. There is inadequate evaluation before introduction of a technology.

Our analysis reveals that innovations become part of medical practice despite the inadequacy of empirical support for their efficacy and usefulness, and information on indications for their use. There is a tendency to apply costly, half-way technologies even before they have been proven to be safe or effective, and ignoring their side-effects. Complex imaging technologies are being adopted even before adequate education and training modalities have been established, carrying serious implications for their safe and effective use. The situation begs the question: 'Why does the healthcare system use technological methods and procedures that have not been proven to be effective, why does it not stop using technological methods and procedures that have proven to be inefficacious, ineffective, or inefficient? Even in the age of evidence-based medicine it appears to be difficult to make the healthcare system implement the results of technology assessment'.[49]

3.3 *Actions of Industry to Promote Adoption and Diffusion of Technologies*

It has been argued that the development and rapid diffusion of the lithotripter technology in Germany was influenced by considerations other than those of therapeutic benefits, and control over costs and distribution. This study brings out the role of interested doctors, the Health Insurance Associations and other private organizations in its promotion, indicating that the market is likely to take precedence over planning needs.[50] In the context of coronary by-pass surgery and cardiac care units, it was observed that an 'industry' was being built around this operation.[51]

The rapid diffusion of CT in USA and Europe led to formulation of several regulatory measures. Policy analysis showed that these regulatory measures did not have much effect on diffusion of

49 In Hofmann (2002)
50 Kirchberger (1988)
51 Braunwald (1977)

technology. According to Blume 'where major economic interests were at stake, ways of circumventing legislation were sought'.[52] He cites the example of Philips, one of the largest corporations, having joined with clinician-customers in avoiding having MRI limited by legislation.

The above observations on the combination of the interests of sections of medical profession and industry in promoting technologies are corroborated by the observations on the activities of the medical equipment industry in contemporary times. There is sufficient basis to attribute the widespread usage of certain kinds of technologies to not only sections of the medical profession, but also to industry actions to promote their use.

- Manufacturers of imaging equipment are undertaking several activities other than production: They offer a variety of services to accompany their products in order to promote and sell imaging equipment. This includes education of personnel, software support, financing for very expensive equipment and specialized construction/modification of buildings. At the immediate level this leads to a kind of dependence on the part of the medical professional purchasing the equipment. Furthermore, the more technically complex the product and the less technically sophisticated the doctor the harder it is for them to experiment with competing brands. While doctors lack the time and resources to evaluate the 'new knowledge' that is being made available, disproportionately, more forces are available to the manufacturers producing such 'knowledge'. This makes the doctor receptive to the selective information presented by the industry side of the medical–industrial complex. This has been extremely well-institutionalized by the pharmaceutical industry through the vast network of medical representatives, and is now spreading to the medical equipment industry too.

- Within the medical equipment industry medical imaging is beginning to occupy a significant place and becoming a big

52 Blume (2000) p 182

business. It is also significant that MNCs with multiple lines of business— Philips, GE, Siemens, Toshiba—are the major players in this sector which holds a lot of glamour among sections of the medical profession.

- It is difficult to ignore the manner in which training and education in new medical technologies takes place, by which new information about them becomes available to the medical professionals, and the way medical knowledge is communicated in and through the marketing practices of the pharmaceutical, equipment and publishing industries.[53]

A major activity of manufacturers is that of organizing education, training and research in medical imaging. The multinational corporations such as GE and Philips are putting resources into not only marketing, but also into education, training and research and trials in academic centers. In case of imaging technological developments and research on new clinical applications are taking place hand-in-hand. As manufacturers need data on the equipment they are teaming up with clinicians and offering incentives to place equipment in hospitals to gather data from patients. Thus the immediate source of information about medical innovations happens to be the industry itself and the specialists/experts involved in the research and development of the innovation. (In India imaging is not taught adequately at the undergraduate level and it is totally a post-graduate course, the number of seats for courses like radiology have remained more or less static for years, while the number of equipment has vastly increased. As a result there are not many competent and well-trained radiologists and sonologists.)

At present continuing medical education (CME), seminars, conferences, live operative workshops demonstrating use of equipment, demonstrations of ultrasound scanning on live subjects, and exhibitions of medical equipment are the major means of acquiring and exchanging information about new technologies and procedures.

---

[53] de Camargo (2002)

Observations on the adoption of endoscopy and minimal invasive surgery during the 1980s well illustrate the situation.

> The surgical revolution set in train by the technological advances of the mid-1980s was largely uncontrolled, with few safeguards to protect patients from enthusiastic, but inadequately trained surgeons… People took it up before it was proven, and before they acquired necessary skills. Some people have certainly tried in the past to do operations for which they were insufficiently trained. Some patients definitely died as a result.[54]

In fact, nowadays these types of activities, sponsored and funded by pharmaceutical and equipment industry, have become annual events and predate publication of refereed articles or studies. A section of doctors justifies practices such as live demonstrations on grounds of providing 'educational benefit'. However, others have raised several concerns, and pointed out that it is unlikely that any increase in skill levels can be achieved from a single demonstration, where the audience is shown the diagnostic capabilities of the equipment. They are essentially marketing exercises and poor alternatives, if at all, to structured teaching and training. There is a serious danger of some degree of over-simpification of the examination process.[55]

- There is also congruence of interests among the various players in the 'healthcare industry'[56] and this should also be considered while analyzing the promotion and adoption of such technologies. Trials of equipment and accessories, related techniques, search for new applications, are being carried out by companies by placing the equipment in hospitals, diagnostic centers, and educational institutions, through joint ventures,

---

[54] Cusheri and Jones (2000)
[55] Barnett (2003)
[56] The term 'healthcare industry' encompasses all types of hospitals, diagnostic centres, pharmaceutical- medical equipment- insurance industry. The hospitals sector is reported to form the major component of this industry; hence the term healthcare industry is commonly used while referring to corporate and other big private hospitals.

> tie-ups, etc. The concern for the industry is not so much regarding clinical needs and priorities or safety, but more to exploit the medical care in both public and private sector, to find new applications, and to use it for further marketing and promotion. We see that without undertaking proper evaluation in institutions equipped to evaluate and test new technologies, medical technologies are being promoted and sold widely based solely on anecdotal or descriptive accounts of a handful of doctors using them. Concerns have been raised from within the medical community itself about the huge differential in availability of funds for technological/commercial development and that available for basic scientific and health-related research.[57]

Such promotional activities of the medical equipment industry have to be viewed against the commercialization of medical care and emergence of a healthcare industry in the neo-liberal regime. This healthcare industry itself is part of a global marketplace, and the medical equipment market is being looked upon as a big marketing opportunity. Medical equipment manufacturers, especially from the USA, are of the view that they must look increasingly at developing economies for future growth.[58]

4
Looking beyond Physicians and the Medical Profession, Defining the Social Context

It emerges that the development, adoption, promotion and widespread diffusion of medical technology since the mid-twentieth century cannot simply be attributed to 'progress in research' and to 'scientific/effective medical practice'; that factors other than the results of objective evaluation are involved in their adoption and diffusion, in the rate and the extent of their spread. Analysis of technology without considering the social context of its origins, development and use tends to be incomplete, and therefore incapable of resolving the dilemmas

---
57 Barnett (2003)
58 See Chakravarthi (2013, 2010)

and problems arising from technology. Any attempt to conceptualize medical technology must be able to encompass the social dimensions, rather than go by a narrow conception solely in terms of procedures and machines that are used by members of the medical profession on sick individuals. It cannot be understood solely with reference to merely technology or to medicine, but needs insights from both areas. Therefore, medical technology is best understood within a broad systems paradigm, incorporating a structural-historical-dialectical approach, and an understanding of technology, of medicine and of healthcare systems in modern societies.

The postulation of the social context common to the social shaping of technology and social medicine[59] approaches are useful in this regard. Thus, viewing medical technologies as part of medical care and public

---

[59] The period from mid-18th to mid-19th century was crucial for the genesis of modern public health in Europe and North America, as a response to the problems of industrialization and the associated processes of urbanization, with the 1830s and 1840s being the formative period, when there was an explosive growth of cities, and concentration of work and workers inside factories and in urban slums—in other words the period of rise of industrial capitalism, and its social and medical problems. Many physicians of that period carried out studies of the relationship between this industrialization, disease and medicine, and some participated in progressive social reform movements, and in the revolutionary movement of 1848 in Europe (Hamlin 1998, 1992). These ideas were denigrated and relegated to the background in Europe and North America, with the professionalization of medicine and growth of 'scientific medicine' by the latter part of the 19th century. Nevertheless, such ideas remain among sections of the medical profession. The study of shaping of health and disease by societal and social factors, and the forms of medical practice that derive from it, became known as social medicine. Social medicine is based on the principles that: social and economic conditions profoundly impact health, disease, and practice of medicine; and that society should promote health through both individual and social means. The way we define health and disease, the methods used for diagnosis and treatment, how we finance and provide healthcare, all these cannot but reflect the social environment in which medicine operates. Social medicine looks at these interactions in a systematic way (Anderson et al 2005), and therefore does not rely solely on technology as the remedy for ill-health. See also Note 33.

health systems, which in turn function within modern capitalist societies, enables an understanding simultaneously of the larger social shaping of health, medicine and public health, as well as of the technologies that are part of these systems.

4.1 *Ideas of Health and Disease, Choice of Health Systems*

In the period that is considered to be 'the golden age' of public health, it was a contested issue, and a choice was made from among different views that existed regarding health and disease causation. These choices have had profound and far-reaching implications for medicine, medical practice, and public health. The debates on ill health and disease-causation in the mid-nineteenth century —for instance between medical people subscribing to a constitutional medicine approach and the Chadwickians—represented different social philosophies and conceptions of health, which in turn implied different kinds of public health activities. There were possibilities of a different kind of public health and medicine, which could have guaranteed social justice and health. However, choices were made in favour of technically based sanitary measures and of single causative factors such as the germ, as opposed to the more encompassing constitutional medicine and social medicine approaches, all of which laid the basis for a technology- intensive medical practice and preventive public health, without having to address the root causes of disease in populations.[60]

With the consolidation and spread of industrial capitalism by the early twentieth century, and the accompanying rise of welfare policies in North America and European countries, living standards had vastly improved and problems of nutrition, hygiene and sanitation got addressed. The accompanying faith in and euphoria regarding progress in science and technology led to intensive use of technology in medicine and public health became the application of scientific and medical knowledge to the protection and improvement of the health of populations. In this notion of public health, technology-based medical interventions held the solution for most disease. The modern medicine based health systems claimed success of their bio-medical based public

[60] Hamlin (1998, 1992)

health strategies for the improved health status of these countries. This in turn provided the rationale for the transfer of such technologies to the colonized countries.

The centrality and dependence of medicine on technology suits the industry, as it creates vast markets for its products. Production of these as a part of the capitalist system is guided by the same notions of profits and markets, and therefore necessitates the continuing development of new products and sales in new markets. That this is widespread in the drugs and pharmaceuticals industry is a well-documented fact. The medical technology industry too, comes with its objectives of profit and markets. In fact, in the context of medical technology assessment, it has been observed that: 'the entrepreneurial basis of industry is not necessarily a sound way to produce the most desirable technologies. A *laissez-faire* approach tends to result in the production of very sophisticated machines, often very costly, which may not meet the most important technological needs …'.[61]

An important group of actors in the developments in medical technology have been the elite class of professionals—doctors, engineers, scientists—all socialized and trained to think about the body, disease and role of medicine and healthcare in the bio-medical paradigm, within the technocratic rationality of modern capitalist societies. In more recent times the imaging technologies in medicine embody such values, and perhaps that is why they are received with so much admiration and awe, as also receive so much professional and public attention and resources. These professionals get significant support from the middle and upper classes to which they too belong, which already have access to basic welfare services and good health status, and now look to medical technology for further improvements of life spans/quality of life.

The state has also been a significant actor in the development and promotion of medical technologies. The provision of such technologically based medical care and preventive measures has taken a certain trajectory, which has matched the developments in health

[61] Stocking and Morrison (1978)

system for an industrialized, capitalist society. Through the 20th century healthcare services and public health measures largely remained a responsibility of the state; healthcare provision was the marker of ‘welfarism’ in Europe, as well as in many developing countries. This created a system where the state financed and provided the health services, but the production of technologies needed for diagnosis and therapy were very often shared by private industry. In spite of the centrality of the state in providing financing and regulatory measures for medical technology, these countries are also faced with problems that accompany heavy use of medical technology, as in the USA.

Since around the turn of the twentieth century the demands of the international economy have started affecting healthcare provisioning. These have led to a transformation from welfare-provisioning to introduction of markets in healthcare, and to health sector restructuring in the name of economy, efficiency and effectiveness. The very concept of public health is being transformed. The model of healthcare that is sought to be implemented through these transformations is largely that of the healthcare system in the USA—provision of medical care based on market principles, which has ramifications at several levels. Among other things it fosters *fetishization* of illness through an increased and intensified effort at selling ineffective, wasteful, and irrational technologies and procedures, like use of unneeded ancillary testing, over utilization of hospitals, ritualistic surgery.[62]

As Brown says:

> Technological medicine combines with the market organization of medical care to divert physicians from areas and types of services in which they are most needed to those that were profitable, most interesting, and professionally rewarding to them.[63]

This analysis shows that there has been nothing ‘inevitable’ about the ‘progress’, the ‘advancement’ of medical technology; and there is

[62] McKinlay (1978)
[63] Brown (1979) pp. 212–215

not much basis for the notion of a 'technological imperative' in medicine. Social choices have been made that have been favourable to biomedical approaches to health and to techno-centric medical and public health systems, by a coalition of forces—influential sections of the medical profession, the industry, and state institutions. The development, adoption, promotion and widespread diffusion of medical technology since the mid-twentieth century cannot simply be attributed to 'progress in research' and to 'scientific/effective medical practice'. Factors other than considerations of being the best possible options, or the results of objective evaluation are involved. A range of commercial activities and interests impinge upon not only development and diffusion of medical technology, but also on delivery of health services and ultimately on medical practice itself. While the industry uses the overall societal concern with health, however, it actually has several other considerations: markets and profits being of over-riding concern. Such transformations, being introduced through the agency of the state, are guaranteeing, creating and expanding markets for specific forms of specialized, high-tech medical technologies. Such a scenario has been unfolding in India too since the 1980s.

The present nature and role of medical technology, and the accompanying problems of irrational use, high cost, thus begin to make sense when seen from the context of the nature and values of the capitalist societies, those of technocracy and consumption, and the logic (the distortions) that this context brings with it. We can discern the influence at several levels:

- *In the thinking and perception of health and disease.* The dominance of the biomedical model of health and disease, embodying the technical rationality.

- *In the mode of production of technologies for profits.* This can explain the introduction and promotion of inappropriate technologies, of technologies with inconclusive assessments of their safety and effectiveness, the high cost of technologies, the overselling of costly and/or ineffective procedures, the lack of attention to /neglect of safety issues, irrational use of technologies, etc.

- *In the mode of delivery of healthcare for profits.* The commercialization and corporatization of health services in the neo-liberal paradigm can explain the emphasis on specialized forms of medical care, of certain forms of prevention such as screening, on secondary and tertiary levels of care, etc. Currently, there is overlap of interests of the medical equipment industry and the healthcare companies, and that is also shaping the delivery of health services as well as medical practice itself.

4. 2 *The Indian Context*

Developing countries such as India have, by and large, adopted the patterns and values of modern, western medicine and the corresponding models of healthcare systems.[64] In India the adoption of western medicine by the dominant, educated classes and the medical-based public health since the colonial period, and the subsequent shifts towards a techno-centric public health system have not been due to any 'technological imperative'. Rather they arise from the political and policy choices made by the ruling classes during and after the colonial period. India has a mixed experience of application of technology for development and welfare. Use of medical technology has been highly influenced by western institutions (through aid, technology transfer, co-operation in research & training, etc.), and therefore, has features in common with the western experience, as well as those specific to the Indian context, given the different social context and the history of colonization.

The political vision after 1947 to establish a comprehensive national health services system as part of welfare state was unfortunately short-lived.[65] The government turned a blind eye to recommendations to re-orient the existing pattern of medical education and to make it less techno-centric. As a result the country continues to produce thousands of highly trained doctors, largely from the middle and affluent classes

[64] However, 'there was nothing inevitable about this process of medical colonization nor was it uncontested' (Arnold 1993). There were opportunities during and since the colonial period to have a pluralist system of medicine, based on indigenous systems and western medicine, and to evolve an appropriate health services based on these.

[65] See Banerji (1985), Qadeer (2011).

who opt to work in the urban areas or to emigrate. The emphasis of medical education on western (modern) medicine, along with the policies that encouraged specialization, has led to doctors concentrating in urban areas where hi-tech medical facilities were made available. The inadequacies of the government health system has re-inforced this trend, and diverted doctors from services and areas where they are most needed to those that are profitable, and professionally interesting and rewarding to them. The training and exposure of these doctors not only emphasizes the bio-medical paradigm of health; it also gives them access to the best technologies, to research and training opportunities in western countries, to the corporate hospitals, as well as to international markets in healthcare. Given the glamour and prestige attached to 'advanced technologies', there is a strong tendency and interest among these elite sections of medical professionals to acquire the 'latest' and to think of 'world class health services', as well as to provide only certain kinds of treatment.

The compulsions of neo-liberal ideology and the structural adjustment policies of the 1980s–1990s provided the justification and legitimacy to completely shift from earlier welfare objectives and goals of state provision of universal health care. Government policies now explicitly encourage commercialization and growth of the private hospitals and diagnostic services, directly by offering various tax subsidies and benefits, and indirectly through the policy of public-private partnership and allowing the public sector institutions to remain dysfunctional. The rising 'Indian healthcare industry' is projecting an increase in demand for healthcare, and working for expansion, in the name of removing pressure off the public sector. This industry is exploiting the overall societal concern with health to re-inforce technological medicine, and 'healthcare products', which may not necessarily enhance health, or be related to epidemiological priorities or needs of the majority.

Concluding Remarks

Regarding medical technology it has been said that an exploration of high technology medicine 'is an exploration of the paradoxes that await anyone anxious to study this problem, the ambivalence of attitudes that the topic provokes and of the real difficulties that lie ahead for those wishing to do something practical to ensure that we make better use of technology in the future'.[66]

While we agree that it is a challenging task, however, it is well within the realm of a *critical inquiry*. This analysis discusses the deficiencies, the pitfalls of the blessing – curse dichotomy and argues for a critical perspective on medical technology, based on systematic examination of the social structures and technologies of the modern, the present, in light of the developments rooted in the past. By bringing out the socially constructed nature of medical technologies, this work draws attention to and builds on the large body of earlier work on this subject, to demonstrate that there is no autonomy or imperative about technologies.

Hence, there exist possibilities of change, of re-orienting, of re-shaping modern medical technologies and health systems to a different kind of rationality. There exist the scope and possibilities of a radical approach—by posing and addressing questions such as what are the root cause of ill health in individuals and in populations; what sort of measures would be appropriate for preservation of health; for prevention, cure and care, what sort of medical and healthcare system we want; are technologies the only means for preventing disease and preserving health; what sort of technologies would be appropriate for it; what should be the nature and quantum of technologies required; and what our priorities are regarding prevention, of disease versus provision of medical care.[67] In other words, this analysis attempts to draw attention to, and also underlines the socio-political nature of the problems and challenges in the realm of medical technology.

Acknowledgement

The author wishes to thank the Director, NMML the editorial team and others in helping her publish this paper.

[66] Jennett (1984) p 132

[67] This would influence allocation of resources. Priority to prevention would imply allocation for supply of clean drinking water and sanitation to prevent general infectious diseases, rather than neglecting this and only spending on providing medical care for affected populations.

References

Anderson, M.R., L. Smith, and V.W. Sidel. (2005) "What is Social Medicine?" *Monthly Review*, vol. 56 no. 8.

Arnold, D. (1993) *Colonizing the Body: State Medicine and Epidemic Disease in 19th Century India.* Delhi, Oxford University Press.

Baber, Z. (1998) *The Science of Empire: Scientific Knowledge, Civilization, and Colonial Rule in India,* Chapter 1: Introduction. Delhi, Oxford University Press.

Banerji, D (1985): *Health and Family Planning Services in India: An Epidemiological, Socio-Cultural and Political Analysis and a Perspective*. Delhi, Lokpaksh.

Banta, D.H. and B.R. Luce. (1993) *Health Care Technology and its Assessment: An International Perspective*. Oxford, Oxford University Press.

Barnett, S.B., (2003) "Live Scanning at Ultrasound Scientific Conferences and the need for prudent policy". *Ultrasound in Medicine and Biology*, Vol. 29 No. 8, pp. 1071–1076.

Blume, S.S. (2000) "Medicine, Technology and Industry". In: R. Cooter and J. Pickstone (eds.) *Medicine in the Twentieth Century*. The Netherlands, Harwood Academic Publishers.

——. (1992) *Insight and Industry—On the Dynamics of Technological Change in Medicine*. Cambridge, Massachusetts, The MIT Press.

——. (1985) "The Significance of Technological Change in Medicine". *Research Policy* Vol. 14, No. 4, p. 173.

Braunwald, E. (1977) "Coronary Artery Surgery At The Crossroads". *New England Journal of Medicine* Vol. 276, pp. 661–663.

Brown, E.R. (1979) *Rockefeller Medicine Men: Medicine and Capitalism in America*. California, University of California Press.

Chakravarthi, I. (2013) "The emerging 'healthcare industry' in India: A Public Health perspective". *Social Change* Vol. 43, No. 2, pp. 165–176.

—— (2010) "Corporate Presence in Healthcare Sector in India". *Social Medicine* Vol. 5 No. 4, pp. 192–204.

—— (2009) *Shifts In Processes of Diffusion Of Medical Technology In India And Implications For Public Health.* Doctoral Thesis submitted to Jawaharlal Nehru University, Delhi.

Cochrane, A.L. (1972) *Effectiveness and Efficiency: Random Reflections on Health Services.* London, Nuffield Provincial Hospitals Trust.

Creditor, M.C. and J.B. Garrett. (1977) "The Information Base For Diffusion Of Technology: Computed Tomography Scanning". *New England Journal of Medicine* Vol. 2, No. 1, pp. 49–52.

Cusheri, A. and J. Jones. (2000) "Where are we going? Minimal access surgery". *British Medical Journal,* Vol. 319 No. 7220 p. 1304.

Davis, P. (1997) *Managing Medicines: Public Policy and Therapeutic Drugs.* Buckingham, Open University Press.

de Camargo, K.R. (2002) "The Thought Style of Physicians: Strategies For Keeping up with Medical Knowledge". *Social Studies of Science* Vol. 32 No. 5–6, pp. 827–855.

Dyson, F (1979) Chapter 9: "The Little Red Schoolhouse", in *Disturbing the Universe*, New York, Basic Books.

Feenberg, A. (2003) "Modernity Theory and Technology Studies: Reflections on Bridging the Gap". In: T. Misa, P. Brey, A. Feenberg, (eds.), *Modernity and Technology*, Massachusetts, The MIT Press.

—— (2002) *Transforming Technology: A Critical Theory Re-visited.* New York, Oxford University Press.

Foote, S.B. (1992) *Managing the Medical Arms Race: Public Policy and Medical Innovation.* California and England.

Filly, R.A. and J.P. Crane. (2002) "Routine Obstetric Sonography". *Journal in Ultrasound Medicine* Vol. 21, pp. 713–718.

Greer, A.L. (1984) "Medical Technology and Professional Dominance Theory". *Social Science and Medicine*, Vol. 18, pp. 809–817.

Groot, L.M.G. (1988) "An overview of the systems and regulations concerning medical technology and the diffusion of six technologies", In: B. Stocking (ed.) *Expensive Health Technologies: Regulatory and Administrative Mechanisms in Europe.* Oxford University Press, Oxford.

Hamlin, C. (1998) *Public Health and Social Justice in the Age of Chadwick: Britain, 1800–1854*. New York, Cambridge University Press.

— — (1995) "Could You Starve to Death in England in 1839? The Chadwick-Farr Controversy and the Loss of the 'Social' in Public Health". *American Journal of Public Health*, Vol. 85, No. 6, pp. 856–866.

Hofmann, B. (2002) "Is there a Technological Imperative in Medicine?" *International Journal of Technology Assessment in Health Care*, Vol. 18, No. 3, pp. 675–689.

Hughes, T.P. (1985) "Edison and electric light". In: D. MacKenzie and J. Wajcman (eds.) *The Social Shaping of Technology: How the Refrigerator got its Hum*. Milton Keynes and Philadelphia, Open University Press.

Illich, I. (1975) *Medical Nemesis: The Expropriation of Health*. London, Calder and Boyars.

Jennett, B. (1984) *High Technology Medicine: Benefits and Burdens*. London, Nuffield Provincial Hospitals Trust.

Kehoe, L. (1976) "Battle For The X-Ray Scanner Market". *New Scientist,* Vol. 72, No. 1028, pp. 457–458.

Liebnau, J (1987) *Medical Science and Medical Industry: The Formation of the American Pharmaceutical Industry*. London, MacMillan Press.

MacKenzie, D. and J. Wajcman. (1985) "Introductory Essay". In: D. MacKenzie and J. Wajcman (eds) *The Social Shaping of Technology: How the Refrigerator got its Hum*. Milton Keynes and Philadelphia, Open University Press.

Martin, B. (1993) "The Critique Of Science Becomes Academic". *Science, Technology & Human Values*, Vol. 18, No. 2, pp. 247–259.

Marx, L. (1994) "The Idea of 'Technology' and Post-Modern Pessimism". In: M.R.Smith and L Marx (eds) *Does Technology Drive History? The Dilemma of Technological Determinism,* Cambridge, Massachusetts, The MIT Press, pp. 237–257.

McKinlay, J.B. (1978) "On the Medical-Industrial Complex", *Monthly Review*, Vol. 30, No. 5, pp. 38–42.

Miglioretti, D.L., Johnson, E., et al (2013) "The Use of Computed Tomography in Pediatrics and the Associated Radiation Exposure and Estimated Cancer Risk". *Journal of the American Medical Association (JAMA) – Pediatrics*, Vol. 167 No. 8, pp. 700–707.

Pinch, T.J. and W.E. Bijker. (1984) "The Social Construction of Facts & Artifacts: or How the Sociology of Science and the Sociology of Technology Might Benefit from Each Other". *Social Studies of Science,* Vol. 14, pp. 399–441.

Qadeer, I. (2011) "Health Services System in India: An expression of socio-economic inequalitites". In: I. Qadeer *Public Health in India: Critical Reflections*. Delhi, Daanish Books.

Reiser, S.J. (1978): *Medicine and the Reign of Technology*. Cambridge, Cambridge University Press.

Stocking, B. and S.L. Morrison. (1978) *The Image and the Reality*. Oxford, Oxford University Press.

Timmermans, S. and Berg, M (2003) "The practice of medical technology". *Sociology of Health & Illness,* Vol. 25, pp. 97–114.

Vessuri, H.C. (1996) "Social Studies of Science and Technology: A Report on a Latin American Workshop". *Science, Technology and Society* Vol. 1, No. 1, p. 173.

Weiner, C. (1987) "Patenting and Academic Research: Historical Case Studies". *Science, Technology & Human Values*, Vol. 12 No. 1, pp. 50–62.

White, K.L. (1991) *Healing the Schism: Epidemiology, Medicine, and the Public's Health*. New York, Springer-Verlag.

Winner, L. (1986) *The Whale and the Reactor: A Search for Limits in an Age of High Technology*. Chicago & London, University of Chicago Press.

— — (1980) "Do Artifacts have politics?" *Daedalus,* Vol 109, No.1, pp. 121–36.

Yearley, S. (1988) *Science, Technology and Social Change*. London, Unwin Hyman.

Yoxen, E. (1987) "Seeing with Sound: A Study of Development of Medical Images". In: W.E. Bijker, T.P. Hughes, and T. Pinch. (1987) *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. Cambridge, Massachusetts, The MIT Press.