A Cost and Production Analysis of Hospital Dental Care Programs

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Synopsis

To provide hospital dental programs with useful information about the expansion of dental services and the identification of pertinent financial information, a production function and cost function analysis was performed. Results showed that hospital ownership (public or private) and size of the dental clinics were associated with the cost of providing dental services and the volume of services provided.

Among 23 hospitals studied, private hospitals had a much lower cost per visit, had more paid attending dentist staff, paid their resident dentists less, and had significantly more billings paid by Medicaid and by patients than public hospitals. When stratified by ownership and size, these basic differences were accentuated for the small clinics. Except for primarily the Medicaid and self-pay billings, the characteristics of large public and private hospital dental clinics were extremely similar. Multiple regression analysis found that a decrease in cost per visit was associated with more visits to dentists and more to hygienists. Production of dental services could be increased by increasing the number of attending dentists, hygienists, and residents. Preliminary econometric analysis reveals that the optimal mix of attending dentists to resident dentists should be approximately 1.8 full-time equivalent (FTE) resident for every 1 attending FTE dentist to produce the most dental services at the lowest cost.

A LONG-STANDING GAP in use of dental services in the United States exists between the poor and nonpoor (*1-4*). This continuing inequity in dental services use has been attributed to the lack of access to dental care. Inequity is further aggravated by an indifferent public perception toward the necessity of dental services, a maldistribution of dental manpower, and an inadequacy or absence of health insurance coverage for dental services. In recognizing the barriers to dental care, the Robert Wood Johnson Foundation began funding 4-year grants in 1979, under the Hospital-Sponsored Ambulatory Dental Services Program, for 25 hospitals throughout the United States. The primary objective of this program is to assist the chosen hospitals in expanding their dental training services and in providing dental care to underserved populations. The program has helped each institution attain financial stability by carefully identifying problems relating to financial management.

Evaluation of dental programs can give insight into the efficiency of dental care services. For instance, the use of production function analysis, which identifies key contributors to the efficient production of dental services, would help each hospital understand the sources of variation in the production of dental services and improve delivery of them. Similarly, cost analysis is a useful tool for determining key factors that affect the costs of providing dental services. By identifying the factors important to the cost and production of dental services, hospital and dental department managers can institute strategies to improve dental productivity and contain costs.

This paper examines the factors associated with the average cost of an ambulatory dental visit and production of hospital-based dental services. In performing the analysis, the factors relating organizational performance measures (cost and production) were categorized by organizational structure, design, and process element factors.

Organizational structure refers to attributes of the dental clinic's size, ownership, location, and

teaching status. Design factors—such as mix of provider compensation, mix of services, scheduling, and management system—are developed by the hospital dental clinic itself and are considered to be well within its control. Process factors are the actual activities performed and inputs used to produce an output or product. Process factors include the average number of clinic visits, mix of payments, and mix of providers at the clinic.

Figure 1 shows the relationship between program design and performance. We postulated that organizational performance is jointly affected by program structure, design, and processs factors. From a managerial perspective, whether a factor that affects cost or production is classified as a structural, design, or process element has differing implications for the managerial intervention that may or may not modify organizational performance measures. For example, structural factors, such as size of the dental clinics, are difficult to change. Design factors, such as the number of dental assistants employed, are more easily changed by management.

Based on this analytic framework, the correlates of dental clinic performance (average cost of a clinic visit and production of ambulatory dental care) were grouped into structure, design, and process categories. For this categorization, the grantee dental department clinics were grouped in terms of their performance according to structural characteristics. When differences in performance among the dental clinics appeared, the sources of the differences were sought so that intervention strategies could be suggested to reduce the cost of providing hospital-based dental services.

Methods

The primary data source was quarterly cross-sectional data collected during 3½ years from 25 hospital-based ambulatory dental programs throughout the United States. Data include more than 76 measures of costs, revenues, facility use, service mix, provider mix, client payment mix, provider compensation mix, and other general facility descriptors that were collected each quarter. Detailed definitions for the study variables are presented in the box.

Due to the incompleteness of data reporting, 2 of the 25 institutions were excluded from the original data base. In addition, because of the lack of uniform standards in data reporting, omissions in data, and poor timeliness of reporting from the participating hospitals in the beginning of the

Figure 1. Organizational components of hospital-based dental programs

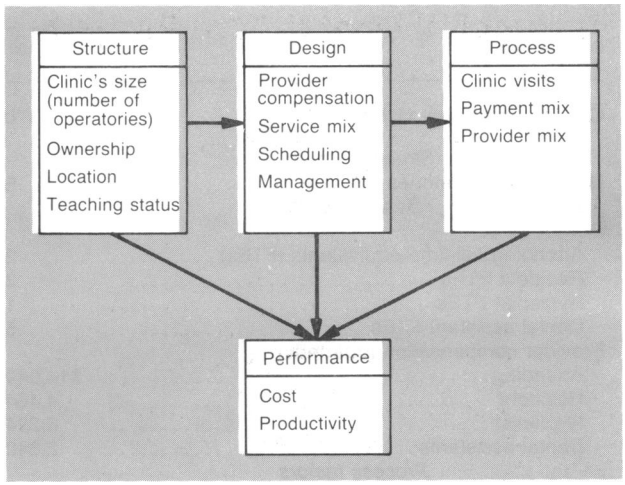
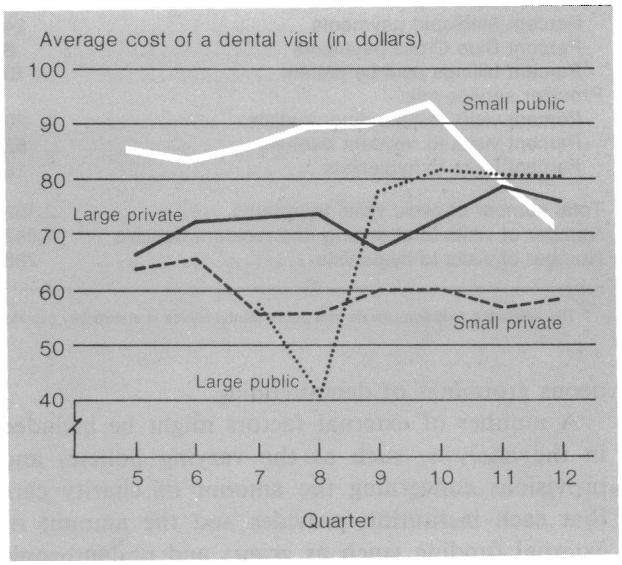


Figure 2. Average cost of a visit to an ambulatory hospital-based dental clinic by quarter, ownership, and size



study, we excluded first-year data and concentrated on the remaining eight quarters (2 years) of data. Missing data for each study hospital were imputed by using the average of the known data of a given hospital to replace the missing value. The imputation of variables ranged from a low of 4.1 percent in one program to a high of 13.3 percent in another, with an overall average of 7.72 percent of all variables being imputed. The primary analytical techniques used were (*a*) multiple regression analysis, which statistically determines the key factors relating to the cost and production of the dental services, and (*b*) analysis of variance, which detects the differences between homoge-

Table 1. Selected characteristics of 23 hospital-based dental programs, by ownership

Characteristics	Total		Private		Public	
	N = 23	SD	N = 17	SD	N = 6	SD
Cost of ambulatory visit	$70.16	30.31	[1]$65.82	20.94	[1]$82.47	45.92
Structural factors						
Number of operatories	6.04	3.10	6.66	3.24	4.26	1.69
Design factors						
Provider mix:						
Attending full-time equivalents (FTEs)	2.49	2.53	2.72	2.89	1.83	0.54
Resident FTEs	3.96	1.87	4.24	2.06	3.18	0.82
Hygienist FTEs	1.29	1.77	1.46	2.02	0.84	0.41
Dental assistant FTEs	5.37	3.95	5.62	4.48	4.66	1.58
Provider compensation (quarterly):						
Attending	$14,040.19	8,270.56	[1]$15,846.50	7,098.4	[1]$8,922.33	9,241.9
Resident	4,464.71	2,793.90	[1]3,813.31	1,643.3	[1]6,310.35	4,234.4
Hygienist	6,224.81	9,448.02	[1]7,506.79	10,598.0	[1]2,592.55	2,588.7
Dental assistants	2,640.84	1,474.81	2,592.76	1,282.36	2,777.04	1,928.7
Process factors						
Service mix:						
Percent diagnostic services	27.92	12.71	28.88	13.43	25.21	10.05
Percent surgical services	10.34	6.31	10.30	5.29	10.48	8.62
Percent hygiene services	11.72	7.28	11.70	6.59	11.78	9.03
Percent operative-pedontic services	26.15	11.32	[1]24.92	11.75	[1]29.64	9.23
Payment mix:						
Percent Medicaid payments	24.22	19.03	[1]31.25	17.13	[1]4.31	4.40
Percent Blue Cross payments	8.41	10.39	[1]10.28	11.17	[1]3.11	4.83
Percent billings paid by patient	40.71	23.47	[1]44.31	19.29	[1]30.53	30.53
Provider service mix:						
Percent visits to attending dentists	29.51	22.26	29.63	24.10	29.15	16.14
Percent visits to resident dentists	52.30	23.96	52.38	27.22	52.09	10.35
Percent visits to hygienists	12.86	8.44	[1]11.65	7.0	[1]16.28	10.99
Total number of clinic visits (quarterly)	2,162.54	1,419.25	[1]2,436.28	1,531.79	[1]1,386.95	521.6
Number of visits to attending and resident dentists	1,897.07	1,373.3	[1]2,111.04	1,466.9	[1]1,148.19	499.9
Number of visits to hygienists	288.31	204.82	[1]309.53	223.53	[1]217.54	89.22

[1] The difference between private and public dental clinics is statistically significant at 0.05 or lower.

neous groupings of dental clinics.

A number of external factors might be included in the analysis, such as the varying policies and provisions concerning the amount of charity care that each institution provides and the amount of external funding (such as grants and philanthropic sources) that individual projects obtained. It is also important to note that, of all clinics studied, the number of clinics was unevenly distributed by region. There were 6 clinics in western, 6 in southern, 10 in northeastern, and 3 in north central regions. The impact of regional differences on costs of employing clinicians or support staff was not examined. Our analysis will only focus on internal organizational factors that affect the cost and production of ambulatory dental services.

Cost Analysis and Findings

The basic structure of cost analysis, according to the literature, relates cost to the size of the facility, patient mix, the cost of resources, the role of input prices, the behavior patterns of the organization, the role of the provider, and the role of uncertainty in decisionmaking (*5*). This type of analysis, although most widely used in hospital cost function analysis, has also been used in analyzing the provision of ambulatory health care (*6*). By using the selected variables with proven relevance to cost function, the correlates of the costs of ambulatory dental services were examined.

Table 1 presents the general characteristics of the 23 hospital-based dental programs. The average cost for an ambulatory dental clinic visit for all programs was $70.16. There was an average of six operatories in a dental clinic. About 26 percent of the clinics were nonprofit, publicly owned institutions, with the remaining institutions being private, nonprofit clinics.

Compared with public clinics, dental clinics in private hospitals were larger (more operative dentistry chairs); paid their attending dentists and

Table 2. Multiple regression analysis of the effects of organizational structural, design, and process factors on average cost of an ambulatory dental visit (184 quarterly observations)

Independent variable	Average cost of an ambulatory dental visit					
	Adjusted for quarterly effect			Not adjusted for quarterly effect		
	Beta	B	T-value	Beta	B	T-value
Structural factors						
Number of operatories	−0.305	−2.985	−1.544	−0.313	−3.063	−1.616
Ownership type [1]	0.409	25.988	[2]4.886	0.412	26.156	[2]5.007
Design factors						
Service mix:						
Diagnostic	0.009	0.021	0.115	0.018	0.044	0.241
Surgical	0.011	0.055	0.141	0.019	0.090	0.236
Hygienists	0.069	0.287	0.828	0.057	0.238	0.713
Operative	0.022	0.060	0.299	0.021	0.055	0.281
Provider compensation:						
Attending	0.454	0.002	[2]5.025	0.445	0.002	[2]5.037
Hygienists	0.049	0.000	0.597	0.056	0.000	0.705
Dental assistants	0.236	0.005	[2]3.206	0.230	0.005	[2]3.212
Residents	−0.113	−0.001	−1.203	−0.118	−0.001	−1.273
Process factors						
Number of clinic visits	0.102	0.002	0.501	0.093	0.002	0.465
Payment mix:						
Medicaid	0.113	17.983	1.388	0.112	17.883	1.404
Blue Cross	−0.056	−16.366	−0.738	−0.051	−14.939	−0.687
Patient	0.034	4.449	0.416	0.045	5.791	0.555
Provider mix:						
Percent visits to attending dentists	−0.003	−0.005	−0.015	−0.004	−0.001	−0.021
Percent visits to hygienists	−0.119	−0.428	−0.844	−0.116	−0.417	−0.843
Percent visits to residents	−0.299	−0.378	−1.475	−0.309	−0.391	−1.553
Quarterly (Q) effect						
Q_1	0.082	7.475	1.062	...	...	...
Q_2	0.091	8.352	1.187	...	...	...
Q_3	0.033	3.052	0.436	...	...	...
Q_4	0.047	4.337	0.612	...	...	...
Q_5	0.061	5.580	0.800	...	...	...
Q_6	0.067	6.148	0.884	...	...	...
Q_7	0.027	2.424	0.350	...	...	...
Intercept	...	52.573	1.519	...	58.645	1.744
R^2 (percent)	...	48.54	...	...	...	47.85

[1] Public clinic is coded as 1 and private clinic is coded as 0. [2] Significant at 0.05 or lower.

hygienists more and paid their residents less; provided fewer operative and pedodontic services; had more billings paid by Medicaid, Blue Cross, and the patient; and had more hygienist visits. Although these characteristics provide a general profile of a hospital-based ambulatory dental program, further examination of the dental programs is warranted through analysis of their operations. The initial cost analysis identified the relationship of selected structural, design, and process factors of the clinics to the average cost of a dental clinic visit, after which the key correlates of the average cost of a dental visit were sought.

A potential problem of regression analysis using cross-sectional time series data is autoregression. Autoregression occurs when the study variables relate to one another simply by the passage of time. To adjust for the correlation between previous and present measures of the output variable (autoregression), a series of time variables (a set of dummy variables) was introduced into the initial regression analysis.

Results of the regression analysis show that the dependent variable (average cost of a dental clinic visit) is most significantly related to the attending dentists' compensation, dental assistants' compensation, and the type of clinic ownership (public or private) (table 2). The positive association of attending dentists' and dental assistants' compensation to the average cost indicates that as the compensation paid to the providers increases, the average cost of a dental visit increases. Although this finding is not unexpected, the important point to be noted is that the two design variables, attending dentists' and dental assistants' compensation, are the key factors affecting the average cost

Table 3. Multiple regression analysis of the effects of organizational structure, design, and process factors on average cost of an ambulatory dental visit by ownership

Independent variable	Average cost of an ambulatory dental visit: Private (N = 120) Beta	Private (N = 120) B	Private (N = 120) T-value	Public (N = 64) Beta	Public (N = 64) B	Public (N = 64) T-value
Structural variables						
Number of operatories	0.677	4.266	[1] 3.036	0.424	−7.843	[1] −3.188
Design variables						
Service mix:						
Diagnostic	−0.106	−0.169	−1.221	−0.192	−0.647	[1] −2.114
Surgical	0.280	1.076	[1] 3.973	−0.369	−1.920	[1] −4.191
Hygiene	−0.004	−0.013	−0.064	0.009	0.046	0.094
Operative	0.236	0.402	[1] 3.106	0.222	0.962	1.994
Provider payment mix:						
Attending	0.479	0.002	[1] 6.709	0.514	0.002	[1] 3.634
Hygienists	0.044	0.000	0.581	0.113	0.001	1.653
Dental assistants	0.212	0.003	[1] 2.887	0.495	0.012	[1] 5.903
Residents	0.287	0.003	[1] 2.620	−0.447	−0.005	[1] −3.073
Process variables						
Number of clinic visits	−0.574	−0.007	[1] −2.581	−0.647	−0.038	[1] −4.344
Payment mix:						
Medicaid	0.384	45.663	[1] 5.425	0.183	53.382	1.264
Blue Cross	0.142	26.387	1.673	0.079	39.759	0.853
Patient	0.090	10.569	1.128	−0.136	−19.974	−1.472
Provider mix:						
Percent visits to attending dentists	−0.099	−0.086	−0.408	0.576	1.233	1.574
Percent visits to hygienists	−0.223	−0.647	[1] −2.056	−0.147	−0.572	−0.590
Percent visits to residents	0.386	−0.304	−1.826	0.079	0.179	0.209
Intercept	...	−5.650	−.248	...	120.300	1.429
R^2 (percent)	...	72.41	...	...	91.09	...
F-ratio	...	[1] 16.90	...	...	[1] 30.05	...

[1]Significant at .05 or lower.

of a dental clinic visit. This finding implies that a change in the mix of providers may influence the cost of providing dental care. The ownership variable is a statistically significant variable, with public facilities having a higher average visit cost than private clinics. There is no serious autoregression, because none of the dummy variables are statistically significant.

Based on the initial finding that ownership of the hospital was a key factor associated with the average cost of a dental visit, the study hospitals were stratified by ownership, followed by a separate multiple regression analysis of the average dental visit cost for public and private institutions.

Regression analysis indicated that the size of the dental clinic was one of the most important correlates of cost (table 3). The mix of surgical procedures performed, number of operatories, and variables in resident provider payment have opposite and statistically significant signs for private and public dental clinics. Evidently, there are economies of scale in dental cost for public dental clinics.

Dental clinics were further stratified by size and ownership. Among the large clinics (six or more operatories), no significant differences in cost between the public and private clinics were observed. However, among small clinics (five or fewer dental operatories), private clinics had lower average costs, had more clinic visits per quarter, had more operatory chairs, employed more dental residents and fewer attending dentists and dental assistants, paid their residents less while paying their attending dentists and hygienists more, had fewer hygiene visits and fewer operative services, and received more traditional payments (Medicaid, Blue Cross, self-pay) from clients than did public clinics.

Regression analysis of the cost of providing dental services in small dental clinics shows that the increased cost of performing oral surgical procedures is associated with the lower cost in the public dental clinic, whereas the higher cost in oral surgery is associated with the increase in more oral surgical procedures in the private dental clinic (table 4). A similar pattern is observed for the variable "resident provider pay mix." These findings suggest that the two design variables (mix of

Table 4. Multiple regression analysis of the effects of organizational design and process factors on average cost of an ambulatory dental visit by ownership in small dental clinics (5 or fewer operatories)

Independent variable	Average cost of an ambulatory dental visit: Private Beta	Private B	Private T-value	Public Beta	Public B	Public T-value
Design variables						
Service mix:						
Diagnostic	−0.329	−0.218	−1.287	−1.234	−0.257	[1] −2.929
Surgical	1.379	0.400	[1] 4.278	−2.092	−0.388	[1] −3.973
Hygiene	−0.645	−0.220	[1] −2.192	−0.746	−0.145	−1.352
Operative	−0.081	−0.036	−0.375	0.358	0.071	0.639
Provider payment mix:						
Attending	0.002	0.662	[1] 5.085	0.001	0.207	1.353
Hygienists	0.000	0.005	0.061	0.001	0.070	0.453
Dental assistants	−0.000	−0.001	−0.008	0.011	0.468	[1] 3.442
Residents	0.004	0.297	[1] 2.723	−0.006	−0.597	[1] −3.045
Process variables						
Number of clinic visits	−0.009	−0.169	−1.686	−0.071	−0.747	[1] −6.449
Payment mix:						
Medicaid	18.231	0.128	1.270	100.375	0.093	0.711
Blue Cross	22.689	0.130	1.141	−101.814	−0.101	−1.234
Patient	−8.621	−0.091	−0.625	−10.668	−0.054	−0.650
Provider mix:						
Percent visits to attending dentists	0.003	0.003	0.022	1.472	0.520	[1] 4.833
Percent visits to hygienists	−0.468	−0.158	−1.102	−0.283	−0.067	−0.440
Intercept	32.496	0.00	1.389	199.846	0.00	[1] 4.794
R^2 (percent)	73.14	...	...	95.80	...	...
F-ratio	[1] 11.09	...	...	[1] 37.44	...	...

[1] Significant at .05 or lower.

surgical services and mix of resident provider pay), exert differential influences on the cost for dental care delivered in small dental clinics.

One of the most interesting findings from grouping the dental clinics into four subgroups, according to ownership and size, is that there was no statistical difference in cost of providing dental services between the large private and large public hospital clinics despite structural, design, and process differences. In contrast to the large clinics, small dental clinics showed differences in cost between private and public hospital clinics; private hospital clinics had a lower cost than public hospital clinics (fig. 2). Small private hospital clinics had a lower visit cost than the other subgroups throughout the eight quarters. The only exception was that large public clinics were lower in quarter 7 than small private clinics.

In summary, costs in hospital-based ambulatory dental clinics can be contained by increasing dental visits. An increase of 100 visits per quarter would cause a corresponding reduction of about 8 percent in the average cost per average dental clinic visit in small public hospital clinics. This finding may be explained by the large fixed cost associated with hospital-based dental clinics. With high fixed costs, the more visits provided, the lower will be the average cost per visit. If small public clinics do increase the number of clinic visits, the cost of providing services will be reduced if all other factors that contribute to cost remain the same. To increase production beyond the capacity of current resources (staff and equipment), additional resources (such as more assistants and attending dentists) would have to be added at an additional cost. To identify the optimal level of services provided, cost and staffing patterns deserve futher research. Another theme underlying cost containment in hospital-based ambulatory dental programs is the use of hygienist's services. Whether it be providing hygienists' services where they had not been available (such as in the small private clinics) or more fully using hygienists' services (as in the large private clinics), the use of hygiene-related services will reduce the average cost of ambulatory dental care. The extent to which substitution between hygiene-related and other dental services can actually reduce the average cost of ambulatory dental care, when the quality of care delivered is considered, needs to be investigated.

Table 5. Multiple regression analysis of the effects of organizational structure, design, and process factors on the number of ambulatory visits per quarter to dentists and residents for 23 dental clinics (184 quarterly observations)

Independent variable	All clinics			Private			Public		
	B	Beta	T-value	B	Beta	T-value	B	Beta	T-value
Structural factors:									
Ownership type	−303.84	−0.099	[1] −4.32	63.62	0.1497	[1] 2.06	...	...	...
Number of operatories	98.99	0.238	[1] 4.58	63.62	0.149	[1] 2.06	119.69	0.450	[1] 2.94
Design factors:									
Attending full-time equivalents (FTEs)	226.17	0.458	[1] 7.08	205.57	0.437	[1] 5.59	875.76	0.708	[1] 4.80
Resident FTEs	117.96	0.134	[1] 3.31	119.64	0.136	[1] 3.02	−243.39	−0.484	−1.90
Dental assistant FTEs	62.34	0.189	[1] 3.08	97.10	0.306	[1] 3.86	35.22	0.116	0.75
Process factors:									
Percent surgical service	−10.02	−0.037	−1.32	−21.11	−0.067	−1.95	8.61	0.107	0.75
Percent operatory-pedodontic services	−8.09	−0.069	[1] −2.82	−5.50	−0.046	−1.64	−10.65	−0.201	−1.12
Percent diagnostic services	−3.77	−0.036	−1.34	−2.08	−0.109	−0.580	−12.53	−0.265	−1.75
Intercept	343.89	...	...	423.18	...	...	61.82	...	...
R-square (percent)	93.7	...	...	94.41	...	...	81.93	...	...
F-ratio	[1] 251.05	...	...	[1] 250.73	...	...	[1] 15.54	...	...

[1] Significant at 0.05 or lower.

Table 6. Multiple regression of the effects of organizational structure and design factors on the number of ambulatory visits per quarter to hygienists for 23 dental clinics (184 quarterly observations)

Independent variable	All clinics			Private			Public		
	B	Beta	T-value	B	Beta	T-value	B	Beta	T-value
Structural factors:									
Ownership type	−41.69	−0.092	[1] −2.37	...	...	...	...	...	...
Number of operatories	21.98	0.350	[1] 6.16	20.3	0.314	[1] 4.50	19.3	0.407	[1] 2.49
Design factors:									
Hygienist full-time equivalents	213.73	0.587	[1] 10.33	223.63	0.632	[1] 9.06	128.5	0.253	11.55
Intercept	−61.74	...	...	−63.57	...	...	−3.39	...	...
R-square (percent)	80.14	...	...	81.83	...	...	22.59	...	...
F-ratio	[1] 188.31	...	...	245.47	...	...	4.23	...	...

[1] Significant at 0.05 or lower.

Production Function Analysis and Findings

Conceptual framework. For our analysis, we developed a production function, which is the physical relationship between the resources used and the subsequent output of goods or services by a firm (*7*). One prevailing mathematical representation of this relationship is $X = f(L,K,T)$, where X is the measure of output, L represents the input of labor, K represents capital input, and T is the level of technical efficiency (*6*). Accepting this mathematical form, a production function for hospital-based ambulatory dental care was developed to show the relationship between selected independent (input) variables and measures of dental care production.

Analysis of production function follows the same framework used for cost function. The measures of output we used are the number of clinic visits per quarter broken down into the number of visits to attending and resident dentists per quarter and the number of visits to hygienists per quarter, as each of these outputs represents similar but noticeably different measures. Production function was analyzed for each measure of output. Clinic visits, as the only output measure for attending and resident dentists, did not account for the total amount of services rendered. Therefore, a vector of service mix proportions was inserted into the equations in an effort to adjust for the output measures by controlling for the differences in the value that might be derived from separate visits (*8*).

In the production function for visits to attending and resident dentists, the structural variables include the number of operatories and ownership.

The number of operatories served as a proxy measure of capital input (K), and ownership is a variable representing technical efficiency (T). The design variables are the number of full-time equivalent (FTE) attending dentists, residents, and dental assistants. These measures represent labor input (L). Finally, as mentioned previously, a vector of service mix is used for adjustment of output. These measures include the percentages of surgical services, operative and pedodontic services, and diagnostic services performed. They also serve as process measures that reflect technical efficiency (T).

In the function for visits to dental hygienists, the numbers of operatories and hospital ownership are used for the same purposes as in the production function for visits to attending and resident dentists. The number of dental hygientists represents a design variable as well as the input of labor. The process variables of service mix were deleted from this function because a detailed breakdown of the services was not available. This is not a problem, however, because of the relatively similar output of dental hygienists.

Both production functions outlined were analyzed by multiple regression using aggregate data (cross-sectional time series). A similar analytical framework was used in the production function and the cost function analysis. Equations were estimated and also showed the relative importance of the independent variables in maximizing the number of dental clinic visits. For example, the coefficients generated (if statistically significant) should reveal, on average, how the addition of an FTE of each type of labor input affects the production of dental visits.

It is important to recognize the assumptions and limitations of the production function used in this analysis. One assumption is that there is sufficient unmet demand or need to make full use of additional labor. The other assumption is the fact that the concepts of cost are not incorporated into the function, and therefore it is not possible here to determine the optimal mix of providers. To determine this optimal mix, an econometric production function should be performed to allow substitution of different inputs. The analysis of dental production in the transcendental logarithmic form may be an appropriate procedure, suggested by Kushman and Scheffler (*10*). Furthermore, linear programming should be performed for each individual dental clinic. Such analysis and programming are beyond the scope of the present analysis; further details are available upon request.

Specifications of production functions for dentistry in the past have taken many forms. Analysis has been carried out for solo practice in general dentistry (*9–10*), for group practice dentistry (*11*), and for the impact of relatively new additional input such as paraprofessional dental assistants (*13*). Most analysis, however, has focused on the for-profit elements of the dental industry. Our analysis takes a different approach to examine not-for-profit dentistry; we also include the labor of general practice residents. Furthermore, unlike past estimates of the production function of dentistry, our analysis includes the structural, design, and process indicators as explanatory variables of dental production.

Analysis and findings. Multiple regression analysis was performed for the entire data base of 23 hospital-based dental clinics, using visits to attending and resident dentists and to dental hygienists as the dependent variables. The average number of visits per quarter to dentists was 1,897 and to dental hygienists was 288.31. For visits to attending and resident dentists, the regression shows that the number of attending FTEs is the most important explanatory variable of clinic visists (table 5). The analysis projects that the addition of 1 full-time attending dentist will, on average, produce 226.17 additional visits per quarter. The regression for the hygienist function shows that, of the design and structural variables included, the number of dental hygienists was the most important correlate of production (table 6). On average, adding a dental hygienist could increase the clinic's production by 213.73 visits per quarter. Furthermore, the type of ownership exerted a significant influence on the number of clinic visits; in both production functions we found that public hospital dental programs produced fewer visits than private hospital dental programs.

With the statistical significance of the structural variable of ownership demonstrated, the next step was to stratify the data base of ownership type. An analysis of variance was performed to determine if there were significant differences between the level of visits to attending and resident dentists and dental hygienists by hospital ownership. The analysis of attending and resident visits revealed that the average number of dental visits for private clinics per quarter was 2,436.28 and for public clinics was 1,386.95.

This difference was also found to be statistically significant. For labor, the significant variables were the number of attending dentists and number

Definition of Study Variables

Average cost of an ambulatory dental visit. Measured by averaging the cost of all types of dental clinic visits.

Number of operatories. Measured by number of general dental operatory chairs in a dental clinic.

Ownership. Dichotomized variable coded "0" for private institutions and "1" for public institutions.

Number of attending dentists. Measures in full-time equivalents (FTEs).

Number of G. P. residents. Measured in FTEs.

Number of hygienists. Measured in FTEs.

Number of dental assistants. Measured in FTEs.

Attending compensation. Quarterly.

Resident compensation. Quarterly.

Hygienist compensation. Quarterly.

Percent diagnostic services. Proportion of services that were diagnostic (examination, X-rays).

Percent surgical services. Proportion of services that were general or surgery.

Percent hygiene services. Proportion of services that were oral hygiene.

Percent operative services. Proportion of services that were operative and pedodontic.

Total number of clinic visits. Measured quarterly.

Number of attending-resident visits. Number of dental clinic visits that involved seeing an attending dentist or a resident (measured quarterly).

Number of hygienist visits. Number of dental clinic visits that involved seeing a hygienist (measured quarterly).

Percent Medicaid payments. Proportion of clients billed with Medicaid benefits.

Percent Blue Cross payments. Proportion of clients billed who had Blue Cross benefits.

Percent billings paid by patient. Proportion of clients billed who indicated that they would pay their bill themselves.

Percent attending dentist visits. Proportion of services rendered by the attending dentists.

Percent resident visits. Proportion of services rendered by general practitioner resident dentists.

Percent hygienist visits. Proportion of services rendered by the dental hygienists.

of residents. The average numbers of attending dentists was 2.72 for private clinics and 1.83 for public clinics, and the averages for residents were 4.24 for private institutions and 3.18 for public institutions. Number of dental operatories also showed significant differences by ownership, with private clinics on average being larger (6.69 operatory chairs) than public clinics (4.82 chairs). For dental hygienist production, the number of visits was also found to be significantly different by ownership. Public hospital clinics produced fewer dental hygienist visits (217.54) than private clinics (309.53). Public clinics on average, however, had significantly fewer hygienists (.84) than private hospital clinics (1.46).

With the differences in production levels for public and private hospital clinics noted, multiple regression analysis was independently performed for both ownership types (tables 5 and 6). The attending-resident analysis showed that the number of attending dentists was still the most important correlate of clinic visits. The addition of an attending dentist in the private institutions produces, other things being equal, an additional 205.57 visits per quarter, while in public institutions an attending dentist adds 875.76 visits per quarter (table 5). This indicates that the private facilities are closer to their optimal level of attending dentists in terms of maximum production, holding constant for structural variables (optimal implying that the addition of a dentist would add nothing to the level of production). Other significant design factors were the number of residents (Beta value, .31) and the number of dental assistants in the private institutions (Beta value, .14), with dental assistants proving more influential to production levels than residents. The results of the regression analysis for dental hygienist visits showed that the number of dental hygienists was significant only for private hospital clinics (table 6). The private hospital clinics would experience an average increase of 223.63 visits per quarter with the addition of 1 FTE hygienist.

Because the number of operatories varies by ownership, shown in the analysis of variance, the 23 dental clinics were further stratified by size (5 and fewer operatories and 6 and more operatories) and ownership. With this stratification, the means were computed and analysis of variance was again performed. There were statistically significant differences found in the number of visits to attending and resident dentists and to dental hygienists. The clinics with fewer than six dental operatories also showed significant differences in the number of attending dentists, number of dental assistants, number of residents, and percentage of operative and pedodontic services. The large clinics, however, displayed significant differences only in the number of attending dentists.

Given these differences in the four subgroups, a separate regression analysis was run for each group (tables may be obtained from the authors). Analysis for visits to attending and resident dentists

showed that the number of attending FTEs is a significant factor accounting for the variation in visits to private hospital clinics. The small dental clinics would gain an average of 327.11 visits per quarter by adding a dentist, while the large clinics would gain 185.57 visits. For public institutions, no significant results were found. The number of dental assistants exerted a significant impact on production only in large private clinics. These private hospital clinics on average would gain 156.76 visits by adding an FTE dental assistant. The production function for dental hygienist visits by size and ownership only produced significant results in the private hospital sector. For the small institutions, an additional FTE dental hygienist would, on average, add 200.58 visits per quarter and, for the large institutions, would add 326.83 visits per quarter.

In drawing implications, it is important to reiterate that the results only shed light on the relationship of input to output in terms of maximizing production. They do not take into account producing the maximum output at the lowest cost. With this in mind, the overall implications point to the potential for increased visits to all private hospital-based ambulatory dental clinics through the increase in the number of attending dentists employed. Private institutions would also apparently benefit from the addition of resident dentists; only the large private institutions would experience increased visits by using more dental assistants. Finally, additional dental hygienist FTEs would also increase the number of visits in private institutions.

In summary, the production function analysis of hospital-based ambulatory dental programs, as in the cost analysis, identified differences in the programs with respect to size and ownership. Different factors affected the goal of maximizing production of dental clinic visits among the subgroups identified. The question of the optimal mix of providers, in terms of maximum number of visits at the lowest cost, needs to be addressed in future research. From a production of visits viewpoint, private hospital dentists appear to produce 20 percent more visits than public hospital dentists. However, hygienists in one public hospital produce 23 percent more visits than hygienists in a private hospital. This higher proportion of visits to hygienists in public clinics may result from a single hospital that hires hygienists instead of dental assistants. This hybrid auxiliary improperly reflects on the productivity of hygienists in private hospitals.

Conclusions

We have analyzed cost and production for hospital-based ambulatory dental programs in an effort to identify the structural, design, and process factors that explain key variables of organizational performance. The analysis systematically identified differences in hospital-based dental clinics by homogeneously grouping hospital-based ambulatory dental clinics according to their structural characteristics. Different factors were found to affect the cost and production of dental services among the clinics. Hospital-based ambulatory dental clinics reduce their average cost of providing dental care by increasing the number of visits. From these analyses, we have identified for management a relatively small number of factors that significantly affect the cost and production of ambulatory dental care. With these factors identified, managers of hospital-based ambulatory dental clinics can see where they might intervene to improve program performance significantly. This knowledge, coupled with the managers' knowledge of intrinsic site-specific clinic variables, will lead to effective intervention to meet the demands of a complex and turbulent environment (*13*).

Several substantive and methodological issues on the cost and production function of hospital dental programs need to be noted. First, our study sample is restricted to a small group of hospital-based dental clinics. Because they were not randomly selected, we caution against drawing any firm conclusion about the efficacy of hospital dental services. Second, the linear form of the production function used in our analysis implicitly does not allow substitution among inputs, and this precludes analysis of an important issue in clinical efficiency. A simultaneous equations model should be used if substitution of different inputs (labor and capital) is assumed in estimation of the production function.

Third, the cost analysis addressed the question of minimizing average cost per visit, whereas the production function analysis examined how to maximize output for a given number of inputs. There is a reciprocal relationship between cost and production. More careful specification of the cost and production function is needed to explore the causal relationship between cost and production of dental services. Preliminary econometric analysis reveals that the optimal mix of attending dentists to resident dentists should be approximately 1.8 FTE resident for every 1 FTE attending dentist to produce the most dental services at the lowest cost.

Finally, analysis of organizational performance could be substantially improved if data on the process indicators of the dental care delivery system were available. Future research should collect work-sampling data through direct observations of dental practice so that the measurement of production (for example, the visit) can be refined by considering the amount of time and quality of care rendered to patients.

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The Control of Hypertension in Persons with Diabetes: a Public Health Approach

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Synopsis

Coexistent diabetes and hypertension affect an estimated 2.5 million persons in the United States. Hypertension occurs approximately twice as frequently in persons with diabetes as without and contributes to most of the chronic complications of diabetes, including coronary artery disease, stroke, lower extremity amputations, renal failure and, perhaps, to diabetic retinopathy and blindness. The proportions of complications in the diabetic population attributable to hypertension range from 35 to 75 percent. Hypertension in the diabetic population increases with age and is particularly associated with obesity and nephropathy. Limited data suggest the control of hypertension in the diabetic population may be better than in the general population, perhaps due to greater contact that persons with diabetes have with the health care system. Yet, in approximately half, hypertension is not controlled.

Control strategies for hypertension in the diabetic population must take into account the higher frequency of hypertension, increased risks for adverse sequelae from the coexistent conditions, more complicated clinical management, and the greater contact with the health care system experienced by persons with diabetes. Community programs to improve hypertension control in the diabetic population may target a subset of the diabetic population and should tailor strategies to meet the needs of the target population. Hypertension control in the diabetic population must be addressed at multiple levels in the health care system, including improved detection, evaluation,