A Field Study on the Limitations of Activity-Based Costing When Resources are Provided on a Joint and Indivisible Basis

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A Field Study on the Limitations of Activity-Based Costing When Resources Are Provided on a Joint and Indivisible Basis

MICHAEL W. MAHER* AND M. LAURENTIUS MARAIS†

1. Introduction

This paper describes conditions under which both conventional costing and activity-based costing based on an assumed linear relation between costs and activities can yield poor approximations to actual expenditures. Applying a simulation approach to data from a field experiment conducted in a hospital, we estimate how a change in anesthetics would reduce the demand for nursing services in the recovery room of the

*University of California at Davis; †William E. Wecker Associates, Inc. This paper was previously titled "Process-Oriented Activity-Based Costing." We are grateful for the helpful comments of James Davlin, William Ferrara, Steven Finkler, Ann Gabriel, Mahendra Gupta, Charles Horngren, Robert Kaplan, Carol J. McNair, Eric Noreen, Ram Ramanan, James Reeve, Frank Selto, Thomas Stober, Miriam Wells, David Woodruff, the anonymous reviewer, and workshop participants at the University of Chicago, the University of California at Davis, Indiana University, and the University of Notre Dame. We are grateful to the medical facility and the pharmaceutical company that provided access to the data for this study. We especially thank the staff at the field site.

1 The literature on activity-based costing usually assumes a linear relation between costs and cost drivers. See Foster and Gupta [1990], Berlant, Browning, and Foster [1990], Cooper and Kaplan [1991], Banker and Johnston [1993], and Atkinson et al. [1997], for example. Although the cost hierarchy approach (Cooper and Kaplan [1991]) recognizes that different categories of costs are not linearly related to output, the cost functions within categories have been treated as linear. For example, Datar and Gupta [1994] assume machine setup costs, which are in the batch-related cost category, vary linearly with setup hours.
hospital's outpatient surgery facility. We use these simulations to estimate nursing resources implied by (1) the costing system used by the hospital (the "conventional costing" system), (2) activity-based costing based on an assumed linear relation between costs and activities ("linear activity-based costing"), and (3) costing that takes into account the joint and indivisible provision of nursing resources caused by the facility's staffing and compensation policies. These policies create the type of problems in using data from linear cost systems previously identified by Noreen [1991] because one nurse may serve more than one patient at a time (i.e., "joint" provision of resources) and nurses are typically scheduled in four-hour shifts (i.e., "indivisible" provision of resources). Further, nurses' pay does not vary with the number of patients served; that is, they are not compensated on an activity-based piecework basis. Consequently, while the new anesthetic linearly reduces patient demand for nursing services, the corresponding reduction in nursing expenditures is not linear.

We aim to ascertain how well conventional costing and linear activity-based costing estimate the change in expenditures on nursing services under these conditions and to ascertain whether any estimation errors are sufficiently large to affect decisions. The results indicate that conventional costing understates and linear activity-based costing overstates the estimated savings in expenditures on nursing services, probably by enough to affect decisions in the setting we study. In particular, conventional costing estimated no decrease in expenditures and linear activity-based costing showed a 33.1% decrease in expenditures, whereas costing that considers the hospital's staffing and compensation policies estimated a 12.4% reduction. These findings support Noreen's [1991] contention that linear activity-based costing may not provide reliable signals for decision making if resources are supplied on an indivisible or joint basis.

Section 2 describes the field research site. Section 3 discusses the research problem and methods. Section 4 discusses the estimated changes in expenditures for nursing services using three alternative costing methods. Section 5 discusses issues in choosing among alternative cost methods and section 6 summarizes and concludes the paper.

2. The Research Site

2.1 THE MANAGEMENT PROBLEM

Our research site is an outpatient surgery facility in a nonprofit teaching hospital. During the period of our study, the chief anesthesiologist was considering using an experimental anesthetic that would reduce patient time in the recovery room.2 Patient time in recovery drives the use of recovery room nursing staff, so reducing patient time there po-

2 This anesthetic had not received Federal Drug Administration approval at the time of our study. It since has been approved.
tentially reduces the cost of nursing services. The proposed anesthetic would cost more than the existing generic anesthetic, so facility managers wished to evaluate the trade-off between the incremental expenditures on the proposed anesthetic and the incremental reduction in recovery room nursing costs. An analogous manufacturing setting is one in which more expensive raw materials could reduce resources devoted to quality inspection.

2.2 NATURE OF THE PRODUCTION PROCESS

The outpatient surgery facility (a responsibility center within the hospital) has a preoperating room, 12 available operating rooms, and a two-part recovery room—phase I for intensive nursing care immediately after surgery and phase II (step-down) for nursing care after patients have partially recovered. The outpatient surgery center provides various types of surgeries such as biopsies, vasectomies, and plastic surgery. Patients typically enter the outpatient surgery center sometime between 6:00 A.M. and 1:00 P.M., have surgery within about three hours, spend less than two hours in the recovery room, then go home.

For our study, the activity is nursing care and the cost driver is the number of patient minutes in the recovery room. This site had a nurse staffing policy of no more than two (three) patients concurrently per nurse in phase I (phase II) recovery. The resulting essential jointness complicates cost estimates because the provision of nursing resources is affected by the arrival of the first patient in the recovery room but not by the arrival of the second patient (nor the third in recovery phase II).

Production constraints in the recovery room further complicate measures of resource behavior. Phase I has seven recovery stations and phase II has ten; we treat these as long-run capacity constraints. Nursing staff, on the other hand, supply services for which capacity can be changed quicker than adding recovery stations but not as quickly as would be the case for piecework labor.

At full capacity, phase I has a staff of four nurses, but needs only 3.5 nurses to meet the facility’s maximum two patients per nurse constraint. Management understood this situation, but space constraints prevented adding another recovery station. Similarly, phase II has ten recovery stations, requiring four nurses at capacity but only 3.33 nurses to meet the facility’s phase II 3:1 patient:nurse constraint. Nurses typically worked four-hour or eight-hour shifts, and less than 40 hours per week. The nurse administrator did not use nurses from a “float pool” nor did she send nurses home without pay before their shifts were completed.

As in the Banker and Hughes [1994] model, the nurse administrator established capacities in the form of a recovery room nursing schedule. Banker and Hughes assume that adding capacity beyond initial levels involves incremental costs above the normal cost of providing initial

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3 A nurse cannot simultaneously attend patients in phase I and phase II.
capacity. In our setting, nurses who worked beyond their scheduled shifts almost never were paid an overtime premium but were compensated with straight-time pay or with time off in increments of one hour for each hour or partial hour worked.4

Based on interviews and our reviews of staffing records, we estimated that the facility provided an average of nine full-time equivalent (FTE) nurses in the recovery room. (One FTE equals one nurse for eight hours.) This number of FTEs excludes time for statistical studies, in-service training, and other assigned duties not involving patient care.

The recovery room generally was staffed from 8:00 A.M. to 6:00 P.M. Although only eight nurses were needed at any one time, more than eight FTEs were required to cover the ten-hour day. Using a schedule of surgeries and patient type, the nurse administrator scheduled nurses in the recovery room for a particular day. Although the recovery room staff did not routinely keep records of patient recovery time (studies like ours are exceptions), the nurse administrator’s experience with the length of recovery typically required for patients of various types helped reduce the difference between the number of nurses scheduled to work in the recovery room and the number required to meet the facility’s staffing constraints. The recovery room was full for several hours each day, further reducing uncertainty in estimating resource use.

The uncertainty in resource use generally came from complications in recovery. Although patients typically were in the recovery room no longer than two hours, some remained as long as five hours. Nevertheless, the uncertainty in resource use in this recovery room appeared to us to be less than in many other settings such as hospital emergency rooms, fire stations, and retail outlets.

3. Research Problem and Methods

To test the effectiveness of activity-based costing, Kaplan [1993] recommends testing reduced support resources consumed while holding output volume constant. Our research site provides an opportunity for such a test because the proposed anesthetic potentially would reduce nursing resources consumed by reducing patient time in the recovery room, without affecting output volume (number of surgeries × the length of surgery).5

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4 If a patient unexpectedly stayed 20 extra minutes, the administrator would assign a nurse who had worked less than an eight-hour shift and less than 40 hours in the week to stay and be compensated for an extra hour.

5 The facility allocates costs to surgeries using this output volume measure and the number of surgical staff required in surgery, as discussed in section 4.1. If using the proposed anesthetic could increase throughput, then the facility might increase the number of surgeries, which would affect the overhead allocated to surgeries under conventional costing. A change in throughput because of the proposed anesthetic is speculative and beyond the scope of this study.
Conventional costing would estimate no change in recovery room nursing resources because of the new anesthetic. Because linear activity-based costing relies on an activity-based cost driver (patient minutes in the recovery room), we expect it to estimate a reduction in nursing resources proportional to the reduction in patient demand. However, because nurses typically work in four- (or eight-) hour shifts, and because nursing services are jointly used by more than one patient, we expect that linear activity-based costing will not correctly estimate the reduction in nursing resources provided.

Our data come from a field experiment conducted to compare the effects of the proposed and existing generic anesthetics. We helped design the research protocol which was administered by anesthesiologists and nurses at the research site.

Subjects in the field experiment were females undergoing laparoscopies, the most common surgical procedure for the facility. Medical staff assigned patients randomly to one of the two anesthetic regimens. All staff who kept records for the study were blinded as to which anesthetic was administered to each subject. The samples were comparable in terms of age, health risk class, and duration of anesthetic, as shown in table 1. Table 1 also shows the patients given the proposed anesthetic spent significantly less time in each phase of recovery compared to those given the existing generic anesthetic.

Because of both the difficulty in getting enough subjects to agree to use an experimental anesthetic and time limitations on the experiment imposed by the outpatient surgery facility, we were not able to obtain sufficient observations to observe how the new anesthetic affected expenditures for recovery room nursing services. As an alternative to empirical estimations, we simulated the outpatient surgery center operating under both anesthetic regimens. We drew actual case histories, with replacement, from the 49 case histories for each anesthetic in the field experiment, and simulated the running of the outpatient surgery center for 250 days for each anesthetic.

We scheduled 80 surgeries per day for each of the two anesthetic regimens which essentially meant the facility operated at capacity with surgeries starting at 8:00 A.M. and continuing until about 3:00 P.M., as was the actual practice. The use of recovery room resources for the generic anesthetic in our simulation approximated actual practice.

The parameters of the simulation were as follows:

1. We randomly selected a patient’s case history from the experimental sample of 49 actual cases for each anesthetic and scheduled that patient in the first available operating room. In practice, no recovery activity took place in the operating room, so our simulation assigned patients to operating rooms only when they could be moved from the operating room to phase I recovery at the end of surgery. We sampled with replacement for 80 cases per day.
TABLE 1

Description of Sample and Results of Experiment to Compare the Effects of Two Anesthetics on Time Spent in the Recovery Room after Surgery at the Outpatient Surgery Facility

<table>
<thead>
<tr>
<th>Anesthetic</th>
<th>Generic</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Patients</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>Median Age (Years)</td>
<td>32</td>
<td>31</td>
</tr>
<tr>
<td>Health Class:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I (Healthiest)</td>
<td>44</td>
<td>38</td>
</tr>
<tr>
<td>II</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>III</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Duration of Anesthesia during Surgery—Average Minutes²</td>
<td>25.6</td>
<td>25.4</td>
</tr>
<tr>
<td>Time in Phase I Recovery Room (Minutes):³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>38.5</td>
<td>27.1</td>
</tr>
<tr>
<td>Minimum</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>Median</td>
<td>40</td>
<td>27</td>
</tr>
<tr>
<td>Maximum</td>
<td>65</td>
<td>47</td>
</tr>
<tr>
<td>Time in Phase II Recovery Room (Minutes):³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>63.3</td>
<td>39.3</td>
</tr>
<tr>
<td>Minimum</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>Median</td>
<td>59</td>
<td>33</td>
</tr>
<tr>
<td>Maximum</td>
<td>131</td>
<td>145</td>
</tr>
</tbody>
</table>

¹Health class refers to a classification of patients according to their health status by medical staff at the facility studied. The difference between groups is not statistically significant at conventional levels (chi-square test after combining classes II and III into one category).
²The difference between means is not statistically significant at conventional levels (two-tailed t-test).
³Phase I began at the time of surgical closure. The end of phase I of recovery occurred when the attending nurse judged the patient capable of moving to the step-down phase of recovery, which we call phase II. That judgment was based on the nurse’s assessment of the patient’s activity, respiration, circulation, consciousness, and color. Patients were discharged from the recovery room at the end of phase II, which occurred when the attending nurse judged the patient able to stand independently, to tolerate 50 ml. of clear liquid, and to void. The difference between the recovery times under the generic and proposed anesthetics is significant at p < 0.01 for each phase using the Wilcoxon rank-sum test.

(2) When a surgery was complete (the time was given in the patient’s case history), we assigned the patient to an available bed in phase I recovery. Our measure of completed surgery was the time the recovery room staff first became responsible for the patient.

(3) We kept the patient in phase I recovery for the number of minutes recorded in her case history. In the field experiment, nurses used the following criteria to indicate the end of recovery-phase I: the patient had stable vital signs, was able to sit independently, and scored a 10 on the 10-point Aldrete score.⁶

(4) At the end of phase I recovery, we freed the phase I bed the patient had occupied and assigned the patient to an available station in phase II recovery where she remained for the number of minutes

⁶The Aldrete score is based on five vital signs—activity, respiration, circulation, consciousness, and color—that are each scored 0, 1, or 2 (Aldrete and Kroulik [1970]). For the vital sign activity, for example, a patient’s ability to move no extremities is scored 0, ability to move two extremities is scored 1, and ability to move four extremities is scored 2.
LIMITATIONS OF ACTIVITY-BASED COSTING

recorded in her case history. In practice, each patient was kept in phase I recovery until a phase II station became available. In that case, some phase II recovery took place while the patient was still in the phase I section of the recovery room. We followed this practice in our simulation.

(5) At the end of phase II recovery, as recorded in the patient’s case history, we discharged the patient and freed that phase II recovery station. In the field experiment, nurses used the following criteria to indicate the end of recovery-phase II: the patient scored 10 on the Aldrete scale, could stand independently, could tolerate 50 ml. of clear liquid, and could void.

(6) In scheduling subsequent cases, we allowed for the following times between surgical cases in each operating room based on information obtained in interviews with medical staff.

(6.1) Postsurgery cleanup time (time between surgeries) was uniformly distributed between 8 and 20 minutes. Uncertainty in cleanup time was due to the readiness of cleanup staff, the number of staff doing cleanup, and the amount of cleanup required.

(6.2) Surgical setup time was set at 15 minutes, the standard at our research site. Setup accounts for the delay between cleanup from the previous surgery and the time the next patient enters the operating room.

(6.3) The delay between the time the patient enters the operating room and the induction of anesthesia was uniformly distributed between 5 and 10 minutes. This delay was uncertain because patients varied in their mental readiness for surgery and their level of comfort with the surgical process.

Our intention was to simulate realistic variations in recovery times, given those actually experienced by the patients participating in the field experiment. Thus, our approach allowed the actual complications in recovery to be reflected in the simulation.

The simulation results appear in table 2. Based on 250 days and 80 cases per day, the results show a 30.8% reduction in patient time in phase I recovery from 3,088 minutes for patients given the generic anesthetic to 2,136 minutes for patients given the proposed anesthetic. The results for phase II recovery show a 35.4% reduction from 4,904 to 3,168 minutes per day.

4. Estimates of Reductions in Nursing Resources Provided under Alternative Costing Systems

4.1 Cost Estimates Using the Facility's Conventional Cost System

At our research site, accountants recorded costs by line item (e.g., nurse salaries, supplies) for the cost pool, which was the entire outpatient
**TABLE 2**

Results of Simulations of Patient Time in the Recovery Room under Alternative Anesthetic Regimens

<table>
<thead>
<tr>
<th>Anesthetic Generic Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovery Room—Phase I:</td>
</tr>
<tr>
<td>Average Minutes Per Case in Phase I Recovery ²</td>
</tr>
<tr>
<td>Average Minutes Per Day in Phase I Recovery ³</td>
</tr>
<tr>
<td>Recovery Room—Phase II:</td>
</tr>
<tr>
<td>Average Minutes Per Case in Recovery Phase II⁴</td>
</tr>
<tr>
<td>Average Minutes Per Day in Phase II Recovery⁵</td>
</tr>
</tbody>
</table>

¹The results are based on simulations that assumed the outpatient surgery facility had 80 cases (i.e., patients) per day for 250 days for each of the two anesthetic regimens (i.e., 2,000 cases over 250 days for the generic anesthetic; then 2,000 cases over 250 days for the proposed anesthetic). Parameters of the simulations were based on the facility's actual patient flow conditions. Cases for the simulations were drawn at random with replacement from the patients that participated in the experiment described in table 1.

²Average minutes per case in phase I recovery is the average time spent by each patient in phase I recovery between the end of surgery and the end of phase I recovery according to the patients' case histories that were prepared for each patient participating in the experiment reported in table 1. This average is derived from the simulated 80 patients per day for 250 days for each anesthetic regimen.

³Average minutes per day in phase I recovery is the product of the average minutes per case x 80 cases per day for each anesthetic regimen.

⁴Average minutes per case in phase II recovery is the average time spent by each patient in phase II recovery according to the patients' case histories that were prepared for each patient participating in the experiment reported in table 1. This average is derived from the simulated 80 patients per day for 250 days for each anesthetic regimen.

⁵Average minutes per day in phase II recovery is the product of the average minutes per case x 80 cases per day for each anesthetic regimen.

Surgery center. Recovery room nurse salaries were allocated to each type of surgery using a volume-based allocation system:

1. Surgical staff time for a particular type of surgery is equal to average time spent performing the surgery times the number of surgical staff (operating nurses and technicians) required for that procedure. If, on average, two surgical staff were needed for laparoscopies that required an average of 30 minutes to perform, then each laparoscopy was assigned one hour of surgical staff time.

2. Allocate total salaries and wages, including recovery room salaries and wages, to each type of surgical procedure based on the ratio of surgical staff time spent on that procedure to total surgical staff time for the period. If laparoscopies required 10% of total surgical time in a month, then 10% of the month's nursing costs, including recovery room nursing costs, would be assigned to laparoscopies.

Because the proposed anesthetic did not affect length of surgery or surgical staff time (the two components of the cost allocation basis), the conventional costing system would estimate no change in recovery room resources.

4.2 COST ESTIMATION USING LINEAR ACTIVITY-BASED COSTING

In contrast to the conventional costing system, which assumed recovery room costs were driven by surgery activities, linear activity-based
costing would have set up a separate cost pool for each recovery room phase because each had a different pattern of resource consumption. The cost driver would have been patient time in each phase of recovery because nurses are in attendance continuously while patients are in the recovery room. Interviews with the nurse administrator and accounting staff indicated they would have used "patient minutes" in each phase of recovery as the operational cost driver. To measure this cost driver, nurses would have recorded the minutes each patient spent in each phase of the recovery room on each patient's chart.\(^7\)

To compute the linear activity-based costing estimates, we used simulated patient minutes in each phase of recovery for the two anesthetics. Because our research site did not separate recovery room nursing costs from other nursing costs, we estimated the recovery room costs per day for the generic anesthetic based on interviews with the nurse administrator and our review of the accounting and operating records. Following actual practice, we assumed that under the generic anesthetic, the recovery room was staffed with nine FTE nurses (72 hours per day), divided equally between phases I and II. This split is reasonable given the facility's staffing practices and patient time in each of the two phases of recovery. (We found that the actual assignment of nurses almost never exceeded 60% in either phase I or phase II.) Nursing wages and benefits averaged $18 per hour based on the facility's accounting records for recovery room nurses.

Table 3 presents the results for linear activity-based costing. The results show a 33.1% reduction in nursing resources required for the recovery room, based on the reduction in patient minutes caused by using the proposed anesthetic. If we assumed two-thirds of the nurses were assigned to phase I (II), then the resource savings would have been 32.4% (33.9%).

4.3. ESTIMATED RESOURCE SAVINGS AFTER INCORPORATING JOINT AND INVISIBLE RESOURCE SUPPLY

Estimated resource savings under linear activity-based costing do not consider the joint and indivisible provision of resources inherent in the facility's patient:nurse constraints and its practice of employing nurses in four-hour shifts. To deal with these limitations, we estimated the number of nurses required using integer programming with the joint and indivisible provision of resources as constraints. Specifically, we constrained the patient:nurse ratios to be satisfied 100% of the time, as was the facility's practice, as follows:

\[
\begin{align*}
\text{Phase I recovery:} & \quad \text{Patient:nurse ratio } \leq 2:1. \\
\text{Phase II recovery:} & \quad \text{Patient:nurse ratio } \leq 3:1.
\end{align*}
\]

\(^7\)For the field experiment, nurses measured precisely the number of minutes each patient in the experiment spent in each phase of the recovery room. In practice, patient time in the entire recovery process was recorded, but the time at which a patient moved from phase I to phase II sometimes was not recorded.
TABLE 3
Estimated Resource Savings Using Linear Activity-Based Costing

These computations assume the facility provided 9 full-time equivalent nurses × $18 per hour × 8 hours = $1,296 per day under the generic anesthetic; it has two recovery room cost pools; it uses patient minutes as the cost driver; and nursing resources are assigned equally to phases I and II recovery.

<table>
<thead>
<tr>
<th></th>
<th>Nursing Costs Per Day</th>
<th>Patient Minutes Per Day</th>
<th>Cost Per Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generic Anesthetic:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase I Recovery</td>
<td>$648^2</td>
<td>3,088</td>
<td>$.210</td>
</tr>
<tr>
<td>Phase II Recovery</td>
<td>$648^2</td>
<td>4,904</td>
<td>$.132</td>
</tr>
<tr>
<td>Total Recovery Room Nursing Costs for the Generic Anesthetic</td>
<td>$1,296</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Proposed Anesthetic:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase I Recovery</td>
<td>$448^3</td>
<td>2,136</td>
<td>$.210</td>
</tr>
<tr>
<td>Phase II Recovery</td>
<td>$419^4</td>
<td>3,168</td>
<td>$.132</td>
</tr>
<tr>
<td>Total Recovery Room Nursing Costs for the Proposed Anesthetic</td>
<td>$867</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Difference:

Recovery Room Nursing Cost Savings from Using the Proposed Instead of the Generic Anesthetic $429 (33.1%)

^1 From table 2.

^2 $648 = .5 × $1,296 based on the assumption that the facility provided 9 FTE nurses who worked 8 hours per day, were paid $18 per hour, and whose time was equally divided between phases I and II recovery.

^3 $448 = 2,136 minutes/3,088 minutes × $648.

^4 $419 = 3,168 minutes/4,904 minutes × $648.

We minimized the number of shifts per day for each of the following scenarios: (1) one-hour shifts, (2) four-hour shifts (the facility’s actual practice), and (3) eight-hour shifts. Once a nurse started a shift, the nurse would be employed and compensated throughout the entire shift, consistent with the facility’s staffing practices.

Recovery room shifts started and finished on the hour, so we provided nurses to start shifts on the hour before the arrival of the first patient in our simulation. If the first patient arrived from surgery at 8:20 A.M., then the nurse caring for that patient began work at 8:00 A.M.\(^8\) In phase I, arrival of the first patient triggered use of a nurse; arrival of the second patient did not. In phase II, arrival of the first, fourth, seventh, and tenth patients triggered use of a nurse.

Table 4 presents the estimated resource savings after incorporating the joint and indivisible supply of resources. Assuming four-hour shifts,

\(^8\) When preparing the recovery room schedule, the head nurse may not have staffed the recovery room as “tightly” as our program. It is not clear that the difference between practice and the simulated results would be greater for either anesthetic regimen, so the effect on resource savings from using the proposed anesthetic is unknown. Operating the facility at full capacity, as in our simulation, reduces this potential difference between practice and our simulated results by reducing uncertainty in staffing.
**TABLE 4**

*Estimated Resource Savings after Taking into Account the Joint and Indivisible Supply of Resources*

Assumptions: Staffing requirements are derived using an integer programming model based on the simulation of patient recovery times reported in table 2 and the facility's minimum nurse staffing requirements: A maximum of two patients per nurse in phase I recovery and a maximum of three patients per nurse in phase II recovery. Nursing costs are assumed to be $18 per hour.

**Panel A: Nurses Staffed in One-Hour Shifts**

<table>
<thead>
<tr>
<th></th>
<th>One-Hour Shifts Worked Per Day</th>
<th>Cost Per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic Anesthetic</td>
<td>70.4 Hours</td>
<td>$1,267</td>
</tr>
<tr>
<td>Proposed Anesthetic</td>
<td>61.5 Hours</td>
<td>$1,107</td>
</tr>
<tr>
<td>Cost Savings of Proposed over Generic Anesthetic</td>
<td>8.9 Hours</td>
<td>$160 (12.6%)</td>
</tr>
</tbody>
</table>

**Panel B: Nurses Staffed in Four-Hour Shifts**

<table>
<thead>
<tr>
<th></th>
<th>Four-Hour Shifts Worked Per Day</th>
<th>Cost Per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic Anesthetic</td>
<td>19.2 Shifts (76.8 Hours)</td>
<td>$1,382</td>
</tr>
<tr>
<td>Proposed Anesthetic</td>
<td>16.8 Shifts (67.2 Hours)</td>
<td>$1,210</td>
</tr>
<tr>
<td>Cost Savings of Proposed over Generic Anesthetic</td>
<td>2.4 Shifts (9.6 Hours)</td>
<td>$172 (12.4%)</td>
</tr>
</tbody>
</table>

**Panel C: Nurses Staffed in Eight-Hour Shifts**

<table>
<thead>
<tr>
<th></th>
<th>Eight-Hour Shifts Worked Per Day</th>
<th>Cost Per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic Anesthetic</td>
<td>11.1 Shifts (88.8 Hours)</td>
<td>$1,598</td>
</tr>
<tr>
<td>Proposed Anesthetic</td>
<td>8.8 Shifts (70.4 Hours)</td>
<td>$1,267</td>
</tr>
<tr>
<td>Cost Savings of Proposed over Generic Anesthetic</td>
<td>2.3 Shifts (18.4 Hours)</td>
<td>$331 (20.7%)</td>
</tr>
</tbody>
</table>

1Average total hours per day of nursing resources provided in both phases of the recovery room based on the simulated 80 patients per day for 250 days of running the outpatient surgery facility for each anesthetic. Constraints are that nurses work in one-hour shifts starting and ending on the hour and that the patient:nurse ratio ≤ 2:1 in phase I recovery and ≤ 3:1 in phase II recovery.

2Same as n. 1 except nurses work in four-hour shifts starting and ending on the hour.

3Same as n. 1 except nurses work in eight-hour shifts starting and ending on the hour.

which represents actual practice, the estimated resource savings are 12.4% as shown in panel B. If the facility had used one (eight-) hour shifts, the estimated resource savings of the proposed over the generic anesthetic would have been 12.6 (20.7)% as shown in panels A and C.9

9 Savings are greater under the eight-hour scheduling policy because the longer the "step" in the supply of resources, the greater the potential benefits of shorter patient demands. Assume, for example, eight-hour shifts and a full complement of nurses at 9:00 A.M. Then any patient who stays beyond 5:00 P.M. triggers a new eight-hour shift. Under one-hour shifts, a patient staying past 5:00 P.M. triggers only a one-hour shift (plus another hour at 6:00 P.M., if needed, etc.). Using the proposed anesthetic reduces the frequency of late patient stays in recovery potentially saving more nursing hours under eight-hour shifts than under one- and four-hour shifts. The inflexibility in matching nursing resources to stochastic patient demand using eight-hour shifts was a primary reason that the facility used four-hour shifts.
Recall that the facility’s conventional costing system estimated the proposed anesthetic would save no nursing resources because the allocation base (length of surgery x number of surgical staff in attendance) was not affected by the adoption of the new anesthetic. Linear activity-based costing estimated a savings in resources proportional to the reduction in the cost driver volume (i.e., patient minutes) resulting in an estimated 33.1% savings in resources.10

5. Issues in Choosing among Alternative Costing Systems

Although the facility’s conventional costing system would have estimated the resource savings as zero and linear activity-based costing would have overestimated the savings, it is reasonable to ask whether those errors would affect decisions. Interviews with anesthesiologists, reviews of literature produced by the pharmaceutical company supplying the proposed anesthetic, and discussions with the outpatient surgery center’s financial staff indicated the incremental cost of the proposed over the generic anesthetic to be about $5 per patient for laparoscopies. This incremental cost includes the additional record keeping, training, and waste associated with adding a new anesthetic to the existing set. Assuming this cost would not be passed on to patients, the short-run financial issue was whether the cost could be justified by resource savings in the recovery room.

Clearly, the anesthetic would not have been justified on a financial basis using conventional costing. Linear activity-based costing, which shows the estimated cost savings to be $429 per day for 80 patients, or $5.36 per patient, would justify the proposed anesthetic. Estimates which incorporate the joint and indivisible provision of resources indicate resource savings of $172 per day or $2.15 per patient, thus not justifying using the proposed anesthetic.

Linear-activity based costing performs poorly in translating changes in user demands into changes in resource demands when servers concurrently provide services to multiple users (i.e., joint services). In such settings, as in our health-care setting, a change in the demand for services would only coincidentally proportionately affect the demand for resources. Linear activity-based costing also is limited when service providers are paid in time increments that do not match the time increments of service user demand (i.e., indivisible provision of services). Situations in which service must be continuously available even though demand is sporadic include hospital emergency rooms, fire stations, and on-call maintenance.11

10 This result is consistent with Cooper and Kaplan’s [1992] argument that changes in the use of resources do not necessarily match changes in the supply of resources.

11 See Banker, Datar, and Kekre [1988] and Cooper and Kaplan [1992] for discussions of settings where changes in the provision of resources are unlikely to match changes in the demand for resources.
Compared to certain other settings, our research site does not seem to be an extreme example of either joint or indivisible provision of resources. The joint provision of resources was not greater than the user:server ratio of 3:1 at our research site; supervisors might face ratios of 10:1 or higher and teachers might face ratios of 30:1 or higher. The potential limitations of linear activity-based costing in translating user demands into resource demands would seem to be greater when the user:server ratio is higher.

This study also demonstrates that linear activity-based costing does not help managers trade off the costs and benefits of proposed shift lengths. For example, compare panels A and B in table 4. If the facility’s actual practice is captured by the four-hour shift scenario (panel B), our analysis indicates the facility would save 6.4 (5.7) nursing hours per day under the generic (proposed) anesthetic by staffing in one-hour shifts. Such information enables management to trade off this cost savings against other costs of shorter shifts, including, perhaps, increased hourly pay and turnover costs.

6. Summary and Conclusions

Using the recovery room of an outpatient surgery center as the research site, this paper analyzes the limitations of conventional costing and linear activity-based costing when resources are provided on a joint and indivisible basis. The surgery center was experimenting with an anesthetic that reduced the time patients spent in the recovery room. We examined how well conventional costing and linear activity-based costing would translate a reduction in demand (i.e., patients’ time in the recovery room) into an estimated reduction in the cost of nursing services.

The organization’s conventional costing system showed no decrease in required nursing resources from reduced user demand because the allocation base used for the conventional system was unaffected by the use of the proposed anesthetic. Linear activity-based costing, which assumed reduced patient time in the recovery room would linearly translate into reduced requirements for nursing services, estimated a 33.1% expenditure savings from using the proposed anesthetic. However, this estimate overstates the savings because it does not account for the joint and indivisible provision of nursing services. Specifically, nurses can serve more than one patient and they provide (and are compensated for) services in time increments that do not match the time increments needed by patients. Taking account of these staffing and compensation policies, we estimated the expenditure savings from using the proposed anesthetic to be only 12.4%. These errors in the estimated resource savings would probably have affected the decision whether to use the proposed anesthetic.

Although our study is limited to a single field site and a particular type of problem, it demonstrates that the linear approach to activity-based
costing is likely to give erroneous estimates when there is a discontinuous relation between the demand for and provision of resources. In terms of contracting mechanisms, the less service contracts resemble activity-based piecework, the more potentially problematic is linear activity-based costing.

REFERENCES


