WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

TECHNOLOGICAL CHANGE AND CLINICAL LABORATORY UTILIZATION

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REVISED 1001-78 January 1980

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Forthcoming in Medical Care

ABSTRACT

Many believe that improvement in laboratory automation has been responsible for the considerable growth in test volumes that has occurred in recent years. Results are presented from an eight-year national survey of hospital laboratory utilization that show no definitive correlation between technological change and growth in volume of well-established clinical laboratory tests. These results leave room for hypothesizing other major contributory factors to volume increases such as a behavioral change on the part of practitioners who order tests and place increased diagnostic importance on laboratory results in addition to medical histories and physical examinations. If the findings prove correct, successful regulatory strategies for the containment of laboratory costs might be as likely to come from those that directly address practitioners' behavior as from those that limit capacity by requiring prior approval for acquisition of new laboratory equipment.

An important question for both policy-makers and health care practitioners has been the relationship between technological change and the utilization of health services. While clinicians have expressed concern that indiscriminant reliance on technology can interfere with efficacious medical practice, some regulators have suggested that availability of technology creates demand which, in turn, increases costs.[7, 17]

The hypothesis that availability of services affects demand for medical care has been addressed in earlier studies of hospital bed and nursing home bed utilization. Results of empirical work by Roemer in the 1950s and Feldstein in the 1960s were interpreted to mean that availability of hospital beds generates its own utilization without regard to medical needs.[3, 12] When Willemain and Farber studied the demand for nursing home services, they also observed that utilization in fact increased with capacity. However, when the applied appropriateness (of use) criteria to nursing home patients, their analysis revealed that overplacement of patients in skilled nursing facilities actually decreased as bed supply increased.[18, 19]

Clinical laboratory test volumes have at least doubled over the period from 1970 to 1977[16] and many believe that improvement in laboratory automation has been responsible.[4] The same availability demand relationships that were earlier observed for hospital beds have been assumed by others to hold in the case of laboratory equipment. The laboratory situation does differ from bed use in a number of important respects, not the least of which is that persons who order tests may have little knowledge of changes in the capacity of their laboratory to perform them and to report the results. Data-based analyses of the utilization of the clinical laboratory have so far been limited to studies centered at particular hospitals.[1, 2, 5, 6, 7, 14, 15]

This paper will attempt to describe the extent to which the observed in-

crease in the volumes of specified well-established clinical laboratory tests can be attributed to automation of laboratory as opposed to other explanatory influences which may have occurred independently of a technological change. In the methods to be described, we use a time series analysis of a national data base on clinical laboratory use to determine whether the tests which have undergone the greatest rates of adoption of automated methods have also led the increases in test volumes. It has been argued that the widespread diffusion of multi-channel test panels has made the adoption of automated versions of some groups of tests inter-dependent on one another. We expect to find, however, that volume increases vary significantly among these inter-dependent tests and plan to draw on behavioral rather than technological factors to explain the variation.

Questions regarding the cost-behavior of increasing laboratory utilization are implicit in the discussion but, unfortunately can only be addressed indirectly from the particular data to be presented. We will confine the discussion to well-established test determinations and resist the temptation to extend the scope of the discussion to emerging diagnostic technologies of unproven significance.

Survey Methods

Time series data for this analysis were made available by IMS America, Ltd.* from its Semi-Annual Audit of Laboratory Tests for the period January, 1970 - June, 1977. The firm has collected this information chiefly for use of its health industries clients in market research. The Health Management Group of the M.I.T. Sloan School of Management has developed an agreement

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*A private firm that conducts surveys of sales and use of health care products. Results are made available to clients by subscription.

with IMS to permit examination of the implications of the data.

A representative sample of non-federal, short term general hospitals stratified by geographical region, bed-size category and type of ownership provided monthly laboratory test volumes for a broad range of specified tests. In 1977, the sample was comprised of 204 institutions drawn from the universe of approximately 5800 hospitals which fit this classification as determined from American Hospital Association (and other) directories. Nearly all hospitals in the universe have some diagnostic laboratory facilities as it is a requirement for accreditation by the Joint Commission on Accreditation of Hospitals. Table 1 characterizes the sample used for the January-June, 1977 survey and the stratification is similar to those used in other years. As can be seen, the matrix is designed to sample more intensively the larger hospitals which are expected to be disproportionte users of the laboratory. The rate of turnover in the sample from one survey period to the next is not known to us at this time.

In addition to the monthly reporting of laboratory test volumes, an interview was conducted between an IMS interviewer and a laboratory official such as the chief technologist or pathologist to determine laboratory procedures, practices, and equipment owned. Test volumes, projected to national and regional totals, were determined as a function of a number of variables including hospital characteristics and the fraction of tests performed on automated equipment. The basis for projection was total hospital bed size. Projections are purposely not made for multi-channel panels or profiles. Rather this information is broken down and included in the totals for the individual tests. Certain tests are known to include duplicate or replicate observations; these are also recorded as individual observations. The automated category of tests includes only those tests run on specified models

of laboratory equipment.* For the purpose of this analysis, observed differences in laboratory test volume have been considered as a function of the technological change that took place between the end points of the period 1970-77, for which data are available from IMS.

In the analysis to follow, we have specified criteria for selecting those laboratory tests whose volume behavior is of interest. Unfortunately, we did not have the opportunity to select the time period for the analysis as the only relevant data we could identify were from the IMS Surveys. Later on, possible significance of this limitation is discussed.

General Findings

In this section, results are described which examine possible relationships between technological change and volume of tests aggregated by functional subdivisions of the laboratory (bacteriology, chemistry, and hematology). In the next section, a model of clinical laboratory utilization is proposed that allows consideration of the same issues at the level of individual laboratory tests.

Findings of volume changes as a function of increasing use of automated technology are reported here for the major functional subdivisions of the laboratory. Volume figures are based upon nationally projected totals as determined by IMS. A list of individual tests classified according to major laboratory subdividions is available. Information regarding equipment ownership is given in the form of uncorrected figures taken from interviews with laboratory personnel of hospitals in the sample. These ownership figures may well reflect the national distribution of technology; however, no

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*Criteria for specifying models of "automated" equipment were those of IMS. For purposes of the present work, the effects of these criteria are to potentially overstate the impact of automated technology on laboratory use. This is fortunate for our analysis as we attempt to show that even allowing for the overstatement the relation between automation and test volume is not strong.

adjustment has been made and reported figures are not national projections.

When characteristics of technological as well as test volume changes in the laboratory subdivisions are considered, the results are interesting. As seen in Table 2, the percent of hospitals using automated blood cell counters increased from 78% in 1970 to 98% in 1977 and the total volume of hematology tests increased 110% over the same period. The fraction of hospitals owning and using automated chemistry analyzers increased from 65% to 85% in the same time interval and chemistry tests increased by 108% in test volume. Finally, in bacteriology there was not a commercially significant change in technological penetration between 1970-77, yet the increase in volume for bacteriology tests was even greater than the chemistry and hematology increases during that period.

In order to consider the possibility that the increases in bacteriology volumes reflected increasing importance of bacteriology testing (for the immunosuppressed and other special categories of patients) relative to chemistry and hematology, we examined the distribution of laboratory tests by major subdivisions during 1970 and 1977. As seen from Table 3, the fraction of all tests accounted for respectively by bacteriology, chemistry, and hematology was not very different for the years shown.

Interdependence of Certain Laboratory Tests: Technology Driven or Not?

Within the chemistry and hematology subdivisions, there has been significant penetration of automated laboratory technology. In both of these areas, as reported earlier in Table 2, the recent trend has been one of increasing test volumes as well as the increased use of automated equipment. Many of the instruments now available offer groups or panels of tests performed in sequence on the same sample. The most common chemistry and

hematology tests have become increasingly inter-dependent, but it remains an unanswered question as to whether this has occurred as a result of the new technology, or whether the increasing popularity of the technology resulted from other underlying changes such as the style of medical practice.

Available data dictates that this question need be addressed indirectly. We argue that if technology is strongly driving this interdependence, then laboratory tests showing the greatest increases in automated methods will also show the highest growth rates in volume. In pursuing this approach, we chose a sample of 20 chemistry tests that were similar in availability, in range of turn-around times and for having met minimum absolute volume criteria in 1977. (An analogous sample of six hematology tests was also established). The plan for the analysis was to develop a series of lists which rank-ordered the tests in the sample according to specified variables. For example, the 20 chemistry tests were first to be rank-ordered (1-20) in descending order of test-volume increases between 1970 and 1977. Next, the same 20 tests were to be rank-ordered according to a different variable, reflecting increased use of automated methods for each test. Then the lists can be compared with extent of similarity calculable from a statistical test, the rank-order correlation. If technological change has been a strong driving force behind volume change for the tests in our sample, then the effect should be reflected in the magnitude and statistical significance of the coefficient of correlation between the two lists.

Listing the tests in the sample according to absolute differences in 1970-77 volume change and change in automated test use are likely to give different rankings than if percent changes (normalized measures) had been used instead. To aid in the decision as to whether absolute measures and normalized measures are equally defensible, we consider a straightforward linear model of laboratory utilization in order to examine changes in the technology

intensive laboratory subdivisions of chemistry and hematology. Our model assumes for a particular laboratory test that the volume of tests reported at a given time can be written as a pair of additive terms, one reflecting the contribution of technological change, and the other encompassing all influences which are independent of technology. Equations (1) and (2) describe these relationships for the same laboratory test at two different times where t_2 is later than t_1 .

(1) $V_1 = v_0(t_1) + a(\frac{A_1}{V_1})$

(2) $V_2 = v_0(t_2) + a(\frac{A_2}{V_2})$

V_1 and V_2 are test volumes at t_1 and t_2 .

The $V_0(t)$ terms represent the volume of tests that would be done at each time irrespective of the degree to which automation of that test has taken place. The second term in each equation is a proportionality constant (a) multiplied by the fraction of all tests performed at each time that were done using automated equipment ($\frac{A_1}{V_1}$ or $\frac{A_2}{V_2}$). Those who hypothesize that technological change is the predominant determinant of test volume might assume that V_0 changes little during the interval compared to the change in the technology related term. We will make that assumption for now and discuss its implications later on. Subtacting equation (]) from equation (2), we can write equation (3), which describes absolute volume change as a function of change in the fraction of tests performed using automated equipment.

(3) $V_2 - V_1 = a(\frac{A_2}{V_2} - \frac{A_1}{V_1})$

With some further algebraic manipulations, we can divide both sides of equation (3) by the initial volume V_1 to arrive at equation (4), which reports normalized volume change as a function of the same measure of automation used above.

(4) $\frac{V_2 - V_1}{V_1} = \frac{a}{V_1}(\frac{A_2}{V_2} - \frac{A_1}{V_1}) = a^1(\frac{A_2}{V_2} - \frac{A_1}{V_1})$

Both absolute measures and normalizes measures of test volume changes appear, from this model to be defensible in our analysis of the impact of automated technology on laboratory test volume. However, only normalized measures of the change in automated test use would seem to be appropriate.

RESULTS

Within our chemistry and hematology sample categories, respectively, the individual tests were listed according to descending rank order of the change in the fraction of each year's tests performed using automated equipment. As suggested by equations (3) and (4), the same test were also ranked according to descending order of the absolute and normalized measures of volume change that our linear model led us to propose.

In two examples, the rankings using the normalized volume change measure $\frac{(V_2 - V_1)}{V_1}$ are compared in Table 4 for chemistry and Table 5 for hematology. Note that some tests which rank high in volume change are low-ranked for change in the use of automated technology and vice versa. The rankings were different when the other, normalized, volume measures were used. As summarized in Table 6, rank-order coefficients of correlation were determined for paired sets of rankings using absolute and normalized volume measures for the chemistry test sample and similarly for the hematology sample. The magnitude of the correlation co-efficients between technological change measures and volume change measures were 0.07 and 0.34 for chemistry; 0.08 and 0.34 for hematology. None of the co-efficients were statistically significant at the 0.05 level showing little positive correlation between technological change and the volume measures used.

It is important to recognize that the linear model proposed for laboratory utilization is one of many that may be plausible to describe the relationship between technological change and test volume. Also, our use of the model in this analysis required an assumption of minimal change over time in the term

V_0 which referred to the set of all influences over volume change that were independent of technology. While it has proven difficult to locate data bearing specifically on that assumption, most analysts would likely agree that it reflected substantial simplification. Refinement of that assumption would seem to lead to a weakening rather than strenghtening of the relationship between technological change and test volume that has been demonstrated here.

Discussion

Other researchers have brought a variety of perspectives to the study of the increasing utilization of clinical laboratories and the consequent cost problem.[1, 2, 6, 7, 14, 15] Scitovsky tracked the change in costs of eight selected illnesses over a twenty year period.[15] In some instances, she found that increases in laboratory test costs were of the same magnitude as savings associated with declining length of hospital stay. Griner's early work reported on patterns of laboratory use among hospitalized patients in a major medical center and observed little relation to optimal needs for patient care, even though the tests accounted for nearly a quarter of the typical hospital bill.[6] The contributory potential of automated technology in raising laboratory test volumes and costs is implicitly recognized in these and other works.

Research that specifically addresses the relationship between increasing penetration of technology and laboratory utilization has been limited. A report by Flax and Brand on laboratory utilization in a large teaching hospital detailed evidence that technological changes were responsible for only a small increase in the laboratory test growth rate, with the effect being predominantly that of facilitating increased demand.[5] The present study is an attempt to analyze the impact of technology on the clinical laboratory using a large national data base.

As seen in Table 3, the total of all clinical laboratory tests performed in the U.S. was found to approximately double between 1970 and 1977.

Growth in the number of hospital admissions in the nation was close to 16% during the same period and this was a contributor to the large growth in laboratory volumes.[8]

If increasing penetration of automated clinical laboratory technology were the major determinant of change in test volume, then one would expect to find larger volume increases among the technology-intensive chemistry and hematology sub-divisions than in bacteriology. And within chemistry or hematology, tests which show large changes in the fraction of all such tests performed using automated equipment should be expected to show correspondingly large volume growth between the years studied.

Contrary to expectation, Table 3 shows that the 1970-77 percentage growth in bacteriology, a field with little commercially significant automated technology in either 1970 or 1977, is larger than that of either chemistry or hematology. Some of the increase in bacteriology volume may have resulted from the introduction and diffusion of narrow spectrum antibiotics that in turn required the use of additional susceptibility discs in evaluating positive cultures.[10] It could also be argued that there has been growth in the number of patients whose clinical needs (e.g., monitoring of immunosuppression) include a legitimate requirement for increased ordering of bacteriology tests. Were these explanations to hold for bacteriology and were increased automation responsible for most of the growth in chemistry and hematology, we could hardly expect the proportion of total laboratory volume accounted for each of these subdivisions of the laboratory to remain stable over the seven year period. As seen in Table 3, however, the distributions in 1977 were similar to those in 1970.

It is at least possible that the growth in chemistry and hematology volumes shown in Table 2 might result from different causes than those of the bacteriology volume increases. But the data do lend support to the view that

factors not wholly dependent on technology played important roles in the volume growth. One such explanatory factor might be that a broad behavioral change has taken place in which physicians now attach greater diagnostic significance to laboratory results in addition to the history and physical examination.

Further support for the view that increases in laboratory utilization have not been predominantly determined by improvements in laboratory automation is gained by examining results of rank order correlations of chemistry and hematology test volume change with measures of changing penetration of automated technology. If technology were driving the volume increases, then the measures of volume increase for each test should be strongly related to the change in the fraction of tests performed on automated equipment over the years studied. When the rank-order correlation coefficients were determined for the chemistry and hematology tests in the sample, little more than 10% of the variation, at best, in test volume order could be explained by increasing use of automated technology. Hence, there was room for other variables either independent or not fully dependent on technological change to influence laboratory utilization.

It may be important to consider the significance of the time period during which data for this study was conducted, 1970-77. The period of study followed the introduction of many of the multi-channel models of automated clinical laboratory equipment that are currently in wide use. Our time period, however, came some years after the introduction of the original automated chemistry and hematology technology that are credited for revolutionizing laboratory practices and, in large part blamed for the volume increases that have been observed. Some readers may correctly point out that our failure to observe any definitive correlation between technological change and volume change during the 1970s does not preclude the possibility that such a relationship would be clear from data covering the 1960s. We do, however, believe it

to be highly significant that if such a relationship were to have held in the early years of automated laboratory technology, that it had become obscured by other factors before the later interval reflected by our data.

Considered as a whole, the information presented here would seem to challenge the conventional wisdom that technological change continues to be the definitive determinant of increased demand, at least among well-established determinations in the clinical laboratories areas. Our inclination would be to attach a good deal of importance to the hypothesis that a broad behavioral change has taken place on the part of the physicians and others who order laboratory tests to depend more on objective measures disease in making diagnoses. Causative factors might range from the better understanding achieved over time of the scientific basis of clinical practice to the greater awareness of liability for diagnostic and therapeutic decision making. This view would seem to be supported in part by the work of Schroeder,[14] Eisenberg,[2] and Dixon and Laszlo[1] as well as the recent study by Griner[7] which reported favorable changes in laboratory test use following educational or administrative interventions directed at high users. These findings would also be consistent with research reported in the behavioral literature on the subject of how individuals in organizations deal with uncertainty. Initial response to the uncertainty in the clinical practice setting could include the ordering of additional laboratory tests for the belief that results reduce the uncertainty. Ultimately, however, the test ordering behavior becomes routinized and uncertainty declines in importance as a motivating factor relative to preservation of the routine.[9]

Finally, while the analysis described above is confined to well-established tests and does not address emerging technologies, the results may have implications for the current efforts on the part of policy-makers to contain laboratory costs. Certification of need review, the consideration by a public

agency of any planned expenditure by a health care institution in excess of a specified dollar amount, has been mandated by Public Law 96-341 and will assume national applicability during the 1980s.[11] The rationale behind certification of need is based in part on a hypothesized relationship between availability of technological and other facilities and the demand for care. Some have even argued that limiting the capacity of medical technology might effectively ration the availability of such technology and require health professionals to establish priorities for access to it. There has been recent work to suggest that certificate of need controls have been less than universally effective in achieving cost reductions via this mechanisms.[13] Similarly, the results of our analysis suggest that for the specific case of clinical laboratory technology that a form of regulation that more directly addresses practitioners' behavior may prove useful in concert with or as an alternative to certificate of need in the containment of laboratory costs.

I gratefully acknowledge the assistance of Professor(s) Arnold I. Barnett, Barbara J. McNeil, and Ralph Katz for their input into the analyses used, and to Matthew E. Farber and Michael Kan for the thoughtful suggestions throughout the work.

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TABLE 1

SAMPLE MATRIX - HOSPITAL LABORATORIES*

	Private Hospitals				City-County State Hospitals				
Bed Size Category	1-99	100-199	200-399	400+	1-99	100-199	200-399	400+	Total
East Region	7	8	15	12	2	3	2	2	51
Midwest Region	7	10	18	14	4	1	3	3	60
South Region	6	9	14	11	4	3	6	7	60
West Region	3	4	9	7	2	2	2	4	33
Total Labs	23	31	56	44	12	9	13	16	204

*Semi-Annual Audit of Laboratory Tests-Hospital Labs, IMS America, Ltd., January-June, 1977.

TABLE 2

VOLUME CHANGE IN MAJOR LABORATORY SUBDIVISIONS WITH CHANGING PENETRATION OF "AUTOMATED" TECHNOLOGY, 1969-77.

	% of Hospital using "automated" technology		% Increase in test volume
	1970	1977	1970-77
Bacteriology	0%	0%	150%
Chemistry	65%	85%	108%
Hematology	78%	98%	110%
All Reported Tests			105%

TABLE 3

DISTRIBUTION OF LABORATORY TEST VOLUMES BY MAJOR LABORATORY SUBDIVISION 1970, 1977

	1970	1977
Bacteriology	10%	12%
Chemistry	52%	52%
Hematology	28%	29%
Other	10%	7%
	100%	100%

TABLE 4

CHEMISTRY TESTS RANK-ORDERED BY 1970-77 VOLUME AND CHANGE IN FRACTION OF "AUTOMATED TESTS"

Test	Rank Normalized Volume Increase (1970-77)	Rank Change in Fraction Automated (1970-77)
Sodium	1	6.5
Potassium	2	5
Chloride	3	12
BUN	4	20
Cholesterol	5	8
Carbon Dioxide	6	13
Bilirubin, Total	7	14
Creatinine	8	10
Calcium	9	18
Uric Acid	10	16
SGOT	11	10
LDH	12	6.5
Alkaline Phosphatase	13	10
Albumin	14	17
Phosphorus	15	19
Total Protein	16	15
CPK	17	4
Triglycerides	18	3
SGPT	19	2
Iron	20	1

TABLE 5

HEMATOLOGY TESTS RANK ORDERED BY 1970-77 VOLUME INCREASE AND CHANGE IN FRACTION OF "AUTOMATED TESTS"

Test	Rank NORMALIZED Volume Increase (1970-77)	Rank Change in Fraction Automated (1970-77)
Red Blood Count	1	4
White Blood Count	2	3
Hemoglobin	3	2
Sedimentation Rate	4	6
Hematocrit	5	1
Differential	6	5

Laboratory Subdivision	Variables		Time Period	Correlation Coefficient	Significant at level P=	
	Technological Change	Volume Change			0.01	0.05
Chemistry	Absolute	Absolute	January 1970-June 1977	0.34	no	no
Chemistry	Normalized	Absolute	January 1970-June 1977	0.07	no	no
Hematology	Absolute	Absolute	January 1970-June 1977	0.34	no	no
Hematology	Normalized	Absolute	January 1970-June 1977	0.09	no	no

Table 6. Summary of rank-order correlation coefficients depending on whether measures of technological change had been normalized. The table shows that the relationship between technological change and volume change for the tests in the chemistry and hematology samples was not statistically significant under any of the circumstances examined.