A "Desperation-Reaction" Model of Medical Diffusion

by Kenneth E. Warner

Knowledge about the adoption and diffusion of innovations is briefly reviewed. A model is then proposed to explain how certain innovations, intended to address dire medical problems, might diffuse in a manner not previously reported, with extensive diffusion occurring during what would be a period of small-scale experimentation and limited adoption in the conventional innovation-diffusion environment. The model is illustrated with findings from a case study of the diffusion of drug therapies for four types of leukemia. Possible implications of "desperation-reaction" diffusion are suggested.

New technology and new techniques in medicine have eased suffering, prolonged survival, and produced cures that would have been impossible a decade ago. At the same time, technical change in medicine has contributed to resource wastage and inflation. The profound and pervasive effects of technical change extend to the organization of medical care delivery, to increasing specialization among health professionals, and to societal expectations about the role and potential of modern medicine [1,2].

Despite their interest and importance, processes of technical change in medicine are only poorly understood. Relatively little of the research on the stages of technical change [3,4] has focused on medical care; and, as Kaluzny observed in this journal [5], "There is a need for caution in making generalizations about the health system based on innovation studies in other areas." In fact, recognizing the economic idiosyncrasies of medical care—the unorthodox nature of both supply and demand—one might expect some of the processes of technical change in medicine to differ from their counterparts in more conventional economic settings.

Through theoretical consideration and through discussion of some findings from an empirical study, this article focuses on diffusion of medical innovations—the final stage of medical technical change—in a specific context: namely, the introduction of an innovation, relatively inexpensive and easy to adopt, that is designed to address a dire medical problem, for example a terminal illness. Diffusion has not been studied in this context before, and

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it seems likely that, in this context, diffusion differs significantly from that which has been reported previously.

Diffusion

Research on the diffusion of innovations can be categorized as multidisciplinary (though individual studies are rarely interdisciplinary). While the majority of studies have been undertaken by scholars in sociology and closely allied fields [4,6], economists [7–9], political scientists [10–12], and others have lent their perspectives to the effort to understand this important phenomenon. Differences in interests and methodologies make comparability difficult at times, but several common themes run through most of the literature. Here I shall note only broad generalizations relevant to the ensuing discussion. Problems and deficiencies have been discussed elsewhere [4,13].

The student of diffusion is concerned with three phenomena: the *speed* of diffusion, its *extent* (what percentage of potential adopters ever adopt the innovation), and *patterns* of diffusion (including the shape of the time path of diffusion, patterns of geographic spread, and patterns of diffusion among members of a social system). A great deal is known about factors that promote adoption of innovations by persons and by organizations; less is understood about the specific mechanisms of diffusion. Much has been conjectured about the latter, but good empirical studies (for example, refs. 8 and 14) are relatively few in number.

Factors that influence adoption decisions and consequently the rate of diffusion include (1) innovation-specific characteristics, (2) adopter-specific characteristics, and (3) situation-specific characteristics. The first of these categories covers matters such as the innovation's relative advantage, the amount and nature of its monetary costs, its compatibility, its complexity, and its testability. The second category includes the potential adopter's position (or integration) in the relevant social system, his or her attitudes toward risk and uncertainty, and his or her education and other socioeconomic and personality characteristics. At the organizational level, relevant characteristics include the organization's size, slack, and centralization. (Innovation-specific and adopter-specific characteristics are defined and discussed in refs. 4 and 6.)

The third category—those contextual or environmental factors that influence adoption decisions, *given* an innovation and a set of potential adopters—is rarely considered, in part because it is not invariably distinct from the first two. However, it plays a significant role in medical technical change, and particularly in the medical diffusion process considered later in this article. A general example of the third category is the influence of a medical organization's financing mechanism on the fact or timing of its adoption of a medical technology: physicians and administrators who are similar in all of the relevant adopter characteristics may arrive at different decisions about the adoption of a given technology if they are in a fee-for-

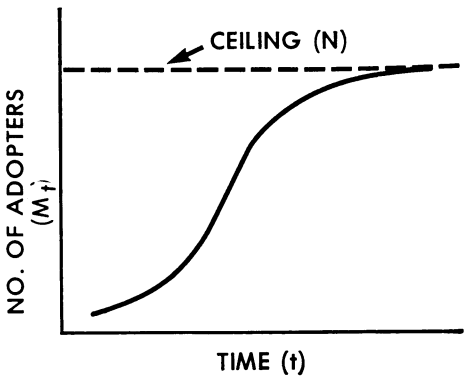

Fig. 1. The conventional diffusion of innovation curve.

service environment than if they operate under prepayment (e.g., ref. 15). Another situational characteristic—the perceived need for an innovation—may affect adoption decisions and diffusion, *all other things being equal.* Diffusion may be more rapid and mechanistically different when a medical situation is truly dire than when it seems less urgent.

Despite the diversity of explanatory variables, most discussions of diffusion share the conclusion that it is a process described by an S-shaped curve (Fig. 1) as are the snowball or chain reaction phenomena characterizing many social and physical processes. Diffusion is characterized as an imitation phenomenon, generally specified as a logistic function where the rate of growth (speed of diffusion) coefficient is a function of variables like the three factors discussed above [13].

(The logistic is not the only function that generates an S-shaped curve. Empirically, the cumulative normal is virtually indistinguishable from the logistic. The logistic is consistent with imitative behavior, the propensity for an individual's probability of adoption to rise with increasing adoption by others. The cumulative normal is more consistent with an independent learning model in which adopters require different levels of, say, information to induce them to adopt the innovation. If these requirements are normally distributed and if information becomes available at a constant rate, the diffusion curve will be the S-shaped cumulative normal.)

In S-shaped diffusion, the spread of adoption is gradual at first—uncertainty is great—but it picks up speed as positive experience diminishes both uncertainty about the value of the innovation and ignorance about how to use it efficiently. (The early period in which limited diffusion occurs is often viewed as a testing phase during which diffusion is naturally limited by the response to ignorance and uncertainty that risk aversion suggests. Some authors choose to speak of diffusion as beginning after this early experimental stage [7].)

The emphasis in the literature on S-shaped diffusion probably reflects the types of innovations and diffusion situations studied [13]. It seems likely that the unorthodox diffusion phenomenon to be discussed here is not restricted to innovations designed to combat catastrophic illness. Similarly, the non-S-shaped diffusion phenomenon reported by Coleman *et al.* [14] must characterize many diffusion processes.

Diffusion in Health Services

A handful of exceptions to S-shaped diffusion have been discussed in the literature. Several of these are from the health services arena [14,16,17], prompting Kaluzny's observation [5] that one should be careful about generalizing from the conventional wisdom to the diffusion of health system innovations.

The most prominent medical diffusion research is the study by Coleman, Katz, and Menzel [14] of the diffusion of a prescription drug. Their sociometric analysis verified several relationships that had been suggested earlier, involving the attributes of and linkages among individual adopters. For example, they found that the diffusion of "gammanym" (the drug's fictitious name) was S-shaped for physicians who were well integrated into the professional system, whereas diffusion among nonintegrated physicians was at a more constant rate, producing a time path that was concave throughout. This finding documents and explains an instance of non-S-shaped diffusion that would seem to be representative of many diffusion experiences; it emphasizes the role of social integration. Each potential adopter of an innovation has a probability of adoption in each time period, and these probabilities may initially be identical for the integrated and nonintegrated groups. What distinguishes the groups is that individuals in the nonintegrated group maintain relatively constant adoption probabilities over time, while for integrated nonadopters, the probabilities increase as their colleagues adopt the innovation. (It should be emphasized that the highly competitive firms in Mansfield's studies [8,9] are every bit as "integrated" as the physicians of Coleman et al. In the diffusion context, integration simply implies awareness of and reaction to the behavior of peers, be they colleagues or competitors.)

Other studies in the health services area have looked at the innovative behavior of individuals and of organizations, in the latter case focusing on public health agencies [11,17,18] and hospitals [16,19,20]. (Kaluzny, Veney, and Gentry [21] compare adoption of innovations in health departments and hospitals.) Overall, health services diffusion research has demonstrated the same diversity as diffusion research in general. The literature has been thoroughly reviewed by Kaluzny [5].

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Researchers have studied innovations that are relatively easy to adopt (e.g., ref. 14), and they have examined the diffusion of innovations used for

serious medical problems (e.g., ref. 20), but they have not considered the intersection of these two sets. The consequence is that they have missed a situation in which diffusion *can* occur rapidly and in which decision makers *want* to adopt rapidly.

Two characteristics of the practice of medicine make the desire to adopt rapidly not uncommon. The "social contract" requires physicians to attend to seemingly hopeless cases of illness and accidents, and therefore they are highly responsive to potentially relevant innovations. Second, the delivery of much medical care, especially in cases of catastrophic illness, occurs in a setting in which relatively few constraints are imposed on the economic behavior of physicians and patients [22–25]. Often the binding constraints on individual treatment decisions are the technology and knowledge available to the physician, with direct economic considerations weighing little. Thus the economic setting permits, and the social contract encourages, the development and early adoption of innovations.

In a more conventional setting (including that of less serious medical problems) risk aversion results in more gradual early diffusion. In a medically desperate situation, the "cost" of using a new technique that fails is simply that things are not better (if real resource costs are ignored). The alternative—for example, a prognosis of a few months to live—is so intolerable that the risk and uncertainty associated with an unknown technique are valued for the hope they permit. The worse the prognosis, the more the physician is encouraged to gamble by using the innovation. In addition, it has been asserted that physicians are not trained how *not* to treat, that they rarely consider nontreatment a viable alternative *even if* available treatments have been demonstrated to be ineffective. The physician's response to a desperate situation is to want to do something, to take positive therapeutic action [26,27].

It is possible to describe a qualitative model of diffusion of easy-to-adopt innovations aimed at serious ("desperate") medical problems. The model is not formalized here; that task remains for later work. However, the case study presented illustrates essential features of the model.

The model has three stages, or periods of adoption and diffusion. The first of these represents preexperiential diffusion in that reasonably extensive diffusion may occur in the absence of significant evidence about the value of the innovation. Understanding of the innovation and often development of the innovation itself will not have achieved the maturation that the conventional diffusion situation appears to require before significant diffusion can begin. Such early adoption is promoted by the noninnovation-specific factors that have been mentioned. The second stage of diffusion is shaped by response to empirical and personal experience with the technique accumulated during the first stage. During the second stage, physicians adjust their Stage I behavior to reflect their experience and newly available information. The third and final stage is a period of reasonably informed diffusion that may be quite similar to the latter part of the conventional diffusion process.

Stage I

A major factor triggering adoption of an innovation in the Stage I period is the tendency for the physician to act more readily—to accept greater risk and uncertainty—the more desperate the situation. "Desperation" has several dimensions. The most obvious is the prognosis: a prognosis of only a few months to live is viewed as a tragic situation. Obviously, the prognosis is a function of the techniques (therapies) available to the physician to manage the illness. Of two diseases with prognoses, untreated, of x months, the disease for which an established therapy promises more than x months will be viewed as less desperate than a disease for which there is no alternative to the contemplated novel therapy. (Assuming that physicians value treatment almost for its own sake, the existence of an established therapy should diminish their desperation, irrespective of the efficacy of the established therapy.) Similarly, certain characteristics of the patient, most noticeably age, exacerbate or mitigate the sense of desperation. Terminal illness in a child would generally be viewed as a more desperate situation than an incipient death in an elderly person. Clearly, "desperation" is an arbitrarily quantified variable. Formalization of the model would require the determination of a measure of "desperation," possibly a composite index of quantitatively tractable variables such as the person's age, prognosis, and the like.

Reaction to a medical crisis, hope concerning an as yet unproved innovation, and the legitimizing role of early adopters combine to promote diffusion in this first stage of the diffusion process, a period in which adopters lack clinical experience and statistical feedback. For an innovation in a conventional setting, the comparable period generally would be one of R&D and testing, with very little if any commercial diffusion.

The factors discussed to this point as influencing adoption and diffusion are largely independent of the innovation itself. Obviously, characteristics of the innovation—and possibly of closely related innovations—will also affect decision making. For example, all else being equal, an expensive new piece of capital equipment will probably diffuse more gradually than will an inexpensive, nondurable item. Innovations requiring that technicians learn novel skills will be put into practice less rapidly than those requiring existing skills. Similarly, if an innovation has been used in treatment of another disease, that experience will decrease uncertainty concerning toxicities and the like. Such familiarity should expedite diffusion in the new context. Also, of two otherwise comparable innovations, one that has a "close relative" proven effective against a similar disease is more likely to diffuse rapidly [25]. In other words, the attributes of innovations are clearly important [28].

If adoption of an innovation is difficult or expensive, diffusion will be gradual. During the additional time between awareness of the innovation and adoption, the innovation may be further developed or its value may come to be better understood; hence, more widespread diffusion will begin only in what is the second stage of the present medical diffusion model. Stage I diffusion will have been precluded by technical or economic factors.

For both innovation-specific and other factors, these Stage I influences operate without the benefit of substantial evidence as to the effects of the innovation.

Stage II

The first stage ends and the second begins when enough evidence has accumulated to lend some insight into the technical relationship between the new therapy and survival time, toxicities, and so on. Stage II is a period of adjustment. If the evidence suggests that the innovation has fulfilled its promise, there will be little adjustment of the Stage I diffusion pattern. Where the evidence indicates therapeutic effectiveness even greater than adopters had hoped for, previous nonadopters might now join the bandwagon, increasing usage relative to the Stage I diffusion pattern.

Alternatively, if the expectations that generated the Stage I diffusion are not realized, "negative diffusion" will occur. "Negative diffusion"—decreasing usage of the innovation—is a phenomenon not reported in the literature. There are three reasons for this. One is that negative diffusion is a collective adjustment to extensive preexperiential diffusion, but reports in the literature have not concerned innovations with significant preexperiential diffusion.

The second reason is that most studies focus on successful innovations. In part this reflects a natural interest in successful social or technical change, and in part it reflects a technical bias: innovations are usually selected for study after they have diffused. An innovation that has diffused reasonably extensively is more likely than not to be of value.

The third reason negative diffusion has not been discussed is a matter of semantics, the manner in which "adoption" and "diffusion" are defined [13]. Diffusion frequently has been defined as the time path of the cumulative number of adoptions or trials of an innovation. Such a definition does not account for those who adopt and then later reject an innovation. By this definition, negative diffusion cannot occur for the tautological reason that diffusion is restricted to being a nonnegative function of time.

The definition of diffusion used in this article is the time path of extensiveness of *use* of the innovation. Thus, if there are N_t possible users of an innovation in period t, and M_t ($\leqslant N_t$) actually use the innovation, diffusion is defined here as the time path of M_t/N_t, instead of cumulative first trials. Negative diffusion occurs when $M_{t+1}/N_{t+1} < M_t/N_t$. Under the standard definition, this situation would cause the diffusion curve to flatten out from period t to period $t+1$ if there were no new adopters in $t+1$; if there are new adopters, the diffusion curve will *rise* despite the possibility of an effective *decrease* in usage of the innovation. The two definitions may yield identical results for a clearly valuable innovation: once a potential adopter tries the innovation, that individual becomes a regular user and thus is included in each period's measure of diffusion.

Where the effect of the innovation falls short of the hopes or expectations that generated Stage I diffusion, the downward adjustment in usage may range

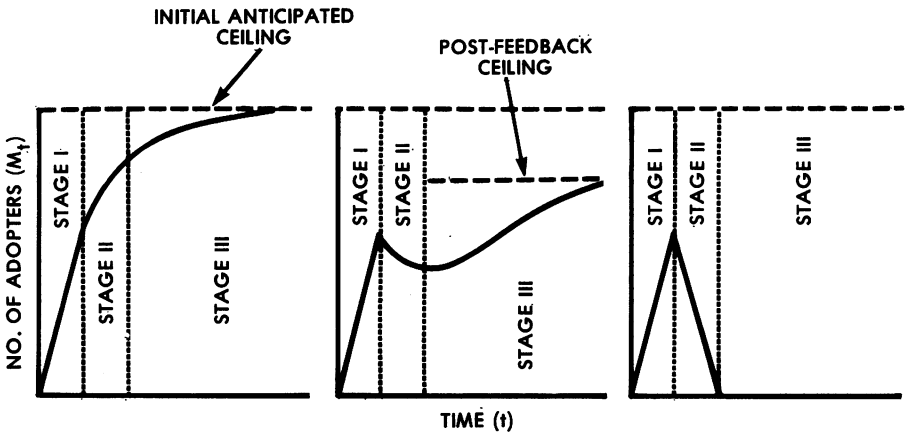

Fig. 2. Three patterns of desperation-reaction diffusion.

from slight (expectations almost but not quite met) to complete (expectations wholly unmet, with serious dangers discovered). The decrease in usage may be temporary or permanent. (In the instance of negative feedback, the second stage might be labeled the "moratorium" stage [29].) In general, Stage II represents the period in which the first significant returns are in, a period of evaluation in which physicians examine the tools they have been employing and respond to the results they are only now learning [27].

An interesting and important phenomenon is occurring here. In contrast with previously reported cases, the experimental (evaluatory) initial phase of this mode of diffusion occurs in full-blown, widespread practice, rather than in a small-scale field experiment investigating the merits of the innovation while little diffusion takes place. Indeed, in much of esoteric disease management, even clinical R&D may be accompanied by significant diffusion in practice. In the conventional setting, diffusion, both as conceptualized and as operationally defined, *begins* in what corresponds to the *second* phase of diffusion of a medical innovation addressing a serious disease problem.

Stage III

The third and final stage of the model is a period of informed decision making. It is similar to the latter part of the conventional diffusion process. Diffusion is here a function of learning and of other variables known to motivate the conventional process. If Stage II information was favorable, Stage III merely represents a continuation of diffusion to a ceiling rate. If Stage II witnessed a temporary moratorium, Stage III will see renewed diffusion, though likely to a lower ceiling rate than might have been anticipated during Stage I. Obviously, if the Stage II moratorium was permanent, there will be no Stage III diffusion.

Figure 2 depicts three general variants of the model, all assuming significant Stage I diffusion. The curves have been drawn with identical first stages.

The curve at the left represents the case in which accumulated evidence equals or exceeds the physicians' hopes, the middle curve represents a case of somewhat disappointing but still positive results, and the curve at the right is a case of wholly negative findings.

Obviously, the crucial part of this model is the first stage. In medical situations in which there is little sense of desperation, or in which an innovation is so complex or expensive as to prohibit rapid adoption, there is no reason for any substantial preexperiential diffusion to occur (ignoring the tendency to adopt innovations for reasons of status). Armed with alternatives to an innovation, physicians are comfortable waiting for scientific data and the experience of their colleagues before considering adoption of the innovation, and Stage I diffusion is minor or nonexistent. The diffusion process will then be the one commonly reported in the literature. The extent to which a particular medical innovation's diffusion deviates from the S-shape is a function of the sense of desperation which physicians and patients associate with the medical problem, constrained by the factors noted above.

The Diffusion of Leukemia Chemotherapy in Connecticut

Background

Prior to the late 1940s, the leukemias represented a disease situation that was ripe for innovation. Acute leukemia is the leading childhood cancer, causing much concern among the public and the medical profession. Until the development of the early chemotherapeutic agents in the late 1940s there was no effective therapy against the leukemias. The new drugs made possible a relatively easy and relatively inexpensive method of treating these diseases. Physicians approached the new therapy with optimism following initial successes in inducing remissions in leukemic children.

Experimenting with over 40 drugs—used individually, in combination, and with varying dosages and timing—the medical profession has fought an uphill battle against leukemias. Only one form of the disease—acute lymphocytic leukemia (ALL)—has yielded significantly to drug therapy. In very recent years, specialty centers have begun to report large numbers of good remissions in adults with acute myelocytic leukemia (AML); however, AML responded little to drugs in the first two decades of leukemia chemotherapy (the period covered in the case study reported here). Drug therapy can provide symptomatic relief in cases of chronic lymphocytic leukemia (CLL) and chronic myelocytic leukemia (CML), but it has never been credited with regularly inducing remissions or extending survival time. The table on p. 378 presents some distinguishing characteristics of the four major leukemias.

The four leukemias are closely related diseases in terms of morphology and course, yet they have responded to similar chemotherapies in dramatically different ways. In addition, they represent varying degrees of "desperation," ranging from a rapidly fatal illness in young children (ALL) to an illness that

Characteristics of the Four Leukemias

Type of leukemia	Blood cell type affected	Most frequent victims	Prognosis without therapy	Prognosis with chemotherapy
Acute lymphocytic (ALL) ..	Lymphocyte	Children	A few months	Complete remission. Median survival 3–5 years; some cures
Acute myelocytic (AML) ..	Granulocyte	Adults	1–2 months	Partial remission possible. No appreciable extension of median survival through period studied (through 1968)
Chronic lymphocytic (CLL) ..	Lymphocyte	Adults, usually middle-aged to elderly	A few years	Unchanged. Chemotherapy treats symptoms only
Chronic myelocytic (CML) ..	Granulocyte	Adults	A few years (shorter on average than for CLL)	Unchanged. Chemotherapy treats symptoms only

commonly afflicts the elderly, is gradual, and is often quite mild for a number of years (chronic leukemia). Thus, leukemia chemotherapy presents a situation in which adoption is relatively easy and in which a range of perceived disease severity lets us examine the plausibility of "desperation-reaction" and the phenomenon of preexperiential diffusion. It should be emphasized that this case study is descriptive and illustrative. It is not possible to empirically verify the desperation-reaction model with only a handful of innovations and disease situations.

The Case Study

Data for the case study are from the Connecticut Tumor Registry of the Connecticut State Department of Health. Defining diffusion as the time path of extensiveness of use, I generated the chemotherapy diffusion curves depicted in Fig. 3. "Usage" (M_t/N_t) is the percentage of patients newly diagnosed in year t who receive chemotherapy. The proportion of physicians who used chemotherapy is also of interest, but the primary question was how many patients who might receive the therapy actually do get it. If the treatment is effective but so sophisticated that only certain specialists can administer it to achieve maximum benefit, one might hope to see extensive diffusion among patients, yet only limited diffusion among physicians.

For the chronic leukemias diffusion is gradual, with a vacillating upward

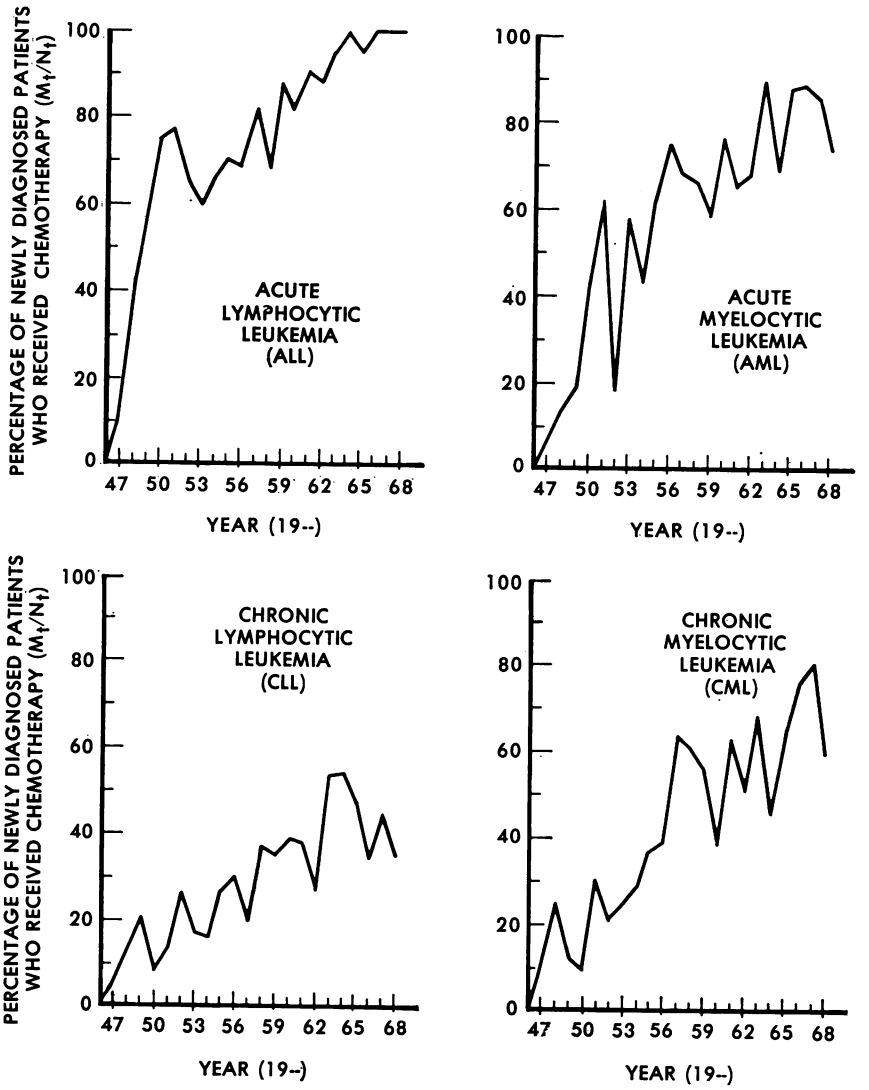

Fig. 3. Diffusion of leukemia chemotherapy in Connecticut.

pattern. Regression analysis (reported in refs. 25 and 30) revealed no preferred fit among alternative time function specifications; no obvious diffusion phenomenon like the contagion or snowball phenomenon implicit in the logistic is suggested.

The chemotherapy diffusion curves for the acute leukemias are more interesting. They reflect the following shared characteristics: usage rises rapidly and continuously during the first five years of leukemia chemotherapy (1947–1951, inclusive), in each case reaching roughly three-quarters of the usage level

attained at the end of the 1960s. Usage then decreases to the extent that the 1951 peaks are not exceeded for several years (six years in the case of ALL, five years for AML). From the mid 1950s on, each diffusion curve sawtooths gradually upward, peaking by the mid 1960s.

In the late 1940s no reasonable alternatives to drug therapy existed, and there were no significant barriers to its adoption: no capital expenditures were necessary, financial liability for drugs and other expenses was often covered by insurance or research monies, and the technical procedure was relatively easy to understand. (Modern drug therapies for acute leukemia are expensive and complex, involving the use of sophisticated support technology. This might well hinder the adoption of the most aggressive therapies, but therapies for the chronic leukemias, for AML prior to the 1970s, and for ALL during the 1940s and 1950s were all relatively simple one-drug or two-drug treatments.) The desperation-reaction model suggests that in the relatively constraint-free environment of leukemia therapy in the 1940s, Stage I diffusion should have been a function largely of desperation about the diseases and hope concerning the new drug therapy. Support for this comes from the heights of the four leukemia chemotherapy diffusion curves achieved in the first few years (through 1951, prior to the availability of significant empirical feedback). Drug therapy for the acute disease in children (ALL) was adopted extensively. The new therapy for the acute disease in adults (AML) was also widely adopted, but not to the same extent; the difference likely reflected the early successes with leukemic children, in addition to the greater sense of desperation in childhood ALL. Early therapy for the chronic leukemias—less serious disease situations primarily affecting older people—did not diffuse very widely, though usage for CML and CLL exceeded 20 percent within three years. Apparently the factor driving this early diffusion was the sense of great loss without the drug therapies and the hope that the use of drugs would extricate physicians from an emotionally untenable position.

Desperation-reaction should be evident in another, more recent aspect of the management of childhood acute leukemia. One may hypothesize that, other things being equal, a physician would have been more likely to adopt the single drug treatment in the late 1940s or early 1950s, when no effective alternative therapies existed and the life expectancy of an afflicted child was only a few months, than the physician would have been to adopt the more complex new therapy of the mid 1960s, when existing treatments promised the child with ALL a year and a half to two years of apparent good health. Unfortunately, the data did not permit analysis of this hypothesis [30], but reading the literature and speaking with experts suggests that it is basically correct. Of course, it must be recognized that "other things" were not entirely equal. The greater complexity of later therapy should have had a negative influence on diffusion, while familiarity with chemotherapy in general and improved sources of information should have had a positive influence.

Perhaps the intent of the desperation-reaction model can best be conveyed by a summary look at the diffusion path for ALL chemotherapy in Fig.

3, which is a good fit to the model variant in the center in Fig. 2. In childhood acute leukemia, expectations in the first stage were that drug therapy would produce large numbers of good remissions and enhance survival experience with only mild toxicity, and that early groundbreaking work would be followed in quick succession by major new therapeutic achievements. The first few years of ALL chemotherapy did see a substantial number of remissions, but the patients' lives were not extended appreciably beyond the untreated life expectancy; no major new developments occurred, and chemotherapy proved to be a more tricky business than anticipated. Therapy produced nausea and other unpleasant side effects, and in several cases it appeared to shorten the patients' lives.

According to the model, the desperate ALL situation in 1947, the hope attached to the first tentative findings concerning drug therapy, and the relative lack of constraints on adoption should have combined to produce preexperiential diffusion. The relatively disappointing findings, which began to be reported in the early 1950s, should have produced some negative diffusion. However, as findings and individual experience were not wholly negative, the downward adjustment should not have been complete. As physicians learned better how to administer chemotherapy and as chemotherapies were developed and improved, positive diffusion should have resumed, thus reflecting the temporary quality of the partial moratorium on ALL chemotherapy. All of this, of course, was the case.

Discussion

The simple description of the diffusion of leukemia chemotherapies, supported by related empirical analysis of factors influencing therapy decisions [25,30], lends credibility to the proposed desperation-reaction diffusion model. That some medical innovations should diffuse in an unorthodox manner is not surprising: the medical profession is saddled with the responsibility of tending to all ills, regardless of their amenability to correction, and medical care is delivered in a unique economic setting relatively free of conventional economic constraints, encouraging "Cadillac care."

In the context of technical change, one manifestation of this environment is that innovations that are easy to adopt may diffuse fairly extensively prior to the availability of information on and understanding of the innovations' merits and deficiencies. Such diffusion, here labeled "preexperiential," occurs during what would be a period of experimental testing and very limited diffusion in the conventional environment. This medical response to innovations sets up the possibility of negative diffusion, a period of retrenchment in which physicians admit by their actions that they overadopted an innovation.

There is nothing inherently wrong with the medical profession's response to innovation; nor is there anything inherently right about the more conventional response to innovation [31]. Indeed, given the economic and ethical environment in which medical care is delivered, much preexperiential inno-

vation adoption must be considered rational behavior, even if the innovation eventually proves not to be worthwhile or even to be deleterious to health. In the event that an innovation proves to be highly valuable, the early diffusion may have served to bring better medical care to patients more rapidly than would have been the case had the diffusion been limited by the usual constraints and attitudes. (Of course, early use of an innovation is likely to be less effective than later use which has benefited from experience, so it is possible that rapid early diffusion will not be unequivocally desirable even if the innovation ultimately proves worthwhile.) If the innovation is shown to be ineffective or deleterious, at minimum early diffusion will have represented an inefficient use of resources; at worst, it may have been a source of iatrogenic morbidity or mortality.

Thus, the ultimate questions of interest are the following: does the diffusion scenario described here represent an important phenomenon within medicine? If so, of the innovations that diffuse significantly during a preexperiential phase, how many prove to be valuable and how many are undesirable? We need now to investigate the significance of this unorthodox diffusion story, its frequency, and its social and economic implications. We must recognize that policy options are available with which to influence the timing, the extent, and the nature of the diffusion of innovations, and that, often unintentionally, policy does affect these variables [32–34]. The challenge is to determine whether or not we should tinker further with the system, and if so, how it might be altered productively [35].

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References

1. Fuchs, V. R. *Who Shall Live? Health, Economics, and Social Choice.* New York: Basic Books, 1974.
2. Illich, I. *Medical Nemesis.* London: Calder & Boyars, 1975.
3. Kamien, M. I. and N. L. Schwartz. Market structure and innovation: A survey. *J Econ Lit* 13:1 Mar. 1975.
4. Rogers, E. M. and F. F. Shoemaker. *Communication of Innovations: A Cross-Cultural Approach.* New York: Free Press, 1971.
5. Kaluzny, A. D. Innovation in health services: Theoretical framework and review of research. *Health Serv Res* 9:101 Summer 1974.
6. Zaltman, G., R. Duncan, and J. Holbek. *Innovations and Organizations.* New York: Wiley, 1973.
7. Griliches, Z. Hybrid corn: An exploration in the economics of technological change. *Econometrica* 25:501 Oct. 1957.
8. Mansfield, E. *Industrial Research and Technological Innovation.* New York: Norton, 1968.
9. Mansfield, E., J. Rapoport, J. Schnee, S. Wagner, and M. Hamburger. *Research and Innovation in the Modern Corporation.* New York: Norton, 1971.

10. Gray, V. Innovation in the states: A diffusion study. *Am Polit Sci Rev* 67:1174 Dec. 1973.
11. Mohr, L. Determinants of innovation in organizations. *Am Polit Sci Rev* 63:111 Mar. 1969.
12. Walker, J. The diffusion of innovations among the American states. *Am Polit Sci Rev* 63:880 Sept. 1969.
13. Warner, K. E. The need for some innovative concepts of innovation: An examination of research on the diffusion of innovations. *Policy Sci* 5:433 Dec. 1974.
14. Coleman, J. S., E. Katz, and H. Menzel. *Medical Innovation: A Diffusion Study*. Indianapolis: Bobbs-Merrill, 1966.
15. Fortney, M. Big demand for newest superfast medical scanners. *Palo Alto Times* Feb. 3, 1976, p. 25.
16. Kaluzny, A. D., J. H. Glasser, J. T. Gentry, and J. B. Sprague. Diffusion of innovative health care services in the United States: A study in hospitals. *Med Care* 8:274 Nov.–Dec. 1970.
17. Mytinger, R. E. *Innovation in Local Health Services*. PHS Pub. No. 1664-2. Washington, DC: U.S. Government Printing Office, 1968.
18. Becker, M. *Patterns of Interpersonal Influence and Sources of Information in the Diffusion of Two Public Health Innovations*. Doctoral dissertation, University of Michigan, 1969.
19. Gordon, G., E. V. Morse, S. M. Gordon, J. deKervasdoue, J. Kimberly, M. Moch, and D. B. Swartz. Organizational structure, environmental diversity, and hospital adoption of medical innovations. In A. D. Kaluzny et al. (eds.), *Innovation in Health Care Organizations*, p. 53. Chapel Hill, NC: University of North Carolina Press, 1974.
20. Russell, L. B. and C. S. Burke. *Technological Diffusion in the Hospital Sector*. N.S.F. grant no. RDA75-14274. Washington, DC: National Planning Association, 1975.
21. Kaluzny, A. D., J. E. Veney, and J. T. Gentry. Innovation of health services: A comparative study of hospitals and health departments. *Health Soc* 52:51 Winter 1974.
22. Arrow, K. J. Uncertainty and the welfare economics of medical care. *Am Econ Rev* 53:941 Dec. 1963.
23. Klarman, H. E. *The Economics of Health*, pp. 10–19. New York: Columbia University Press, 1965.
24. Sorkin, A. L. *Health Economics*, pp. 4–17. Lexington, MA: Heath, 1975.
25. Warner, K. E. Treatment decision-making in catastrophic illness: A case study. Working paper, University of Michigan School of Public Health, 1976.
26. Crosby, W. To treat or not to treat acute granulocytic leukemia. *Arch Intern Med* 122:79 July 1968.
27. Freidson, E. *Profession of Medicine*, pp. 158–184. New York: Dodd, Mead, 1975.
28. Bernstein, L. M., V. H. Beaven, J. R. Kimberly, and M. K. Moch. Attributes of innovation in medical technology and the diffusion process. In G. Gordon and G. L. Fisher (eds.), *The Diffusion of Medical Technology*, pp. 79–114. Cambridge, MA: Ballinger, 1975.
29. Swazey, J. P. and R. C. Fox. The clinical moratorium: A case study of mitral valve surgery. In P. A. Freund (ed.), *Experimentation with Human Subjects*, p. 315. New York: Braziller, 1970.
30. Warner, K. E. *The Diffusion of Leukemia Chemotherapy: A Study in the Nonmarket Economics of Medical Care*. Doctoral dissertation, Yale University, December 1974.
31. Nelson, R. R., M. J. Peck, and E. Kalachek. *Technology, Economic Growth, and Public Policy*, p. 109. Washington, DC: Brookings Institution, 1967.
32. Cooper, J. D. *The Economics of Drug Innovation*. Washington, DC: American University, 1970.
33. Cooper, J. D. *Regulation, Economics, and Pharmaceutical Innovation*. Washington, DC: American University (in press).
34. Peltzman, S. *Regulation of Pharmaceutical Innovation: The 1962 Amendments*. Washington, DC: American Enterprise Institute for Public Policy Research, 1974.
35. Gordon, G. and G. L. Fisher (eds.). *The Diffusion of Medical Technology*. Cambridge, MA: Ballinger, 1975.