Small Area Variations in Health Care Delivery

A population-based health information system can guide planning and regulatory decision-making.

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Recent legislation has extended planning and regulatory authority in the health field in a number of important areas. The 1972 amendments to the Social Security Act provide authority for regulating the construction of facilities and establish Professional Standard Review Organizations (PSRO's), which are accountable for setting standards and evaluating professional performance. Phase 3 of the Wage and Stabilization Act of 1970 and state insurance commissions provide authority for regulating dollar flow by controlling the price of services and the price of insurance.

Taken together, this legislation influences major factors determining how a specific health care organization performs—the expenditures it can incur, the facilities and manpower it can use, and the kind and amount of services it produces. While the immediate effects of these decisions are on an institution, there are important questions concerning their effects on the communities that receive the services: How much in the way of resources, money, manpower, and facilities is expended for the residents of the community? What cases are treated and what types of therapy employed? How do decisions made by the public sector change the situation? Answers to these questions depend on statistics that describe, on a per capita basis, the input of resources, and the production of services, and the effect of these on health status. If this information were available for the different communities of a region or state, it would be possible to appraise the impact of regulatory decisions on the equality of distribution of resources and dollars and the effectiveness of medical care services.

For technical and organizational reasons, documentation of the health care experience of populations has been restricted to large political jurisdictions such as counties, states, or nations. Studies at this level of aggregation have used indicators that support direct comparisons among areas. Relationships between the supply of manpower, facilities, and expenditures and the population on whose behalf these resources are expended are expressed as direct input rates—for example, the number of physicians or beds per thousand persons or per capita expenditures. The quantity of services produced or the kinds of cases treated are commonly expressed as "utilization rates." Examples of hospital utilization statistics include the number of days the residents of an area spend in hospital (called "patient days"), number of surgical procedures, and number of cases of a given diagnosis admitted—all expressed in terms of events per thousand persons at risk. These rates are commonly calculated on an annual basis and, for utilization, are often "age-adjusted" so as to remove the effect of age as an explanation of difference between regions.

With these indicators, a number of studies have shown population-based differences in use of health manpower and facilities and delivery of health services that are difficult to attribute to differences in illness rates. In Canada, hospital utilization rates tend to be as much as 50 percent higher than rates in the United States. Variations among states are large. Medicare expenditures per enrollee in 1970 were twice as high in California as in Arkansas. The number of physicians per thousand persons has been up to three times higher in some states than in others. International comparisons and studies of regions within states show that there are large differences in the rate of delivery of specific surgical procedures (*1*).

In 1969, there was implemented in the state of Vermont a data system that monitors aspects of health care delivery in each of the 251 towns of the state. When the population of the state is grouped into 13 geographically distinct hospital catchment, or service, areas, variations in health care are often more apparent than they are when the population is divided into fewer, larger areas. Population rates can be used to make direct statistical comparisons between each of the 13 hospital service areas. Since the medical care in each area is delivered predominantly by local physicians, variations tend to reflect differences in the way particular individuals and groups practice medicine. The specificity of the information in Vermont's data system makes it possible to appraise the impact that decisions controlling facility construction, price of insurance, and the unit price of service have on the equality of distribution of facilities and dollars in a given population.

Our article examines the extent to which bed and manpower use, expenditures, and utilization vary among hospital service areas in Vermont. Variations in utilization appear to indicate that the effectiveness of a given level of delivery of service is uncertain. Observed variations in expenditure are evaluated in terms of lateral transfer of income among areas; these variations occur because in some areas the average price of insurance is consistently higher than the average per capita reimbursement. Past decisions of the Price Commission and the state Hill-Burton agency are reviewed. Evidence is presented that their decisions, based on institutional rather than population data, have served to increase rather than decrease inequalities among areas.

Concepts and Measures

Vermont, with a population in 1970 of 444,000, is largely rural; less than a third of its population lives in towns and villages of over 2500 persons. The state is organized administratively into

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251 towns, averaging 37 square miles (1 square mile = 2.59 square kilometers) in area and ranging in population from 10 to 35,000 persons, with a median of 825. Relevant health data on these populations have been assembled from sources of data and published reports in order to develop files on hospital discharges, nursing home admissions, Medicare reimbursements, health manpower, facilities, expenditures, and mortality (*2*). Several special surveys were necessary to complete data sets. At least the following data on each patient are available: age, sex, residence, length of stay in the hospital, diagnoses, procedures, and referring and attending physician and surgeon. In this article, data describing the use of medical services are based on 1969 abstracts, hospital and nursing home discharges, and home health agency encounters—except for (i) Medicare Part B, which is an estimate for 1972 based on all billings processed by the third-party carrier during January and February 1972, and (ii) a 1963 patient origin study by the Vermont State Health Department that we used to estimate 1963 hospital expenditure rates. We believe that, for each set of data used in this article, the information includes nearly the total medical care experience of the populations under study.

To study particular health care systems, we have grouped towns into hospital service areas surrounding the hospital used most frequently by the town (Table 1 and Fig. 1). Residents of towns located near a hospital show a high percentage of use of the local facility. In the smaller, more rural towns located between hospitals, use tends to be divided. Service areas were set up to maintain geographic continuity (*3*). Three areas contain two hospitals in the same community, while the remainder contain a single facility. Three areas with populations under 5000 have been excluded, leaving 13 available for analysis. Twelve of the 13 areas are served primarily by community hospitals, varying in bed size from 32 to 207. Area 12 contains a 100-bed community hospital and a 587-bed teaching hospital, which serves both as a community hospital and as the principal referral hospital for most of the state. A university hospital in New Hampshire is the principal referral hospital for three service areas located in the eastern portion of Vermont.

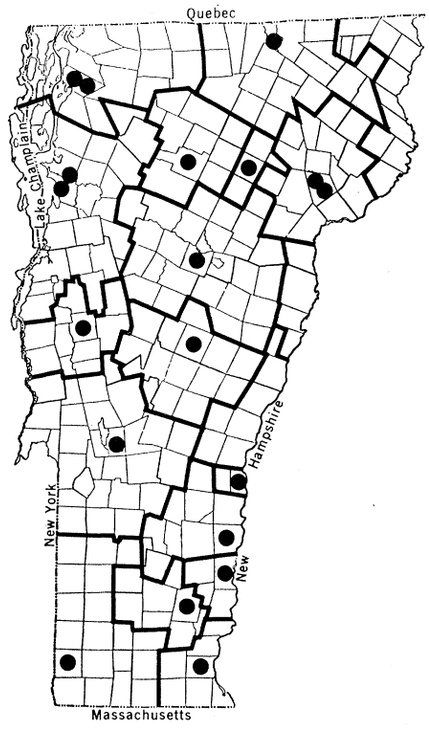

Fig. 1. Map of Vermont showing minor civil divisions, the Vermont town (lighter line). Darker line shows boundaries of hospital service areas. Circles represent hospitals. Areas without circles are served principally by hospitals in New Hampshire.

Measures of health care delivery include age-adjusted utilization rates and indices of manpower, facilities, and expenditures. Estimates of manpower and facility use in a geographically defined population present technical and conceptual difficulties. Patient mobility, regionalization of specialized services, and the absence of residential qualifications for admission to facilities contribute to these difficulties. While the number of hospital beds physically situated in an area provides a rough index of supply, it does not account for hospitalization of residents outside the area or for local use by nonresidents. We have estimated the rate of input of hospital beds based on total hospital utilization by the population of each service area. Estimates are made by allocating facilities to each service area of the state in proportion to the use of these facilities by residents. For example, if 10 percent of a hospital's admissions originate in a given service area, 10 percent of its beds are assigned to that area. The sum of all hospitals' contributions to the service area provides a measure of total input of beds to that service area (*4*). In effect, the procedure assigns an average cost and unit of effort to each admission (*3*, *4*).

A similar allocation approach has been used to develop estimates of nursing home beds, hospital expenditures, medical manpower, and nonphysician hospital staff. For each physician acting as attending physician or surgeon in a hospital, one full-time equivalent (FTE) physician was allocated to the area, in proportion to the distribution of his patients' residences. The sums within speciality classes and overall physicians for a given service area have been used as estimates of physician labor input. Active physicians in the state who did not use hospitals (fewer than 10 percent) were assigned

Table 1. Admissions, by area of residence, and admissions to hospital in area, by residential status, Vermont, 1969.

Hospital service area	Population	Admissions, by area of residence				Admissions to hospital in area		
		Number	Hospital			Number	Residents	Nonresidents
			Local (%)	Referral (%)	Other (%)			
1	12,301	2,669	81	12	7	2,526	85	15
2	18,762	2,798	85	13	2	2,910	82	18
3	7,960	1,271	72	11	17	1,658	55	45
4	18,057	3,060	86	7	7	3,735	71	29
5	31,187	4,469	85	6	9	5,171	74	26
6	32,886	5,637	82	16	2	5,550	83	17
7	12,175	2,595	76	18	6	2,703	73	27
8	20,170	3,676	86	10	4	3,538	89	11
9	20,624	3,454	75	14	11	3,235	80	20
10	53,389	8,553	86	10	4	8,515	87	13
11	53,002	8,544	82	14	4	7,713	91	9
12	109,750	17,423	95*		5	24,400	67	33
13	13,200	1,760	63	31	5	1,862	60	40

* Includes referral hospital, which was located within the service area.

Table 2. Variation in utilization, facilities, manpower, and expenditure rates among 13 hospital service areas, Vermont, 1969.

Resource input and utilization indicators	Lowest two areas		Entire state	Highest two areas	
Utilization rates per 1000 persons					
Hospital days	1015	1027	1250	1380	1495
Hospital discharges	122	124	144	195	197
All surgical procedures	36	49	55	61	69
Respiratory disease	10	13	16	29	36
Genitourinary disease	8	9	12	15	18
Circulatory disease	12	13	17	22	25
Digestive disease	15	16	19	24	26
Nursing home admissions, age 65 and over	14	22	52	81	81
Beds per 10,000 persons					
Hospitals	34	36	42	51	59
Nursing homes	9	26	42	62	65
Personnel per 10,000 persons					
Hospital	68	76	100	119	128
Nursing home	8	23	32	51	52
FTE physicians per 10,000 persons	7.9	8.4	10.3	11.9	12.4
General practice	1.5	1.7	2.5	3.8	4.4
Internal medicine	.9	.9	1.6	1.7	2.6
Pediatrics	.1	.2	.7	1.1	1.2
Obstetrics	.1	.2	.7	1.0	1.1
General surgery	.7	.9	1.1	1.5	1.7
Expenditures per capita ($)					
Hospitals	58	63	89	92	120
Nursing homes	5	13	17	25	26
Medicare Part B, age 65 and over (1972)	54	84	127	147	162

to the hospital service area in which their practices were located. Estimates of expenditures for hospitals and nursing homes by each hospital service area were based on allocations of total reported institutional expenditures, according to frequency of admission of area residents. Medicare Part B expenditures were obtained directly from reimbursement data on the unit record claims forms.

Variations among Service Areas

Tables 2 and 3 present the ranges of variation in expenditures, input of manpower and facilities, and production of health services, measured by utilization, for the 13 hospital service areas of Vermont.

Variations in use of resources: We recorded variations in hospital bed rates and nonphysician manpower over the 13 service areas. The number of beds per 10,000 persons ranged from 34 to 59, and the number of hospital personnel per 10,000 persons from 68 to 128. Nursing home beds varied from 9 to 65, nursing home employees from 8 to 52. The input of physician effort ranged between 8 and 12 FTE physicians per 10,000 persons, with individual specialties having wider variations. The input of internists and general surgeons was more than twice in some areas what it was in others; pediatrician and obstetrician effort was more than ten times greater in some areas than in others.

Variations in expenditures: The estimated 1969 per capita expenditures for hospital services were more than twice as much in some areas as in others; for nursing some services, they were more than five times greater in one area than another. The range of reimbursements for Medicare Part B among Vermont communities is larger than that among the 50 states—and reimbursements can be up to twice as great in one state as in another.

Estimated Part B expenditures in 1972, primarily reflecting physician services, ranged between $54 and $162 per capita in the population over age 65. Greater variations are seen for specific types of Medicare services. Reimbursement for diagnostic x-ray services differed by 400 percent over service areas, electrocardiogram reimbursements by 600 percent, and total laboratory services by 700 percent.

Differences in expenditures among areas apparently are long-standing. Estimated expenditures for hospital services in 1963 correlated .82 with 1969 rates (*5*). Both 1963 and 1969 hospital expenditures were related to 1972 Medicare reimbursements ($r = .79$ and .75, respectively). Of Medicare reimbursements to physicians, 52 percent were for services delivered in hospitals.

Variations in utilization: Hospital discharge rates for all causes, adjusted for age composition, varied from a low of 122 to a high of 197 per 1000 persons. The Vermont rate of 144 was similar to the rate for the New England region. Age-adjusted hospital patient days per 1000 persons ranged between 1015 and 1495. Nursing home admissions rates varied from 1.3 to 10.0 and were not significantly correlated with hospital admissions or expenditures.

The variations in use of hospitals for broad classes of diagnoses and in rate of performance of surgical procedures is shown in Table 2. The annual rate at which respiratory conditions were treated in hospitals showed marked differences among areas: the lowest rate was ten admissions per 1000 persons, the highest 36. Defining surgery as procedures (excluding biopsies) generally requiring anesthesia and performed in operating rooms, the total surgery rate varied between 360 and 689 per 10,000 persons over the 13 service areas.

The age-adjusted rates of nine frequently performed surgical procedures are exhibited in Table 3. The rates varied tremendously over the 13 service areas, the most striking example being tonsillectomy, which varied from a low of 13 to a high of 151 cases per 10,000 persons. The neighbors of the highest tonsillectomy area recorded rates of 32, 35, 38, and 39. Primary appendectomy rates ranged from 10 to 32, with a state total of 18 per 10,000 persons. Similar variations were observed in the rate of removal of prostates, gall bladders, and uteri. For each of the procedures, the differences in rates were statistically significant by chi-square tests.

The per capita number of days spent in a hospital, reflecting the combined effect of medical decisions about admissions and about length of stay, also varied widely over the Vermont service areas. Tonsillectomy days per 10,000 persons, adjusted for age, varied from 17 to a high of 314. Appendectomy days ranged from 42 to 204, prostatectomy from 65 to 524, hysterectomy from 64 to 616, and mastectomy from 21 to 198.

Evaluation of Variations

There are a number of indications that there is uncertainty concerning the value of a given level of health care

delivery. This appears to apply to the aggregate of all services, as measured by expenditures, as well as to specific procedures. Expenditures for hospitalizations and for physician services under Medicare Part B show no significant correlation with age-adjusted mortality ($r = .05$ and .01) and perinatal mortality ($r = .08$ and .10). Hospitalization rates for specific admitting diagnoses and for surgical procedures are almost ten times greater in some hospital service areas as in others. Neither the medical literature nor our data provides substantial clues as to whether spending six times more for electrocardiograms or seven times more for laboratory services results in greater improvement in health for persons age 65 and over than does a lesser expenditure. Tonsillectomy provides an example of variability. Assuming that age-specific rates remain stable, there is a 19 percent probability that a child living in Vermont will have his tonsils removed by age 20. The probability recorded in the highest service area is over 66 percent, as contrasted with probabilities ranging from 16 percent to 22 percent in the five neighboring communities, which are ostensibly similar in demographic characteristics. There are no data available that would allow us to relate these variations to the prevalence of tonsilitis, but it appears that the variations are more likely to be associated with differences in beliefs among physicians concerning the indications for, and efficacy of, the procedure.

Because of lack of data on the prevalence of disease in the Vermont communities, the relationship between health needs and input of physician services cannot be measured directly. However, since a general association exists between serious illness and age, the age structure of the population should be an indicator of the relative health needs of a community. The percentage of the population 65 years of age and varied among service areas from 8.9 to 13.4. Multiple regression analysis of the influence of community size, population structure, and income on supply of physicians shows that physicians concentrate their efforts in the more populous service areas and in those with higher per capita incomes. They tend to avoid areas with larger proportions of persons age 65 and above. The multiple correlation between rate of physician input and population size, income, and age structure was $r = .90$, a result significant at the .001 level. The simple correlations were .51, .60, and $-.64$, respectively. Hospital service areas with small populations have proportionately more persons age 65 and over. These data suggest a poor correspondence between physician input and population need.

Table 3. Variation in number of surgical procedures performed per 10,000 persons for the 13 Vermont hospital service areas and comparison populations, Vermont, 1969. (Rates adjusted to Vermont age composition.)

Surgical procedure	Lowest two areas		Entire state	Highest two areas	
Tonsillectomy	13	32	43	85	151
Appendectomy	10	15	18	27	32
Hemorrhoidectomy	2	4	6	9	10
Males					
Hernioplasty	29	38	41	47	48
Prostatectomy	11	13	20	28	38
Females					
Cholecystectomy	17	19	27	46	57
Hysterectomy	20	22	30	34	60
Mastectomy	12	14	18	28	33
Dilation and curettage	30	42	55	108	141
Varicose veins	6	7	12	24	28

Factors intrinsic to the operation of the health care system appear to be responsible for variations in performance. The results of most medical encounters are primarily dependent on medical decisions and the economic circumstances and behavior of patients seeking care. The wide variations in utilization rates between different Vermont populations suggests that provider and consumer behavior is rarely uniform, even when economic circumstances are more or less constant, as they are for Medicare enrollees. The observation that native Vermonters of similar age and income use physician services approximately one-half as often as nonnatives suggests the importance of consumer behavior (*6*). Further evidence suggests that, once a patient is "in the system," the actual services he receives depend in part on provider characteristics.

The correlation between the total surgery rate and the input of physicians performing surgery is positive and significant, with $r = .64$. Table 4 presents simple correlation coefficients for three categories of physicians and selected surgical procedures ranked by complexity (*7*). The supply of general surgeons is positively related to the surgery rate at all levels of surgical complexity and for nearly all types of individual procedures. Populations served by proportionately higher numbers of general practitioners performing surgery tend to have lower surgery rates for the more complex procedures and higher rates for the less complex procedures. By contrast, a higher supply of physicians who do not perform surgery, particularly internists, tends to be either associated with lower surgery rates or unrelated altogether.

The ancillary, nonsurgical diagnostic procedures obtained through Medicare Part B exhibited opposite trends. Electrocardiogram, x-ray, and laboratory expenditure rates among persons age 65 and over tend to correlate posi-

Table 4. Simple correlation between medical manpower rates and rates for surgical and diagnostic procedures in 13 Vermont hospital service areas, 1969.

Procedure	Physicians performing surgery		Physicians not performing surgery
	General surgeon	General practitioner	
Surgical			
Most complex	.54	−.25	−.19
Intermediate A	.21	−.21	−.04
Intermediate B	.68	.12	−.42
Intermediate C	.55	.16	−.39
Least complex	.48	.40	−.27
Mastectomy	.48	−.20	−.24
Hysterectomy	.39	−.21	−.34
Cholecystectomy	.48	.24	−.04
Appendectomy	.31	.14	−.28
Tonsillectomy and adenoidectomy	.46	.42	−.28
Varicose veins	.07	.31	−.16
Dilation and curettage	.08	.38	−.42
Total	.54	.19	−.44
Diagnostic			
Electrocardiogram	−.12	−.36	.41
Laboratory	−.06	−.30	.30
X-ray	−.10	−.28	.35

tively with the supply of internists and other physicians who do not perform surgery and to be unrelated to the supply of surgeons. All three kinds of procedures were positively related to the input of hospital beds and nonsurgeons, the multiple correlations being $r = .69$ for x-rays, .67 for electrocardiograms, and .82 for laboratory procedures.

Variations in the health care experience of different Vermont populations may be explained more by behavioral and distributional differences than by differences in illness patterns. We are, of course, unable to state which utilization rates are "normal" or which input rate represents a better allocation of resources. For example, for a given kind of surgery or diagnostic technique, it is not clear which rate indicates that medically unnecessary procedures are being performed or that not enough is being done. An important reason for uncertainty is that few prospective studies under controlled circumstances have been performed. Because the outcome of one type of service compared to another (or to none at all) is often not known, the variation in therapeutic and diagnostic procedures observed among different Vermont communities cannot be strictly evaluated (*8*). However, given the magnitude of these variations, the possibility of too much medical care and the attendant likelihood of iatrogenic illness is presumably as strong as the possibility of not enough service and unattended morbidity and mortality.

While interpretation of variations in utilization poses rather than answers questions concerning effectiveness, the data provide prima facie evidence of inequality in the input of resources. Variations in expenditure, sustained in large part through third-party payment mechanisms, pose questions of equity, since the price of insurance is not adjusted to reflect these differences. Under Medicare Part B, the enrollee and the federal treasury each contribute $68 annually (1972). The lowest per capita reimbursement in the B areas of Vermont is $54, 20 percent less than the average amount contributed by the enrollee. In contrast, the highest reimbursement in the state was $164 per capita, representing a benefit recovery that exceeded combined patient and federal contributions by more than 20 percent. A similar situation obtains for private medical and hospital insurance. Under Blue Cross–Blue Shield, premiums are established on a Vermont- and New Hampshire–wide "community rating" basis, with residents of low expenditure areas paying similar amounts for similar levels of coverage as residents of high expenditure areas.

Table 5. Population-based indicators of bed input and patient days, compared to bed need as determined by Hill-Burton planning formula (Vermont service areas, ranked by 1969 bed input rates).

Hospital service areas*	Bed input (per 1000 persons)	Patient days (per 1000 persons)	Percent increase in bed need
1	5.9	1495	44
2	4.4	1361	5
3	4.3	1027	22
4	4.0	1292	27
5	3.7	1174	18
6	3.7	1132	8
7	3.6	1077	6
8	3.4	1015	2

* Contains only hospital service areas that are coterminous with Hill-Burton areas.

Price Commission and Hill-Burton Decisions

A review of the decisions of the Hill-Burton and Price Commission agencies in Vermont reveals the difficulties of public regulation without the benefit of information about variations in per capita facility and manpower input, expenditures and service utilization. The information available to these agencies is based on indicators that do not describe the experience of the population receiving services from the regulated health care organizations. They cannot take into account the effect of their decision on lateral transfer of income nor appraise the value of increasing the rate of delivery of services.

The planning method used by the Hill-Burton agency in Vermont is similar to that used in most states. The formula for estimating hospital bed need is based on manifest demand, as measured by hospital patient days (without reference to the population), and an average daily patient census equal to 80 percent of a hospital's total beds. Population coverage enters the formula only through projected growth. No account is taken of admissions of area residents to other hospitals or of services delivered to nonresident patients (which in area 12, for example, comprise over one-third of all admissions). The single underlying premise is that demand, in terms of the total number of days a hospital bed is used, constitutes need.

Application of the Hill-Burton technique is illustrated by the recommendations for more hospital beds in the state contained in the 1971 Vermont State Plan (*9*) (Table 5). The recommended increase bore little relation to existing bed input and service utilization. The greatest increment (44 percent) was assigned to a hospital with a bed rate of 5.9 and a patient day rate of 1495, both the highest in all 13 areas. The lowest increment (2 percent) was assigned to a hospital with a bed rate of 3.4 and a patient day rate of 1015, both the lowest in all 13 areas. The second highest increase (27 percent) was assigned to a hospital of intermediate service utilization and bed rates, but with an average daily census approaching 100 percent and a mean length of stay exceeding the state average by 22 percent.

Since 1969, three hospitals in Vermont have undertaken construction projects financed under the Hill-Burton program. Assuming that the geographic distribution of patients using these facilities remains the same, the increased number of beds in two of the hospitals will move the bed input rates in these service areas to the second and third highest positions in the state. Examination of subsequent years' data will be required to ascertain whether the increase in bed input is associated with increase in service utilization or a general drop in average daily census.

The Federal Price Commission's control of expenditures on hospitals is indirect, since it is concerned with limiting increases in prices of routine, daily hospital services and of ancillary services, including x-ray and laboratory procedures. Decisions are based on unit pricing structure and other institutional contingencies and do not take volume of services into consideration. Since the expenditure rate for a community represents the combined effects of volume and unit price, both factors must be considered. For hospital expenditures, the per capita rate may be expressed as a function of the patient day rate and the average cost per patient day. Over the 13 service areas, volume and the weighted average cost per day each accounted for nearly 40 percent of the variation in per capita hospital expenditures, with the rest attributed to differences in the amounts of ancillary services. The implication is that the two

factors are of about equal importance in the determination of expenditures.

Since the inception of phase II Price Commission guidelines limiting annual increases in unit service price to under 6 percent, three Vermont hospitals have initiated requests for exceptions. The first was withdrawn voluntarily before a public hearing was held, the second was denied, and the third was approved. The hospital receiving the exception was the principal institution serving an area that ranked first in the state in hospital manpower input rate and first in patient day rate. While the average patient day charges were relatively low, the high admission rate resulted in a per capita expenditure rate that ranked second highest in the state.

Both the Hill-Burton and the Price Commission decisions have served to *increase* variations in health care in Vermont. The decisions of the Price Commission to award a selective exception to a Vermont area with high hospital manpower use and expenditure rates will probably increase the disparities among areas and increase horizontal transfer of income. The building of additional facilities in high utilization areas presumably will lead to increased utilization. Both decisions probably will result in the delivery of additional health services without evidence that additional health services are of specific value for the receiving population.

For the Medicare and Medicaid populations, PSRO's are assigned broad responsibility for establishing the medical necessity of current health care patterns within their particular regions. This responsibility suggests that PSRO's are the appropriate agency to come to grips with the meaning of variations in population-based utilization rates among different medical care markets. However, rational inquiry into the meaning of variations in probability of surgical removal of organs, diagnostic procedures, hospital admission case mix, and so forth, will often require formal testing of an hypothesis concerning the relations between health care and outcome. This is a long-range proposition and requires a high level of organization and technical attainment, which will not be easily developed. However, specifically in those instances where public decisions precede the implementation of new health care technology (for example, the installation of coronary intensive care units), it seems reasonable to tie implementation to the willingness of PSRO's to develop explicit clinical standards and perform prospective evaluations of the effect of the technology on medical outcome. This strategy could convert the essentially uncontrolled experiments in health care delivery that characterize the majority of health care efforts to a situation in which both the profession and the public can reach some certainty concerning the value of the investment.

Short of engaging in extensive evaluation of alternative levels of service, PSRO's could provide a valuable service by reviewing medical necessity through more routine methods of peer review. Population-based indicators of resource input, utilization, and mortality are particularly useful in identifying communities whose health care experience deviates from regional averages. These profiles can aid in the selection of areas for further review, when the likelihood is high that medically unnecessary care is being delivered. Further, continuous monitoring of these communities will identify the successes and failures of PSRO's in dealing with performance that departs from regional norms.

Summary and Conclusions

Health information about total populations is a prerequisite for sound decision-making and planning in the health care field. Experience with a population-based health data system in Vermont reveals that there are wide variations in resource input, utilization of services, and expenditures among neighboring communities. Results show prima facie inequalities in the input of resources that are associated with income transfer from areas of lower expenditure to areas of higher expenditure. Variations in utilization indicate that there is considerable uncertainty about the effectiveness of different levels of aggregate, as well as specific kinds of, health services.

Informed choices in the public regulation of the health care sector require knowledge of the relation between medical care systems and the population groups being served, and they should take into account the effect of regulation on equality and effectiveness. When population-based data on small areas are available, decisions to expand hospitals, currently based on institutional pressures, can take into account a community's regional ranking in regard to bed input and utilization rates. Proposals by hospitals for unit price increases and the regulation of the actuarial rate of insurance programs can be evaluated in terms of per capita expenditures and income transfer between geographically defined populations. The PSRO's can evaluate the wide variations in level of services among residents of different communities. Coordinated exercise of the authority vested in these regulatory programs may lead to explicit strategies to deal directly with inequality and uncertainty concerning the effectiveness of health care delivery. Population-based health information systems, because they can provide information on the performance of health care systems and regulatory agencies, are an important step in the development of rational public policy for health.

References and Notes

1. For example, see J. P. Bunker, *N. Engl. J. Med.* **282**, 135 (1970); A. M. Burgess, Jr., T. Cotton, O. L. Peterson, *ibid.* **273**, 533 (1965); C. E. Lewis, *ibid.* **281**, 880 (1969); L. S. Reed and W. Carr, *Soc. Sec. Bull.* **31**, 12 (1968); S. Shapiro, L. Weiner, P. M. Densen, *Amer. J. Public Health* **48**, 170 (1958); Department of Health, Education, and Welfare, Social Security Administration, *Reimbursement by County and State; Medicare 1970* (Government Printing Office, Washington, D.C., 1972).
2. Each data set has been modified into a standard format and code system for individual physicians, diagnoses, procedures, and other key variables. Since 1969, hospital discharge abstracts have been collected for all patients discharged from the 18 short-term, voluntary hospitals in the state and for Vermont residents discharged from referral hospitals in New Hampshire and New York. Patient information from hospitals participating in the Professional Activities Study (PAS) was obtained from the Commission on Professional and Hospital Activities, Ann Arbor, Michigan. Four smaller, nonparticipating hospitals were surveyed directly by the staff. Although hospitalization of Vermonters outside these areas has not been recorded, the resultant underreporting is estimated to be less than 3 percent for all classes of admission. Nursing home admission files and home health agency files have been obtained through staff surveys of each institution and agency in the state. Medicare Part B information has been obtained from the third-party carrier responsible for reimbursement. Problems of data accuracy are bound to arise in multi-institutional studies. Despite extensive consistency checks made by PAS and by the staff, the reliability of certain items of information is primarily dependent upon the initiators of the record form. This applies particularly to diagnosis and cause of death, where the criteria are unspecified and the extent of diagnostic work-up highly variable. Simple facts such as sex, age, dates, place, and procedures appear to be recorded with a reasonable degree of accuracy, based on independent reabstracting of samples of records from several institutions. An age-specific rate relates to the events in the population within a particular age category. An age-adjusted rate is the weighted average of age-specific rates within a given group. It is designed to account for differences in age structure among populations and to permit direct comparisons between areas and groups. In this article, the weights are the proportions of persons in each 5-year age group in the entire state. Since many of the occurrences under consideration are highly age-dependent, we have used age-adjusted rates whenever the relevant data were available to us.

3. In contrast to highly urbanized centers, the hospital service areas of Vermont tend to be relatively discrete and seldom overlap. Over 85 percent of all hospitalizations of Vermont residents in 1969 took place in the service area of residence. Maternity patients, patients requiring general surgery, and most patients with medical conditions that comprise the majority of admissions are usually hospitalized in their own area. Patients with conditions requiring specialized services were more often referred to other areas. In the community hospital areas, about two-thirds of the admissions for neoplasms were treated locally and one-third treated in referral hospitals. Neoplasm was the major diagnosis in 5 percent of hospital admissions.
4. The major effect of the allocation procedure on estimated bed supply was to distribute one-third of the 587 beds of the referral hospital to the other hospital service areas in and outside of the state. In four areas, the number of allocated beds was lower than the number of resident beds, reflecting overlap at service boundaries. In none of the community hospital service areas did the allocated number of beds differ from the resident beds by more than 20 percent.
5. Significance level for simple regression coefficient with 11 degrees of freedom: r: .55 = 5 percent; .68 = 1 percent.
6. Unpublished report prepared by the Northern New England Regional Medical Program for the Connecticut Valley Health Compact, Springfield, Vermont, 1971.
7. Blendon's classification of level of difficulty of surgical procedures was used [R. J. Blendon, thesis, Johns Hopkins University (1969)].
8. Cochrane has recently summarized technical and organizational problems encountered in appraising the effectiveness and efficiency of health services. Failure to subject particular medical actions to randomized, controlled trials is, in his opinion, the major reason for uncertainty about the value of many common preventive, therapeutic, and diagnostic activities [A. L. Cochrane, *Effectiveness and Efficiency* (Nuffield Provencial Hospital Trust, London, 1972)].
9. Modified from *Vermont State Plan for Construction and Modernization of Hospital and Medical Facilities* (Vermont State Health Department, Burlington, 1971).
10. Partially supported by Public Health Service grant PHS-RM0303. We gratefully acknowledge the help of W. Gifford, R. Gillim, P. Hickcox, K. Provost, and J. Senning in the work leading to the development of this article.

NEWS AND COMMENT

Watergate: Verification of Tapes May Be Electronic Standoff

The long legal skirmish over possession of the White House's Watergate tapes is over, but a new battle of wits between opposing experts is about to begin, this time with scientists instead of lawyers as the adversaries.

Last month Judge Sirica, in consultation with the White House and the Special Prosecutor's Office, appointed a panel of six experts to advise on the authenticity of the surrendered tapes. If the tapes have been altered, and altered by amateurs, the panel will probably have little difficulty proving it. But if the tapes have been edited by the most sophisticated means available, the result may be a technical impasse between the counterfeiters and the verifiers from which no clear conclusion is possible.

A second technical issue raised by the tapes is whether the panel can succeed in resurrecting the conversation on the 18-minute portion of tape, part of which the President's secretary says she may have erased by accident. The erasing procedure on tape recorders reduces sound to an inaudible level but often leaves a residual signal from which, by suitable computer enhancement, the original conversation can be reconstructed. The reconstruction process is so well recognized in the intelligence community that the Department of Defense requires tapes containing classified material to be specially demagnetized. According to George O'Toole, a former CIA computer specialist with experience in signal processing, restoration of the 18-minute gap in the 20 July tape would certainly be difficult, but he says, "I don't know of anyone in the field who would say it is impossible if it were important enough to do."

Sirica's panel of experts* has been chosen to represent the best available level of competence outside of the federal government. Selection of the panel was coordinated by Carl Feldbaum, a member of the Special Prosecutor's Office, who spent 2 weeks in ascertaining what disciplines were pertinent to the verification of the tapes and who were the best people to represent them. Panel members have been instructed by the court not to comment on the procedures they will follow, but they will probably be guided by an outline of possible approaches prepared for Feldbaum at an early stage of the selection process. The author of the outline is Barry Blesser, an assistant professor at MIT whose research field includes both electrical engineering and acoustics. Three features that should be studied for evidence of tampering, Blesser told *Science*, are the various electronic fingerprints left by the tape recorder, the environment in which the microphone was operated, and certain speech factors including what are known as coarticulation features.

Potentially the most useful kind of fingerprint is the high frequency added to the tape at the same time as the sound frequencies in order to smooth out the nonlinear character of the magnetic tape. The bias frequency, as it is known, varies from one production line model to another and is a special, though not necessarily unique characteristic of each machine. Most sound engineers assume that the bias frequency cannot be picked up from a tape. It seems to be a little known fact that the bias can be usually recovered with sufficiently fine recording heads. Study of bias frequency should tell first of all whether one or more machines were used in making the tapes given to the court.

The bias frequency should also indicate the presence of any spliced-in segments of tape that may have been recorded on the same recorder. Because of its periodic nature, the bias frequency of a spliced-in segment will be out of phase with that of the original recording, unless special precautions have been taken. Mismatching of the two phases can be detected by a device known as a phase-lock loop.

A third application of the bias frequency is to determine if the original tape has been either rerecorded or overdubbed. The system used by the White House is said to have been voice activated, which means that the tape spools begin to turn each time the microphone starts picking up voices. The acceleration of the tapes from rest to their normal speed can be measured by the change in pitch of the recorded bias

* Panel members are as follows: Richard H. Bolt, chairman of Bolt, Beranek and Newman; a former professor of acoustics at MIT, Bolt has available to him the expertise of some 40 specialists in his own company. Franklin Cooper, adjunct professor of linguistics at the University of Connecticut and one of the pioneers of speech analysis. James L. Flanagan, Bell Laboratories, a specialist in the digital coding of speech. John G. McKnight, consultant to the Dictaphone Corporation, formerly at Ampex and involved in specifying standards for audio tape recorders. Thomas G. Stockham, professor of computer science, University of Utah, specialist in the processing of sound and pictures with digital methods. Mark R. Weiss, vice-president for acoustics research, Federal Scientific Corporation, New York; Weiss has developed techniques for reducing background noise and other interference on speech recordings in order to increase the detectability and intelligibility of speech.