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Analysis of the Geographical Distribution of Anesthesia Manpower in the United States

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The 1970 geographical distributions of total anesthesia manpower, anesthesiologists, and nurse anesthetists by state were analyzed by multiple regression to account for their unevenness. Independent variables included factors relating to prior professional contact in the state, professional satisfaction, practice income, demand for services, and environment. The distribution of training programs accounted for 41 per cent of the variance in the distribution of total manpower, but 55 per cent was explained by the number of operations, location of nurse anesthesia schools, and proportion of total state employment in service occupations (a proxy for the availability of consumer services). Location of training programs and the absence of the other type of personnel were good predictors for the manpower subgroups. The distribution of nurse anesthesia schools, anesthesiologists, number of surgical operations, and the relative value schedule conversion factor together accounted for 60 per cent of the variance in the nurses' distribution. The location of residency programs (or positions) was a better predictor for the anesthesiologists' location than medical schools or factors characterizing the demand for services. The distribution of nurse anesthetists, hospital cost per day (considered a proxy for a satisfying professional life and for regionalization of services), and residency programs explained 81 per cent of the variance in the anesthesiologists' distribution. Although the regression predicts that increasing the number of residency programs in an underserved state should be associated with an increase the number of anesthesiologists, such a policy may be infeasible due to pending federal health manpower legislation unless matched by decreasing a greater number of programs in relatively oversupplied states. (Key words: Anesthesiologists, distribution; Nurse anesthetists, distribution; Manpower, anesthetic.)

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PROPOSALS FOR CHANGE in the organization, financing, and delivery of health services are being made with increasing force and frequency as health care becomes a more pressing social and political issue. Among the most debated health care topics is the maldistribution of physicians with respect to specialty and location. Qualitatively the anesthesiologists' geographical distribution resembles that of all physicians, with the preponderance located in densely populated areas. However, quantitatively the anesthesiologists' distribution is more uneven (fig. 1, *top*), with some states having nine times as many anesthesiologists per population as others.[1,2] The Committee on Manpower of the American Society of Anesthesiologists notes that anesthesiologists "tend to be clustered in the cities where there are larger hospitals, medical centers, and more physicians."[1] Further, there is a reciprocal relationship between anesthesiologists and nurse anesthetists[2]; those states having a large number of anesthesiologists have fewer nurse anesthetists (fig. 1, *middle*). A study performed for the Bureau of Health Manpower Education found "little consistency of pattern" in the distribution of nurse anesthetists, other than the reciprocal relationship with anesthesiologists.[3] The distribution of the total manpower is also very uneven (fig. 1, *bottom*).

Planning for the future delivery of anesthesia services requires a more precise description of the determinants of the geographical distribution of manpower, as well as their utilization and productivity. Suitable analysis should not only identify specific factors that account for the distribution but also permit inferences, if not predictions, given changes in the factors. Additionally, the analysis should

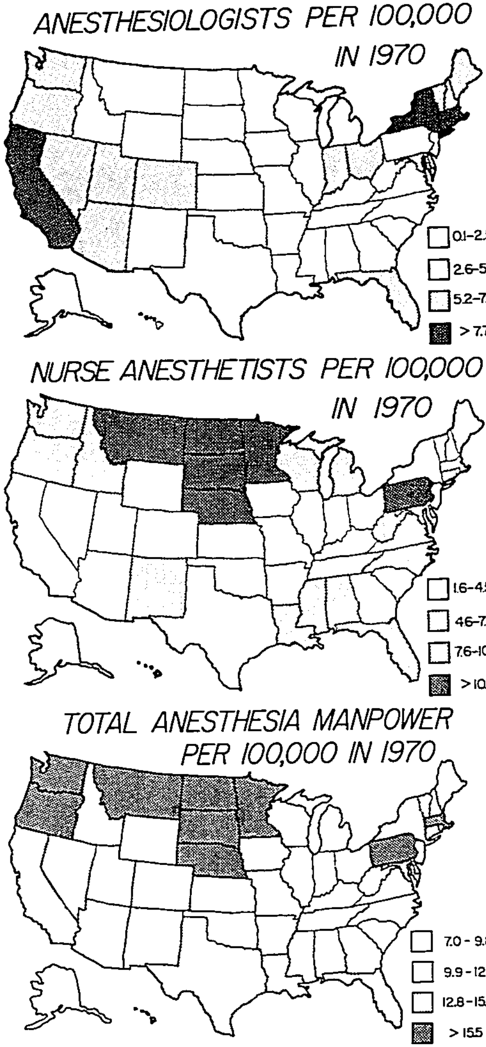

FIG. 1. Distributions of anesthesiologists, nurse anesthetists, and total anesthesia manpower by state in 1970. The means were 5.13, 7.57, and 12.70; the standard deviations were 2.52, 3.03, and 2.79, respectively.

TABLE 1. Major Categories of Influence on Location of Physicians*

1. Prior exposure	Events in the physician's life that permitted contact with a community
2. Professional relationships	Practice-related aspects contributing to a satisfying and successful professional life
3. Economic factors	Visible quantities directly influencing practice net income
4. Demand determinants	Characteristics associated with the demand for medical services
5. Environmental factors	Attributes contributing to quality of life in a community

* After McFarland.[6]

evaluate the potential roles of factors that are amenable to public policy influence, such as the presence of medical schools, residency programs, and advanced postgraduate training.

In an attempt to satisfy these objectives, data relating to the distribution of anesthesia manpower were subjected to multiple regression analysis. Multiple regression is a statistical technique that yields an equation predicting the dependent variable (the manpower distribution) in terms of a combination of independent or predictor variables, describes the contribution of each predictor in the accounting of the total variance within the dependent variable, and measures the strength of association between the dependent and independent variables.† The analysis was conducted using a cross-sectional design (by state and the District of Columbia) for the year 1970. That year was chosen to use both the A.S.A data on anesthesiologists and the extensive statistics collected during the 1970 U. S. Census. Factors that have been identified among the major categories of influence upon the location of physicians (table 1) or might be expected to affect the distribution of anesthesiologists were chosen for analysis. Presumably some of these factors may influence the distribution of nurse anesthetists. The distributions of anesthesiologists and nurse anesthetists have been studied separately, as well as combined, because of an assumption that different determinants operate (*vide infra*).

† An intuitive approach to regression is provided by Colton[4]; a more advanced treatment is given by Armitage.[5]

Methods and Materials

Source of Data

Table 2 lists the manpower ratios and the factors (predictor or independent variables) with their summary statistics.‡ The variable *Anesthesiologists* relies upon the 1970 data prepared by Medical Mailing, Inc., which includes individuals in active, resident, and academic (teaching and/or research) categories, irrespective of membership in the A.S.A.§ *Nurse Anesthetists* is derived from the membership list of the American Association of Nurse Anesthetists and includes some inactive persons, because their 1970 data are not broken down by clinical activity.¶ Data relating to residency positions enumerate *approved* and not necessarily occupied positions. The variable pertaining to the relative value schedule is based upon a nonrandom sampling of 324 anesthesiologists reported by A.S.A. districts. The other two variables requiring comment are *Non-estimated Operations* and *Estimated Operations*. The former is derived from the 1970 American Hospital Association questionnaires submitted by 6,266 acute care hospitals, which performed 14,057,861 surgical operations; the latter includes an A.H.A. estimate for the non-reporting facilities, bringing the totals to 7,123 hospitals and 14,818,744 operations.

‡ The complete data matrix, as well as correlation matrix and regression results not shown here, may be ordered as NAPS Document 02871 from ASIS/NAPS, Microfiche Publications, 440 Park Avenue South, New York, N.Y. 10016, remitting $3.00 for microfiche copy or $5.00 for photocopy. Foreign orders add $3.00 for postage.

§ Dr. Richard Ament (22 Lake Ledge Drive, Williamsville, N. Y. 14221), personal communication.

¶ Approximately 15 per cent of the A.A.N.A. membership was inactive in 1970 [Nancy A. Fevold (A.A.N.A., 111 E. Wacker Drive, Chicago, Ill. 60601), personal communication]; in addition, the membership data include student nurse anesthetists, of whom the first-year group may contribute little to clinical coverage because of didactic work.

TABLE 2. The Variables*

	Mean	Standard Deviation
Manpower ratios (per 100,000 pop.)		
Total manpower	12.70	2.79
Anesthesiologists	5.13	2.52
Nurse anesthetists	7.57	3.03
The factors		
Prior exposure		
Residency programs	0.76	0.85
Residency positions	6.31	8.30
Advanced residency positions	1.64	1.94
Total residency positions	7.96	9.91
Four-year medical schools	0.57	0.65
Nurse anesthesia schools	1.22	1.41
Professional relationships		
Hospital cost per day ($)	76.1	16.0
Acute care beds in 1969/1,000 pop.	5.15	1.15
Economic factors		
Relative value schedule conversion factor ($)	6.82	0.74
Health insurance benefits paid per capita ($)	65.4	29.1
Malpractice premium for fifth risk category ($)	1367.	847.
Malpractice actions closed/100 physicians	5.82	2.71
Demand determinants		
Personal income ($)	3712.	615.
Disposable income ($)	2939.	438.
Population change (% of 1960 pop.)	113.3	12.7
Urbanization (% pop. in SMSA†)	54.0	26.7
Aged (% pop. aged ≥ 65)	9.64	2.02
Education (% pop. aged ≥ 25 with	10.72	2.36
≥ 4 years' college)	71.04	25.20
Non-estimated surgical operations (,000's)	75.08	24.20
Estimated surgical operations (,000's)		
Environmental factors	5110.	2218.
Annual heating degree days	765.	175.
Public school quality ($/pupil)	20.1	5.67
Consumer services availability (per cent	8.19	16.92
services employment/total employment)		
Recreation (recreation areas/sq km)		

* All data refer to 1970 unless specified otherwise; enumerative statistics relating to training and operations are per 1,000,000 population. Appendix 1 lists the sources of these data.
† Standard Metropolitan Statistical Area.

THE METHODS

Because a *linear* regression model was to be used to account for the manpower distributions by state, each of the three dependent variables was plotted (program BMDO5D**) against each of the independent variables to demonstrate curvilinear relationships requiring transformations to obtain linearity. Each of the dependent variables was subjected to stepwise regression (BMDO2R**) to reduce the number of independent variables to a more manageable number, as well as identify the group of independent variables that would explain the bulk of the variance in the dependent variable. This regression program also yielded a correlation matrix from which Pearson's coefficients of correlation were obtained (table 3); standard tables were used to estimate the statistical significance of these simple correlation coefficients. A multiple regression program (BMDO3R**) yielded equations (tables 4, 5, and 6, and Appendix 2)

** Dixon WJ: BMD: Biomedical Computer Programs. Berkeley (Cal.), University of California Press, 1973.

whose overall statistical significance were estimated with *F*-ratios and whose regression coefficients were evaluated with *t*-tests.

The Results

Table 3 shows that *Total Manpower* correlates moderately with operations, *Nurse Anesthesia Schools*, *Beds*, several residency variables, and *Consumer Services Availability*. *Anesthesiologists* correlates highly or moderately with all residency variables, *Medical Schools*, *Hospital Cost*, *Insurance Benefit*, *Personal Income*, *Disposable Income*, the square of *Urbanization*, *Education*, *Recreation*, and the number of operations. There is also an inverse correlation with *Nurse Anesthetists* and a low but positive correlation with *Malpractice Premium*, *Public School Quality*, and *Consumer Services Availability*. *Nurse Anesthetists* correlates moderately with *Nurse Anesthesia Schools* and inversely with *Anesthesiologists*; lesser correlation is found with *Residency Programs*, *Hospital Cost* (inverse), *Beds*, and *Urbanization* (inverse).

Forty-one per cent of the variance in *Total Manpower* is accounted for by training variables (equation 1, table 4), but the best prediction is obtained by combining *Nurse Anesthesia Schools*, *Non-estimated Operations* and *Consumer Services Availability* (equation 2), which explains 54 per cent of the variance. Inability to account for more variance is probably related to the heterogeneity in the aggregate manpower.

The bulk of the variance in *Anesthesiologists* is accounted for by *Nurse Anesthetists* (with a negative coefficient), a medical training variable, and *Hospital Cost* (table 5). Seventy per cent of the variance is explained by the regression equation when the training variable is *Medical Schools* (equation 3). S

TABLE 3. Pearson's Coefficients of Correlation

	Total Manpower	Anesthesiologists	Nurse Anesthetists
Total manpower	1.000	0.353*	0.629‡
Anesthesiologists	0.353*	1.000	−0.505‡
Nurse anesthetists	0.629‡	−0.505‡	1.000
Residency programs	0.383†	0.797‡	−0.309*
Residency positions	0.464‡	0.772‡	−0.213ns
Advanced residency positions	0.504‡	0.694‡	−0.112ns
Total residency positions	0.487‡	0.781‡	−0.200ns
Medical schools	0.330*	0.513‡	−0.122ns
Nurse anesthesia schools	0.491‡	0.001ns	0.452‡
Hospital cost	0.287*	0.694‡	−0.312*
Beds	0.513‡	0.207ns	0.301*
Relative value schedule	0.205ns	0.040ns	0.156ns
Insurance benefit	0.463†	0.669‡	−0.129ns
Malpractice premium	0.080ns	0.329*	−0.199ns
Malpractice actions	0.255ns	0.127ns	0.130ns
Personal income	0.354*	0.650‡	−0.214ns
Disposable income	0.408†	0.619‡	−0.137ns
Population change	−0.063ns	0.192ns	−0.217ns
Urbanization	0.216ns	0.579‡	−0.282*
(Urbanization)²	0.288*	0.677‡	−0.297*
Aged	0.160ns	0.053ns	−0.168ns
Education	0.362†	0.604‡	0.104ns
Non-estimated operations	0.553‡	0.580‡	0.030ns
Estimated operations	0.555‡	0.595‡	0.015ns
Heating degree days	0.270ns	0.082ns	0.181ns
Public school quality	0.291*	0.420†	−0.080ns
Consumer services availability	0.549‡	0.449†	0.133ns
Recreation	0.375†	0.712‡	−0.246ns

* $P < 0.05$.
† $P < 0.01$.
‡ $P < 0.001$.
ns = not statistically significant.

TABLE 4. Regression Results for Total Anesthesia Manpower

Independent Variables	Coefficients: Equation 1	Coefficients: Equation 2
Nurse anesthesia schools	0.844 (3.807)†	0.802 (3.910)†
Total residency positions	0.119 (3.766)†	
Non-estimated operations		0.025 (1.745)ns
Consumer services availability		0.191 (3.137)*
Intercept	10.728	6.125
Standard error of estimate	2.183	3.864
Coefficient of determination, R^2	0.414 [16.953]†	0.535 [18.016]†

All values in parentheses are t-values; those in brackets are F-ratios.
* $P < 0.005$.
† $P < 0.001$.
ns = not statistically significant.

TABLE 5. Regression Results for Anesthesiologists

Independent Variables	Coefficients: Equation 3	Coefficients: Equation 4
Nurse anesthetists	−0.246 (−3.533)†	−0.181 (−3.200)†
Residency programs		1.663 (7.650)†
Medical schools	1.424 (4.501)†	
Hospital cost	0.083 (6.152)†	0.058 (4.978)†
Intercept	−0.109	0.853
Standard error of estimate	1.417	1.131
Coefficient of determination, R^2	0.702 [39.902]†	0.810 [66.800]†

All values in parentheses are t-values; those in brackets are F-ratios.
* $P < 0.005$.
† $P < 0.001$.

per cent when *Residency Programs* is used (equation 4). Substitution with other residency variables does not materially alter the equation's predictive ability.

The training program is also a significant variable for the prediction of *Nurse Anesthetists* (table 6). *Anesthesiologists* with a negative coefficient and *Nurse Anesthesia Programs* together account for almost half of the variance (equation 5). Additional variance is accounted for by the relative value schedule and *Estimated Operations* (equation 6).

Addition of and/or substitution with other variables does not increase the predictive powers of equations 4 and 6. These equations predict values for the manpower groups that are quite close to the actual values (fig.2). The approach used here has been validated by a split-data technique (Appendix 3).

TABLE 6. Regression Results for Nurse Anesthetists

Independent Variables	Coefficients: Equation 5	Coefficients: Equation 6
Anesthesiologists	−0.609 (−4.764)‡	−0.849 (−5.929)‡
Nurse anesthesia schools	0.972 (4.262)‡	0.918 (4.196)‡
Relative value schedule		1.112 (2.817)†
Estimated operations		0.039 (2.571)*
Intercept	9.512	0.327
Standard error of estimate	2.273	2.006
Coefficient of determination, R^2	0.460 [20.402]‡	0.596 [16.995]‡

All values in parentheses are t-values; those in brackets are F-ratios.
* $P < 0.025$.
† $P < 0.01$.
‡ $P < 0.001$.

Discussion

Health manpower should be distributed in such a way as to enable reasonable access to quality care at the lowest cost to society. Although it is widely believed that the access to health care is inequitable, there is little agreement regarding what level of health care should be available or how to measure the "quality" of what is provided. Nonetheless, even though the conventional health indicators do not support the allegation,[7] a shortage of physicians in a given area is said

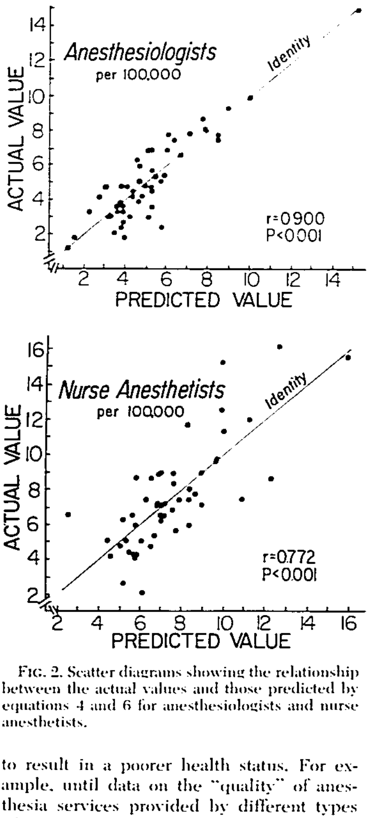

FIG. 2. Scatter diagrams showing the relationship between the actual values and those predicted by equations 4 and 6 for anesthesiologists and nurse anesthetists.

to result in a poorer health status. For example, until data on the "quality" of anesthesia services provided by different types of personnel become available, it is presumed that a general anesthetic not involving an anesthesiologist, say because of a shortage, denotes a lower standard of care. Moreover, the poor utilization of operating rooms, which is an almost universal phenomenon,[8] is probably exacerbated in areas of shortage.

At the other extreme, a relative surplus of physicians leads to inflationary pressures on the cost of medical care in the area, given the pivotal role of the physician in health care expenditures: Although he receives only 18 per cent of health care expenditures,[9] he chooses how almost all such expenditures are made.[10] Because his geographical distribution is a reasonably good proxy for the distribution of all health services,[11] the effects of physician maldistribution on medical care costs may be pervasive. To date, manpower policy has been largely unsuccessful because of inadequate analysis.

Multiple regression is an appropriate tool to search massive amounts of seemingly unrelated data for significant associations. What is identified is *association*, however, and not causation. It is entirely possible that the independent variables which "explain" the manpower distribution so well are themselves influenced by some unidentified factor(s). The other pitfall that must be avoided is extrapolation from this *inter*state study to an *intra*state situation. For example, it may be true that an underserved state may increase its number of anesthesiologists by increasing the number of residency programs. If such an initiative is undertaken to correct an *intra*state inequality between rural and urban regions, that inequality is likely to be intensified.[12] Nevertheless, the regression analysis has validity as shown by its predictive ability (fig. 2).

The regression results suggest that factors characterizing the demand for medical services are not particularly important predictors of the geographical distributions of the manpower, except in the case of the total manpower, where the number of operations is the best predictor, explaining 31 per cent of the variance. The number of operations makes a much smaller contribution to the best explanation of the distribution of only the nurse anesthetists. Factors such as the proportion of aged in the population,[13] the level of education,[14] and the income level of the community,[15] which are associated with increased demand, do not find their way into the optimum equations. For the distribution of the anesthesiologists, all the variance accounted for by these demand variables and even more variance is accounted for by the distribution of the residency programs.†† Hence, the more highly associated variable has overpowered the effect that the demand variables might have had in the equations.

A similar situation prevails with environmental factors, of which the availability of consumer services makes a small contribution to accounting for the total manpower. Such factors as quality of public schools, quality and availability of housing, and presence of recreational facilities are often volunteered as "important" in the location decisions of physicians.[6] In a survey of the graduates of a midwestern medical school, climate and recreational factors discriminated those who stayed in the state from those who migrated.[16]

Economic factors relating to the net income of the manpower made a small contribution to explaining the anesthesiologists' distribution, a larger contribution to that of the nurses. That such factors do not play a more important role, as they do with physicians in general,[15] may be related to the variables used. The studies on unselected physicians often use the office-visit fee. The equivalent fee in anesthesiology is the relative value schedule conversion factor; however, the variable relating to that fee may be defective as a result of the method used to collect the data. Moreover, any attempt now to obtain better data might be construed to be a preparatory step toward price-fixing and, thus, held to an antitrust violation. The variable relating to insurance benefits paid is not only not specific to the anesthesiologist but is colinear with *Residency Programs* (r = 0.786) and *Hospital Cost* (r = 0.539), both of which describe the anesthesiologists' distribution better.

The economic variable that by itself accounts for almost half of the variance in the anesthesiologists' distribution is *Hospital Cost* (because r = 0.694). To the extent that *Hospital Cost* contains the salaries of anesthesia personnel paid by the hospital, this variable belongs with others relating to net income. Yet, the variable has broader implications because it correlates with the community's educational level (r = 0.697), degree of urbanization (r = 0.634), disposable income (r = 0.780), number of residency programs (r = 0.465), hospital size,[17] and the variety of hospital services provided.[17] Hence, *Hospital Cost* is a surrogate for the large metropolitan medical center, with its full complement of services and consultants, which affords professional contacts, continuing education and more "challenging" cases; the variable is also a surrogate for the degree of regionalization of services. Thus, *Hospital Cost* is more appropriately categorized as a measure of the quality of professional relationships than of net income. That the regression identifies this variable confirms the conclusion of the A.S.A. Committee on Manpower and also accounts for the tendency for anesthesiologists to practice in the larger hospitals, leaving nurses in the smaller, more rural facilities.[18]

Even more pervasive as a predictor of the distribution of both types of manpower is the training program.‡‡ There are two ways in which the site of training may be influential in the location decision: During training, personal and professional ties to the area develop.[20] The training program also creates opportunities for practice for a small number, as well as improving the practice environment for many others in the vicinity. One corollary is that the last training site should have the greatest influence upon location. Indeed, for anesthesiologists the residency program is a considerably better predictor than is the medical school (equations 1 and 2, table 4). This has been found for general practitioners, unselected specialists, and several of the larger specialties.[21] Moreover, when

†† That such colinearity is responsible is apparent in the correlation matrix: *Residency Programs*, which correlates very highly with *Anesthesiologists*, also correlates with *Non-estimated Operations* (r = 0.788), *Education* (r = 0.384), *Disposable Income* (r = 0.467), and *Personal Income* (r = 0.445).

‡‡ Although nurse and physician trainees seemed relatively small subsets of their respective groups (9.5 per cent for nurses, 17.3 per cent for physicians), there was a possibility that the identification of the training program as a good predictor was merely an artifact of including trainees among the manpower in the dependent variable. However, repeating the analysis using only active, non-federal anesthesiologists[19] yielded a similar result:

$$0.713 - 0.143\,\textit{Nurse Anesthetists} + 0.326\,\textit{Residency Programs} + 0.049\,\textit{Hospital Cost}$$

$$(R^2 = 0.646, P < 0.001)$$

residency and medical school are combined with other "events" such as birthplace or internship, the probabilities of physician retention may be calculated. Not unexpectedly, the greater the number of "events" occurring in a state, the greater the probability of retention. For residency alone the retention probability is 0.16 for unselected specialists (anesthesiologists were not identified separately). When medical school or internship occurs in the same state as residency, the probability jumps to about 0.7; when all three occur in the same state the probability is 0.85. Although it appears that establishing more residency programs should lead to increased retention, caution is needed because interpretation results from taking data about one "event" out of the context of a sequence. Undoubtedly the location for some physicians is chosen *prior* to the residency, which may be taken in a state in which the individual anticipates eventual practice.[22]

Nonetheless, expanding or establishing residency programs has been suggested as a feasible and potent policy for increasing general medical manpower in an underserved state.[23] Starting a residency where there is no local demand for services, of course, would not be expected to be associated with an influx of manpower. Yet, there is only a fair correlation between residency variables and the conventional demand variables: even the distribution of operations explains only 60 per cent of the variance (because r = 0.788) in the residencies' locations. Moreover, the distribution of hospital cost per day—which could probably be shown (if data were available) to be colinear with the distribution of open-heart surgery, neurosurgery, and other specialized services requiring anesthesiologists—has only a fair correlation (r = 0.465) with the distribution of residencies. These considerations suggest that the apparent effect of residencies on manpower is at best only partially mediated through demand factors, and that there may be some flexibility in the location of training programs. To gauge the magnitude of the expected effect of altering the distribution of residency programs, one need only substitute values into equation 2. For example, adding 0.5 residency program per million population in the average state should be associated with a 16 per cent increase in the number of anesthesiologists. Moreover, the regression predicts this effect would be enhanced if fewer nurses elected to train in anesthesia consequent to the phasing out of diploma nursing schools and the lengthening of nursing education, as has been suggested.[24] The effect of additional residency programs is even greater in the most underserved states, given the fact that their populations are less than a million, they usually have no existing program,§§ and one cannot establish a fraction of a residency program.

Whether it is really feasible now to start new residencies or enlarge existing ones substantially is uncertain. At present about 7.2 per cent of the budgeted academic positions in anesthesiology are unfilled; this vacancy rate is higher than that for any other specialty except orthopedics (8.3 per cent), urology (10.3 per cent), and family medicine (16.4 per cent).[25] A more severe constraint is posed by the pending federal legislation designed to increase the proportion of physicians in primary care specialties, decrease geographical maldistribution, and decrease the number of foreign medical graduates. Based upon the more prominent bills (H.R. 5546 and S. 3239), the total numbers of residency positions are likely to be cut sharply over a few years to about 125 per cent of the prior year's graduating class from medical and osteopathic schools. For anesthesiology these initiatives may mean a considerable loss of positions.[26] Although the immediate fate of this legislation is uncertain at this writing, these bills represent a growing interest of government in correcting physician maldistribution with policy aimed at postgraduate training. Nevertheless, even if such constraints should be applied, increasing (or establishing) programs in underserved states is still possible if matched by decreasing the numbers of programs in oversupplied areas.

This study has identified the location of training programs as an important variable in the geographical distribution of anesthesia

§§ Of the ten states lacking a residency program in 1970, only one had more than the national mean for the number of anesthesiologists per population, with the mean for this underserved group being 3.33 anesthesiologists per 100,000 (65 per cent of the national mean).

manpower, particularly in the case of the anesthesiologists' distribution, for which almost two-thirds of the variance is accounted for by the residency programs alone. Although by the very nature of regression analysis one cannot be certain that the observed relationships are in any way causal, these observations are consistent with those of unselected physicians[20] and recent medical school graduates[21] from studies using different designs.

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Note added in proof (October 6, 1976): On September 30, 1976, the health manpower education bill (H.R. 5546) was reported out of conference committee without the stringent "125% residency restriction" but with lesser controls on residency positions and foreign medical graduates. In order for medical and osteopathic schools to receive federal capitation funds at least 35 per cent of graduates must elect residencies in primary care specialties (family medicine, pediatrics, and internal medicine but not obstetrics–gynecology) in the first year following enactment (40 per cent in the second year, 50 per cent thereafter). The bill does not deal with the apportionment of the *non*-primary care positions, so the implications for anesthesiology are unclear. The section on foreign medical graduates requires that such persons have a "commitment" to return home, pass parts I and II of the National Board examinations and a test of competency in written and oral English within 90 days of arrival, and stay no longer than two years (renewable upon review). Given that 55 per cent of residents in anesthesiology are foreign medical graduates,[26] such legislation is likely to result in the effective loss of many positions.

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Appendix I

Sources of Data

Anesthesiologists
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Nurse Anesthetists
Courtesy of Nancy A. Fevold, American Association of Nurse Anesthetists, 111 E. Wacker Drive, Chicago, Ill. 60601

State Populations
U. S. Bureau of the Census: Statistical Abstract of the United States, 1974. Washington, D. C., U. S. Government Printing Office, 1974, p 12

Anesthesiology Residency
Directory of Approved Internships and Residencies, 1969–70. Chicago, American Medical Association 1969, pp 144–150

Medical Schools
Medical School Admission Requirements, 1970, U. S. A. and Canada. Washington, D. C., Association of American Medical Colleges, 1969

Nurse Anesthesia Schools
Ament R: Demographic Study of Nurse Anesthetists, 1972. Bureau of Health Manpower Project Grant NIH 72-4269(P). Chicago, American Society of Anesthesiologists, 1972, Table IX

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Statistical Abstract of the United States, 1972, ibid., p 67

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Health Resources Statistics: Health and Manpower Facilities, 1970 (U. S. Public Health Service Publication No. 1509). Rockville, Md., National Center for Health Statistics, 1971, p 258

Relative Value Schedule Conversion Factor
Siker ES, Stewart WD, Edwards JW: Anesthesia costs, Public Health Aspects of Critical Care Medicine and Anesthesiology, ibid., p 364

Malpractice Premium
Dornette WHL (editor): Legal Aspects of Anesthesia. Philadelphia, F. A. Davis, 1972, pp 575–576

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Report of the Secretary's Commission on Medical Malpractice [DHEW Publication No(OS) 3-88], Washington, D. C., U. S. Government Printing Office, 1973, p 8

Personal and Disposable Incomes
Statistical Abstract of the United States, 1972, ibid., pp 319, 395, 418

Urbanization
Statistical Abstract of the United States, 1974, ibid., p 19

Aged
Ibid., p 31

Education
Ibid., p 119

Surgical Operations
Courtesy of M. Jonathan Arlook, American Hospital Association, 840 N. Lake Shore Drive, Chicago, Ill. 60611

Annual Heating Degree Days
Statistical Abstract of the United States, 1974, ibid., p 194

Public School Quality
Simon KA, Grant WV: Digest of Educational Statistics, 1971. Washington, D. C., U. S. Government Printing Office, 1972, pp 24 and 55

Consumer Services Availability
U. S. Bureau of the Census: County Business Patterns, 1971. Washington, D. C., U. S. Government Printing Office, 1972

Recreation
Statistical Abstract of the United States, 1974, ibid., pp 172 and 207

APPENDIX 2*

Regression Equations for Anesthesiologists Examining Importance of Demand Variables

Independent Variables	Coefficients: Equation 7	Equation 8	Equation 9	Equation 10
Nurse anesthetists	−0.294 (−3.618)§	−0.278 (−3.480)‡	−0.265 (−3.607)§	−0.316 (−5.000)§
Hospital cost	0.056 (2.283)†	0.064 (3.052)‡	0.111 (7.551)§	0.066 (5.209)§
Disposable income	0.002 (1.978)ns			
Education		0.285 (2.099)†		
Aged			0.409 (3.667)§	
Estimated operations				0.047 (5.994)§
Intercept	−1.865	−0.669	−5.292	−1.024
Standard error of estimate	1.628	1.621	1.494	1.276
Coefficient of determination, R^2	0.606 [24.125]§	0.610 [24.512]§	0.668 [31.579]§	0.758 [49.149]§

* Additional regression equations will be supplied with data matrix by National Auxiliary Publication Service.

Values in parentheses are t-values; those in brackets are F-ratios. † $P < 0.05$. § $P < 0.001$. ‡ $P < 0.005$. ns = not statistically significant.

APPENDIX 3

Validation Procedure

From the 51 geographical regions comprising the "cases," seven were selected randomly and removed from the data matrix. The regression program was run on the 44 remaining cases using equations 4 and 6 to recalculate the coefficients and the intercept. The resulting revised equations were used to predict values of the dependent variables for each of the seven cases, which could be compared with actual values. Five of the seven predicted values for anesthesiologists and six of seven predictions for nurse anesthetists were within one standard error of the actual values, with the remaining predictions lying slightly beyond this interval.

Revised Equation	Anesthesiologists: 0.825 − 0.179 *Nurse Anesthetists* + 1.657 *Residency Programs* + 0.058 *Hospital Cost*				Nurse Anesthetists: 0.170 − 0.862 *Anesthesiologists* + 0.893 *Nurse Anesthesia Schools* + 1.145 *Relative Value Schedule* + 0.039 *Estimated Operations*			
SE	1.187				2.116			
State	Actual	Pred.	Error	% Error	Actual	Pred.	Error	% Error
CT	7.9	8.33	+0.43	5.4	6.35	5.08	−1.27	20.0
FL	5.2	4.65	−0.55	10.6	8.72	6.56	−2.16	24.8
TX	5.0	5.02	+0.02	0	7.44	8.02	+0.58	7.8
NH	7.5	6.24	−1.26	16.8	4.72	4.91	+0.19	4.0
ND	1.8	2.05	+0.25	13.9	15.65	15.82	+0.17	1.1
NY	9.4	8.80	−0.60	6.4	4.10	4.70	+0.60	14.7
TN	3.8	4.93	+1.13	29.7	7.09	6.80	−0.29	4.1
MEAN	5.8	5.72		11.8	7.72	7.41		10.9