A Cost-construction Model to Assess the Total Cost of an Anesthesiology Residency Program

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Background: Although the total costs of graduate medical education are difficult to quantify, this information may be of great importance for health policy and planning over the next decade. This study describes the total costs associated with the residency program at the University of Texas—Houston Department of Anesthesiology during the 1996–1997 academic year.

Methods: The authors used cost-construction methodology, which computes the cost of teaching from information on program description, resident enrollment, faculty and resident salaries and benefits, and overhead. Surveys of faculty and residents were conducted to determine the time spent in teaching activities; access to institutional and departmental financial records was obtained to quantify associated costs. The model was then developed and examined for a range of assumptions concerning resident productivity, replacement costs, and the cost allocation of activities jointly producing clinical care and education.

Results: The cost of resident training (cost of didactic teaching, direct clinical supervision, teaching-related preparation and administration, plus the support of the teaching program) was estimated at $75,070 per resident per year. This cost was less than the estimated replacement value of the teaching and clinical services provided by residents, $103,436 per resident per year. Sensitivity analysis, with different assumptions regarding resident replacement cost and reimbursement rates, varied the cost estimates but generally identified the anesthesiology residency program as a financial asset.

Conclusions: In most scenarios, the value of the teaching and clinical services provided by residents exceeded the cost of the resources used in the educational program. (Key words: Economics; finance; funding.)

THE recent possibility of changes in the financing system for graduate medical education has engendered renewed interest in understanding the costs of medical education.1-7 Identifying the cost of training anesthesiologists can assist medical educators and administrators in academic medical institutions by providing the necessary information to justify budgets, negotiate funding, and participate in the dialogue with managed care organizations regarding the future of health care.

There are several different ways to think about costs in medical education (see Jones and Korn for an excellent exposition).2 First, the meaning of education costs varies with the individual point of view. From the educators’ perspective, the costs of education are the expenditures borne by the medical schools and hospitals. These depend heavily on historic agreements between the various participants in the educational endeavor and vary significantly from setting to setting. Although these costs are important, this study presents education costs from society’s perspective because it is society that ultimately bears the costs of training new physicians. Therefore, all monetary and nonmonetary costs, independently of how they are financed or supported, are included in this analysis.

While in training, residents not only consume resources as learners but also provide services such as delivering patient care and teaching medical students. We attempt to quantify the value of these services to obtain a more complete picture of the resources produced and consumed in the educational program.

This study assesses the cost of the anesthesiology residency program at the University of Texas—Houston (UT—Houston) using a cost-construction model. The cost-construction method was first introduced by the
National Academy of Science\textsuperscript{\dag} to assess the cost of education in the health professions and was used recently to estimate the cost of medical education in Canadian and United States medical schools.\textsuperscript{1--5} The advantage of the model is that it not only provides cost data about the current training program but also allows for analysis of the impact of policy and curricular changes on resource requirements.

\textbf{Methods and Definitions}

\textit{Cost Definitions}

Medical education costs can be categorized as instructional costs and total educational costs.\textsuperscript{2} Instructional costs are costs directly related to teaching and include faculty time directly related to teaching and support of the teaching program. These are the costs typically thought of as the costs of education. Total educational costs are more inclusive and represent the costs of supporting all activities essential to education; they include instructional costs and the cost of all activities considered essential in maintaining the currency and competency of the teaching effort, such as research and scholarship, administration, and professional development.

Costs also can be categorized as marginal costs and proportionate share costs.\textsuperscript{2} Marginal costs are meaningful in settings with more than one mission, for example patient care and education. Thus the marginal costs of education are the incremental costs of having an educational program in an existing clinical setting. They are usually measured by the cost of the extra time required or lost productivity attributable to having students (residents). The drawback of marginal cost analysis is that it takes a narrow and limited view by not including any fixed costs; therefore, the sum of marginal costs for the different missions does not add to total cost. Proportionate share cost analysis solves this problem by allocating all costs, including fixed costs, to the separate missions based on some agreed-on method. The obvious difficulty is that there is no unambiguous way to allocate the cost of joint product activities (activities that serve more than one mission). The allocation of joint product costs to clinical care and education requires judgment, which may differ among observers. Proportionate share cost analysis usually yields a higher cost than marginal cost analysis and is thus more “pessimistic.”

During training, residents provide patient care and teaching and supervision of medical students. The value of these services was assessed by the residents’ replacement cost, the cost of replacing residents in those activities by faculty, adjusting for the difference in supervision requirements and the residents’ clinical productivity relative to that of the faculty.

This study assessed the proportionate share instructional costs and the replacement costs for the anesthesiology residency program. These were then compared to determine the overall economic benefit of the program.

\textit{Cost-construction Model}

The technique used in cost construction involves constructing a model of an educational program and using this model to identify the individual costs within the program. The cost of the educational program is developed from information on program description, resident enrollment, professional activity profiles and salary levels of faculty and residents, and the costs of supporting resources.\textsuperscript{3} We developed a cost-construction model using data from the UT—Houston anesthesiology residency program during fiscal year 1997 that computed the proportionate share instructional cost in five steps and the instructional cost less the value of the services provided by the residents in two additional steps (fig. 1 and Appendix 1). The model assessed the cost of the program as it was structured at that time and was not intended to assess its quality or effectiveness.

\textit{Residency Program}

The anesthesiology residency program at the UT—Houston Medical School offers 3 yr of training in postgraduate years 2, 3, and 4 (also denoted as clinical anesthesia years 1, 2, and 3) and a small number of postgraduate year 5 (clinical anesthesia year 4) positions. Entering class size is nominally 18–22 residents per year; most residents enter the program after 1 postgraduate year of general medical training. During the 1996–1997 academic year, 53 residents were enrolled. For the purpose of this study, the program was assumed to be operating with 17 residents in each year, clinical anesthesia years 1, 2, and 3.

\textit{Data Collection}

The allocation of time to the missions of education, service, and research was obtained from surveys of fac-
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Fig. 1. Cost-construction model.

The Budget and Financial Reporting Office of the UT—Houston Health Science Center, which includes the UT—Houston Medical School, provided financial data at the department, medical school, and institutional levels for fiscal year 1997 (September 1, 1996–August 31, 1997). All costs were expressed in 1997 dollars. Hermann Hospital, UT—Houston Medical School’s main teaching hospital, provided actual expenditures during fiscal year 1997 for residents’ benefits and hospital expenses directly related to residents (such as meals and parking).

Results

Instruction Cost

The model computed the proportionate share instructional cost in the following five steps (the computations are detailed in Appendix 1).

Step 1: Demand for Educator Contact Hours. Educator contact hours were the hours of direct contact teaching residents received during the residency program. Educator contact hours included didactic activities (conferences, rounds, and tutorials) and direct clinical supervision (which occurs when faculty member is physically present and directly supervising the resident’s clinical performance). General clinical supervision, which requires that a faculty member be immediately available should the resident need him or her, was not included in the educator contact hours.

Educator contact hours were obtained from the sur-
Table 1. Anesthesiology Resident Activity Profile at UT-Houston Medical School

<table>
<thead>
<tr>
<th>Activity</th>
<th>Hours per week</th>
<th>Faculty to Resident Ratio</th>
<th>Hours per week in the Residency Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junior residents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Didactic events</td>
<td>4.1</td>
<td>1:25</td>
<td>2.8</td>
</tr>
<tr>
<td>Direct clinical supervision†</td>
<td>13</td>
<td>1:1</td>
<td>220.9</td>
</tr>
<tr>
<td>General clinical supervision</td>
<td>48.6</td>
<td>1:2</td>
<td>412.7</td>
</tr>
<tr>
<td>Interaction with medical students</td>
<td>2.3</td>
<td></td>
<td>39.7</td>
</tr>
<tr>
<td>Research/scholarship</td>
<td>3.8</td>
<td></td>
<td>64.6</td>
</tr>
<tr>
<td>Professional development</td>
<td>1.4</td>
<td></td>
<td>23.8</td>
</tr>
<tr>
<td>Total</td>
<td>72.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senior residents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Didactic events</td>
<td>3.7</td>
<td>1:25</td>
<td>5.1</td>
</tr>
<tr>
<td>Direct clinical supervision†</td>
<td>11.5</td>
<td>1:1</td>
<td>390.7</td>
</tr>
<tr>
<td>General clinical supervision</td>
<td>54.9</td>
<td>1:2</td>
<td>932.9</td>
</tr>
<tr>
<td>Interaction with medical students</td>
<td>2.7</td>
<td></td>
<td>91.6</td>
</tr>
<tr>
<td>Research/scholarship</td>
<td>8.1</td>
<td></td>
<td>275.4</td>
</tr>
<tr>
<td>Professional development</td>
<td>1.3</td>
<td></td>
<td>44.2</td>
</tr>
<tr>
<td>Total</td>
<td>82</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Obtained from surveys of UT-Houston anesthesiology residents.
† Computed as hours per week per resident multiplied by faculty to resident ratio multiplied by the number of residents (17 junior residents and 34 senior residents).
‡ Direct clinical supervision occurs when faculty is physically present directly supervising the resident's clinical performance.

The surveys completed by the residents. The surveys provided detailed information about didactic activities, direct and general clinical supervision by faculty, faculty to resident ratio, supervision of medical students, scholarship and research, and professional development.

Table 1 reports the average hours per week spent in the various activities by junior and senior residents. The educator contact hours received (direct clinical supervision and didactic) by the 17 junior residents amounted to 223.7 h/week (13 h/week per junior resident). The corresponding number for the 34 senior residents were 395.8 h/week (11.6 h/week per senior resident).

Step 2: Supply of Educator Contact Hours. The supply of faculty contact hours reflects the faculty’s allocation of time to the school’s missions of education, research, and service. Education was further broken down into direct contact teaching measured by educator contact hours (see step 1), preparation for teaching, administration related to teaching, and general supervision of clinical care. We determined the supply of educator contact hours in the department from the surveys completed by faculty.

Table 2 reports the average hours per week spent in professional activities by faculty. On average, a faculty involved in teaching provided 26.3 educator contact hours per week. Faculty spent 48% of their time in instructional activities including educator contact hours, teaching preparation, and teaching related administration (estimated at one half of total administration time).

Step 3: Faculty Cost. The faculty cost was computed by adding the average salary for faculty members with M.D. degrees to the cost of supporting resources. Supporting resources included faculty benefits and overhead at the departmental, medical school, and institutional levels.

Departmental benefits and overhead were computed as the difference between total departmental expenditures and faculty salaries. They included, for example, administrative and secretarial support, liability insurance, travel, and office supplies.

Medical school benefits and overhead were allocated to the anesthesiology department based on departmental expenditures relative to the medical school total departmental expenditures. Medical school benefits and overhead included expenditures for benefits (group insurance premium, longevity, matching retirement, vacation and sick leave fund, workers’ and unemployment compensation, and benefit replacement pay); medical school administration and the dean; the library and other resources (the recreation center, the animal care center, the office of resource management); and, medical school-level funds (equipment fund, interdisciplinary instruction and research fund, and funds for other medical school programs).

Institutional overhead was assessed by proportionally allocating a part of institutional overhead to the medical school (based on budget size) and then proportionally.
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allocating to the department based on expenditures relative to the school. Institutional overhead included expenditures for the UT—Health Science Center administration (president and vice presidents’ offices, financial and legal services, employees’ health and other institutional services and programs) and the operation and maintenance for the medical school buildings (plant depreciation was not included).

The cost of supporting resources per faculty member were obtained by dividing supporting resources for the department by the number of full-time equivalent (FTE) faculty. The average cost for a faculty member with an M.D. degree cost in the anesthesiology department was then $336,313—the sum of the average M.D. faculty member salary, $134,525, and the cost per faculty member of all supporting resources, $201,788.

The cost of residents included salary and related supporting resources. Supporting resources for residents were benefits and hospital expenses directly attributable to residents (such as meals and parking). No departmental, medical school, and institutional overhead costs were allocated to residents. Hospital overhead was not included, as it was not included for faculty. The average cost for one resident was $45,680—the sum of average stipend, $31,976, and cost per resident of supporting resources, $13,704.

Step 4: Faculty Requirements. The faculty requirements were the number of FTE teaching faculty needed to teach in the residency program. The number of FTE faculty required was computed by dividing the total educator contact hours required in the program (step 1) by the number of educator contact hours provided on average by a teaching faculty member (step 2). To differentiate the cost of teaching and direct supervision of anesthesiology residents from the cost of teaching and directly supervising other students, it was assumed that those teaching faculty members were directing all their teaching and direct supervision effort to anesthesiology residents. The program would require 23.6 FTE faculty teaching or directly supervising solely anesthesiology residents. It is important to note that the number of FTE reported is not the total requirement for faculty headcount because anesthesiology faculty also teach and supervise medical students and residents from other departments.

Step 5: Instructional Cost. Instructional costs are the costs directly related to teaching and include the costs of direct clinical supervision, didactic teaching, teaching preparation, and administration related to teaching. As only information on total administration time was available, half was allocated to education and half to clinical and academic administration. Instructional costs were computed by multiplying the number of FTE faculty required (23.6 from step 4) by the faculty cost ($336,313 from step 3) and by the percent time spent in instructional activities (48% from step 2). Instructional costs for the residency program were $3,828,582. Instructional costs to train one resident for 1 yr were assessed at $75,070. Junior residents consumed more resources on a per resident basis, $81,317, than senior residents, $71,947. The cost of a resident graduating in 3 yr was $225,210.

Value of Services Provided by the Residents

While in training, residents not only consume resources as learners but also provide services, such as delivering patient care and teaching and supervising medical students. The next two steps assess the value of the services provided by residents and compute the costs less these benefits.

Step 6: Value of the Services Provided by the Residents—Replacement Cost. We used the activity profiles obtained from the residents’ surveys to estimate the amount of resident time spent providing patient care (without faculty immediately present) and the time spent teaching and supervising medical students. The value of the residents’ services was computed as the cost of having a faculty member with the rank of clinical instructor provide these services, assuming similar productivity. The cost of employing a clinical instructor at UT—Houston was $174,340 ($69,736 salary plus $104,604 supporting resources as defined in step 3). The replacement cost per resident per year was obtained in the following manner.

First, the time residents spent in patient care not under direct faculty supervision and the time spent interacting with medical students (from step 1) was multiplied by the cost of having a faculty member with the rank of clinical instructor spend time on those activities. The cost of the time under direct clinical supervision (when faculty member is physically present and directly supervising the resident’s clinical performance) was allocated to the educational mission and was therefore excluded from the time providing patient care.

The cost of employing the resident ($45,680 from step 3) was then subtracted because the replacement cost measured the cost of a faculty member with clinical instructor rank rather than a resident providing the services. The replacement cost for the residency program was $5,275,253. As expected, the replacement cost for a
senior resident, $109,446, was higher than for a junior resident, $91,417 (table 3).

**Step 7: Instructional Cost Less Replacement Cost.**

The net instructional cost was the difference between the instructional cost and the replacement cost. It was negative and implied that a resident provided $28,366 in resources more than what he or she consumed as a learner. As junior residents cost more to train and produce fewer services, the net instructional cost, $–10,100, was higher, although still negative, than that for senior residents, $–37,499 (table 3, top).

**Sensitivity Analysis**

The robustness of the above results was investigated by varying each of the following elements.

1. **Allocation of the Cost of Direct Clinical Supervision to the Instructional Cost.** During direct clinical supervision, clinical care and instruction are produced jointly. In the baseline model reported in results, all of the cost of direct clinical supervision was allocated to instructional cost. We varied this portion and considered the instructional cost for two scenarios: (1) one half of direct clinical supervision allocated to instructional cost, and (2) three quarters of direct clinical supervision allocated to instructional cost. The instructional cost per resident per year decreased to $45,283 and $60,177 respectively (table 4).

2. **Total Educational Costs.** Total educational costs are more inclusive than instructional costs. They include the costs of activities considered essential in maintaining the currency and competency of the teaching effort.

Total educational costs consist of the instructional costs and the costs of joint product activities (such as general clinical supervision) and research and scholarship, clinical/academic administration, and professional development. Total educational costs were computed by multiplying the number of FTE faculty members required (23.6 from step i) by the faculty cost ($336,313 from step 3) and by the percent time spent in educational activities (95% time spent in instructional activities plus general clinical supervision, research/scholarship, clinical/academic administration, and professional development from table 2). Educational costs were $7,531,519 for the residency program and $147,677 per resident per year (table 4). The corresponding cost for a graduating resident was $413,031 over the 3 yr of the program.

Figure 2 illustrates the increasingly inclusive costs as the cost of portions of direct supervision, general supervision, research and scholarship, faculty development, and academic/clinical administration are added to the cost of didactic teaching, teaching preparation, and teaching-related administration.

3. **Allocation of Supporting Resources for Faculty.** In the baseline model, all benefits and overhead at the department, medical school, and institutional levels were included in the faculty-supporting resources used to compute faculty costs. We next computed faculty-supporting resources including (1) only departmental and medical school benefits and overhead, and (2) only departmental benefits and overhead. When departmental, medical school, and institutional benefits and overhead were included, supporting resources represented...
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Table 4: Instructional Cost per Year and Total Educational Cost per Year

<table>
<thead>
<tr>
<th>Portion of Direct Clinical Supervision* Allocated to Instructional Cost†</th>
<th>Residency Program Instructional Cost ($)</th>
<th>Instructional Cost per Junior Resident ($)</th>
<th>Instructional Cost per Senior Resident ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% (baseline model)</td>
<td>3,828,582</td>
<td>61,317</td>
<td>71,947</td>
</tr>
<tr>
<td>75%</td>
<td>3,069,018</td>
<td>65,184</td>
<td>57,673</td>
</tr>
<tr>
<td>50%</td>
<td>2,309,454</td>
<td>49,052</td>
<td>43,399</td>
</tr>
</tbody>
</table>

Total educational cost‡

<table>
<thead>
<tr>
<th>Program Total Educational Cost ($)</th>
<th>Total Educational Cost per Junior Resident ($)</th>
<th>Total Educational Cost per Senior Resident ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total educational cost</td>
<td>7,531,519</td>
<td>159,966</td>
</tr>
</tbody>
</table>

* Direct clinical supervision occurs when faculty is physically present directly supervising the resident’s clinical performance.
† Instructional costs include the costs of direct clinical supervision, didactic, preparation for teaching, and teaching-related administration.
‡ Total educational costs include instructional costs plus the costs of general clinical supervision, clinical/academic administration, research/scholarship, and professional development.

60% of total faculty cost. The corresponding percentages were 55% for departmental and medical school benefits and overhead and 49% for departmental benefits and overhead. Supporting resources per faculty member decreased from $201,788 when departmental, medical school, and institutional benefits and overhead were included to $140,016 when departmental and medical school benefits and overhead were included, and to $110,066 when only departmental benefits and overhead were included. Cost per faculty member correspondingly decreased from $336,313 to $298,944 and to $263,775. The corresponding instructional costs per resident were $75,070, $66,729, and $58,879. The corresponding instructional costs less replacement cost per resident were all negative: $−12,596, $−20,138, and $−28,366. These results are illustrated in figure 3.

4. Resident Productivity Compared with Clinical Instructor Productivity. In computing the replacement cost in the baseline model, it was assumed that residents were clinically as productive as the faculty of clinical instructor rank replacing them. We next considered the case where junior resident productivity was 50% of clinical instructor productivity and senior resident productivity was 80% of clinical instructor productivity. The replacement costs decreased to $22,868 for junior residents and to $78,420 for senior residents, decreases of 75% and 28% respectively. The net instructional cost became positive, $58,449, for junior residents, increased to $6,474 for senior residents, and was positive, $15,167, for an average resident (table 3, bottom). The dual interaction of changes in resident productivity and the allocation of the cost of direct supervision on the net instructional cost is illustrated in figure 4.

5. Replacing Residents by Assistant, Associate, or Full Professors. In the baseline model, it was assumed that faculty with the rank of clinical instructor replaced residents. We then considered the replacement cost if faculty members with different rank replaced the resi-

Fig. 2. Increasing cost per resident as the cost of general supervision, research and scholarship, faculty development, and academic/clinical administration are incrementally added to the instructional cost (cost of direct supervision, didactic lectures, teaching preparation, and teaching-related administration). %DS = percent direct supervision; Instr cost = instructional cost; +GS = plus general supervision; +RS = plus research and scholarship; +FD = plus faculty development; +AD = plus academic administration.
students. The replacement cost if assistant professors replaced the residents would be $220,106; for associate professors, $340,387; and for full professors, $464,888. These results are illustrated in figure 5.

6. Valuation of Clinical Care Provided by Residents. Instead of valuing the clinical care provided by residents by the cost of having faculty with the rank of clinical instructor provide the care, we assessed the charges and collections that could be attributed to residents. This method has serious drawbacks as charges and collections are very institution specific and the atmosphere created by the Health Care Financing and Administration Agency rules makes it difficult to link charges to residents productivity. We attempted, however, to estimate the dollar value of the clinical care provided by UT—Houston residents by considering two scenarios: Residents increase faculty productivity and revenues (1) by 100% and (2) by 50%. In the first scenario, a team of one faculty member and two residents cares for two patients in the operating room, allowing productivity to increase 100% higher than that of one faculty member alone. The gross patient charges attributable to residents were estimated to be $11,247,077, half the actual fiscal year 1997 charges generated by faculty working with residents. These charges attributable to residents were allocated to the 53 residents actually enrolled during fiscal year 1997 to obtain $212,209 in charges attributable to each resident. The corresponding collections were $3,877,427 for the residency program and $73,159 for each resident. The second scenario assumes that the two residents increase faculty productivity by only 50%. The instructional cost less charges and the instructional cost less collections for the two scenarios are reported in table 5. It is noteworthy that the charges attributable to residents are higher than the instructional cost in both scenarios. These scenarios do not allocate a value to the supervision of medical students by residents.

7. Number of Residents in the Program. The costs reported were computed assuming that the program was operating at approximately 77% capacity, close to the
capacity at which the UT—Houston residency was operating during 1996–1997. Varying the number of residents in the program, provided there is a minimum enrollment of 25 residents (the lowest resident-to-faculty ratio during didactic events), affects the total costs for the residency program but not the costs per resident. This follows from the structure of the cost-construction model used in this study. A more complex treatment of overhead costs would be required to analyze the optimum size for anesthesiology residencies and related issues.

Discussion

In this study, we used a cost-construction approach to assess the economic cost of training anesthesiology residents at UT—Houston Medical School and found that the instructional cost of training one resident for 1 yr was $81,317 for a junior resident and $71,947 for a senior resident. The replacement value of the teaching and clinical services provided by residents was greater than the instructional cost, so that the net instructional cost was negative and ranged from $−10,100 for a junior resident to $−37,499 for a senior resident. For a wide range of scenarios, the value of the clinical and educational services provided by the residents exceeded the cost of the resources used in the educational program. This result and its implications are important considerations when planning reductions in graduate medical education for anesthesiologists.

The cost-construction method used in this study required assumptions about the allocation of joint product costs to the educational program. In the baseline model, all the costs of direct clinical supervision and none of the costs of general clinical supervision were allocated to the instructional cost. We then used sensitivity analysis to explore scenarios in which we varied these assumptions. Only portions of the costs of direct clinical supervision were allocated to instructional cost, with the remaining portions allocated to clinical care. The resulting range of instructional cost estimates can be useful at the department or medical school level in identifying the bare-bones costs of teaching.

Instructional costs, however defined, do not represent the costs of providing the environment necessary for quality graduate medical education. Total educational costs are better representative of the costs of the educational endeavor, as they include not only instructional costs but also the costs of general clinical supervision, research, scholarship, professional development, and clinical/academic administration. Although some of these activities have other sources of

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Table 5. Gross Charges and Collections Attributable to Residents’ Clinical Care

<table>
<thead>
<tr>
<th>Increase in Faculty Productivity due to Residents</th>
<th>Gross Charges Attributable to One Resident ($)</th>
<th>Collections Attributable to One Resident ($)</th>
<th>Instructional Cost Less Charges ($)</th>
<th>Instructional Cost Less Collections ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>212,209</td>
<td>73,159</td>
<td>−137,139</td>
<td>1,911</td>
</tr>
<tr>
<td>50%</td>
<td>141,473</td>
<td>48,773</td>
<td>−66,403</td>
<td>26,297</td>
</tr>
</tbody>
</table>

* Instructional costs ($75,070) include the costs of direct clinical supervision, didactic, preparation for teaching, and teaching-related administration.

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support, they are essential in creating an environment conducive to high-quality education, and it is legitimate to consider their costs when assessing the cost of the educational program. Not all of these costs are supported through the educational program, but they are still necessary for the educational program (it is important not to confuse issues of costs and issues of their support). The total educational costs, by better representing the burden of providing graduate medical education, could be useful in negotiating support at the state and federal level.

The instructional cost less the replacement cost analysis attempted to assign a cost to all resources used in the training of residents and to all services provided by residents. In computing the replacement value of the patient care and supervision provided by residents, we assumed that faculty with the rank of clinical instructor would replace the residents and then varied the rank of faculty. The replacement cost increased with the faculty’s rank. But even when faculty with the rank of clinical instructor replace the residents and when considering the lower productivity of the residents, the replacement cost may be an overestimate as it is likely that other personnel, such as nurse anesthetists, would replace residents in at least some patient care activities.

We investigated the effect on cost of including different levels of supporting resources costs. Further research is needed, however, to allocate benefits and overhead costs to the various missions of the school and to identify the portions that directly apply to the residency teaching program. As the computed supporting resource costs are average costs, further research would be needed if marginal supporting resource costs are of interest.

Although the cost-construction method is relatively straightforward, the approach has limitations that must be recognized before any applications of the findings. First, the validity of the estimated costs depend heavily on the assumptions about the demand and supply of educator contact hours. We relied on surveys of faculty and residents, validated by preliminary surveys and departmental schedules. Despite their shortcomings, surveys and effort reports have been used extensively in medical education cost studies. As a source of internal validation for our data, we compared hours of direct clinical supervision obtained from the faculty surveys with those obtained from the residents surveys. They were consistent. Faculty reported providing 25 h/week of direct clinical supervision (12.5 h/resident/week), and junior and senior residents reported receiving 13 and 11.5 h/week of direct clinical supervision, respectively (average, 12 h/week).

As this was a single institution study, the costs reported were specific to this program. Accreditation requirements for anesthesiology residency programs, however, ensure that educational programs in different institutions are similar enough that the UT—Houston program could be considered typical. The costs were in part influenced by the economics of this geographic area through its effects on faculty and supporting resources costs. With UT—Houston faculty compensation close to the national average, the estimated costs, although not directly applicable, could still be useful to other institutions.

Despite its limitations, the model provides a starting point for identifying the total costs of an anesthesiology training program. It can be used to assess current costs and to examine the cost implications of changes in the availability of faculty time for teaching and of changes in the curriculum and implications of changes in the cost of educators and overhead. It is a useful tool for administrators and educators who need to anticipate the effect on costs of the changing health care environment that threatens the diverse funding streams of medical schools. Our study shows that, even with generous assumptions about cost allocation, this anesthesiology residency program is an asset; the program produces more resources than it consumes.

The authors thank Tom C. Nguyen for help with data collection and analysis in the first stage of this study.

References

3. Franzini L, Low MD, Proll MA: Using a cost-construction model to assess the cost of educating undergraduate medical students at the University of Texas-Houston Medical School. Acad Med 1997; 72: 228-37

Appendix 1

Discrepancies in the numbers are attributable to rounding.

**Instructional Cost**

**Step 1.** Educator contact hours (ECH) for 17 junior residents = 225.7 ECH/week = [13 h direct clinical supervision + (4.1 didactic/25 residents)] × 17 residents. See table 1.

ECH for 34 senior residents = 395.8 ECH/week = [11.5 direct clinical supervision + (3.7 didactic/25 residents)] × 34 residents. See table 1.

Total ECH for 51 residents = 619.5 ECH/week = 225.7 ECH/week for junior residents + 395.8 ECH/week for senior residents.

**Step 2.** ECH provided by one faculty member = 26.3 ECH/week = 25 h direct clinical supervision + 1.3 h didactic presentations. See table 2.

**Step 3.** Cost of faculty with M.D. degrees = $336,313 = $134,525 in average M.D. salary + $201,788 in supporting resources cost. Resident cost = $45,680 = $31,976 in average stipend + $13,704 in supporting resources cost.

**Step 4.** Required number of full-time equivalent (FTE) faculty members teaching anesthesiology residents exclusively = 23.6 FTE = 619.5 total ECH from step 1/26.3 ECH per faculty member from step 2.

**Step 5.** Instructional cost for residency program = $3,828,582 = 23.6 FTE required from step 4 × $536,313 in cost per faculty member from step 3 × 48% time in instructional activities from table 2.

Instructional cost per resident per year = $75,070 = $3,828,582/51 residents.

Similar computations were performed for junior residents and senior residents separately.

**Value of Services Provided by Residents**

**Step 6.** Cost of having a faculty member with rank of clinical instructor providing the teaching done by the 51 residents = $420,572 = [(39.7 h interaction with medical students by junior residents + 91.6 h interaction with medical students by junior residents from table 1)/26.3 ECH provided by a clinical instructor from table 2] × $174,340 in average cost for a clinical instructor × 48% time spent in instruction from table 2.

The cost of having a faculty member with rank of clinical instructor providing the teaching done by one resident = $8,247 = $420,572/51 residents.

The cost of having a faculty member with rank of clinical instructor providing the clinical care done by the 51 residents = $7,184,368 = [(48.6 h of clinical care multiplied by 17 junior residents under general clinical supervision + 54.9 h of clinical care multiplied by 34 senior residents under general clinical supervision from table 1)/50.9 h clinical care provided by a clinical instructor from table 2] × $174,340 in average cost for a clinical instructor × 78% time spent in clinical care from table 2.

The cost of having a clinical instructor providing the clinical care done by one resident = $140,870 = $7,184,368/51 residents.

The replacement cost of having a faculty member with the rank of clinical instructor provide the services provided by a resident = $103,436 = $8,247 in teaching replacement cost + $140,870 in clinical care replacement cost = $45,680 in resident cost (step 3).

Similar computations were performed for junior residents and senior residents separately.

**Step 7.** Net instructional cost per resident per year = $28,366 = $75,070 in instructional cost − $103,436 in replacement cost.
Similar computations were performed for junior residents and senior residents separately.

Sensitivity Analysis

1. Allocation of Direct Clinical Supervision to Instructional Cost. Multiply ECH in step 1 by 0.5 for scenario 1 and by 0.75 for scenario 2.

2. Total Educational Costs. Replace 48% time spent in instructional activities by 95% time spent in total educational activities (from table 2) in step 5.

3. Allocation of Faculty-Supporting Resources. Compute faculty costs in step 3 with different levels of faculty-supporting resources. Repeat steps 5–7.

4. Resident Productivity. Multiply the hours of interaction with medical students and the hours of clinical care under general supervision by 0.5 for junior residents and by 0.8 for senior residents in step 6.

5. Replacing Residents by Assistant Professors, Associate Professors, and Full Professors. Replace cost of faculty member with clinical instructor rank with cost of faculty at different ranks in step 6.