■ ECONOMICS

Anesthesiology
1999; 91:1882–90

Nursing Workload Associated with Adverse Events in the Postanesthesia Care Unit

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Background: **The authors used a nursing task inventory system to assess nursing resources for patients with and without adverse postoperative events in the postanesthesia care unit (PACU).**

Methods: **Over 3 months, 2,031 patients were observed, and each task/activity related to direct patient care was recorded and assigned points according to the Project Research in Nursing (PRN) workload system. PRN values for each patient were merged with data from an anesthesia database containing demographics, anesthesia technique, and postoperative adverse events. Mean and median PRN points were determined by age, sex, duration of procedure, and mode of anesthesia for patients with and without adverse events in the PACU. Three theoretical models were developed to determine the effect of differing rates of adverse events on the requirements for nurses in the PACU.**

Results: **The median workload (PRN points) per patient was 31.0 (25th–75th percentile, 25-46). Median workload was 26 points for patients with no postoperative events and 155 for ≥ six adverse events. Workload varied by type of postoperative event (*e.g.*, unanticipated admission to the intensive care unit, median workload = 95; critical respiratory event = 54; and nausea/vomiting = 33). Monitored anesthesia care or general anesthesia with spontaneous ventilation used less resources compared with general anesthesia with mechanical ventilation. Modeling various scenarios (controlling for types of patients) showed that adverse events increased the number of nursing personnel required in the PACU.**

Conclusions: **Nursing care documentation based on requirements for individual patients demonstrates that the rate of postoperative adverse events affects the amount of nursing resources needed in the PACU. (Key words: Anesthesia costs; patient outcomes.)**

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Received from the Departments of Health Administration and Anaesthesia, the Clinical Epidemiology and Health Care Research Program, Faculty of Medicine, and the Faculty of Nursing, University of Toronto, Toronto, Ontario, Canada. Submitted for publication August 12, 1998. Accepted for publication July 15, 1999. Supported by grant no. 6606-5569-302 from the National Health Research Development Program, Health Canada, Ottawa, Ontario, Canada; and a Senior Scientist Award from the Medical Research Council of Canada, Ottawa, Ontario, Canada (to Dr. Cohen). Presented in part at the annual meeting of the Canadian Anaesthetists' Society, Vancouver, Canada, June 8–12, 1997.

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RECENTLY there has been a marked interest in knowing more about the costs associated with anesthesia.[1] Given the changes in the health-care systems in North America, all components of the health-care system are under scrutiny, anesthesiology included. Despite the importance of the topic, there is little written on how best to estimate anesthesia costs.

Macario *et al.*[2] used a hospital cost management system to estimate and compare the cost of anesthesia to that of other activities in the hospital. They found that "direct variable" costs (the component varying with the number of cases, including labor and supplies) contributed the most to hospital expenditures for anesthesia and surgical care. Dexter and Tinker[3] also used a hospital information system database in this case to evaluate strategies to reduce costs (charges) in the postanesthesia care unit (PACU). They found that nursing costs made the greatest contribution to overall PACU charges.

To examine nursing resource needs, most studies have relied on simple *per diem* methods using total labor costs divided by the number of patients or duration of stay in the PACU.[4,5] This method does not allow for the intricacies of nursing resource requirements given differences in the patient case-mix and specialized care for

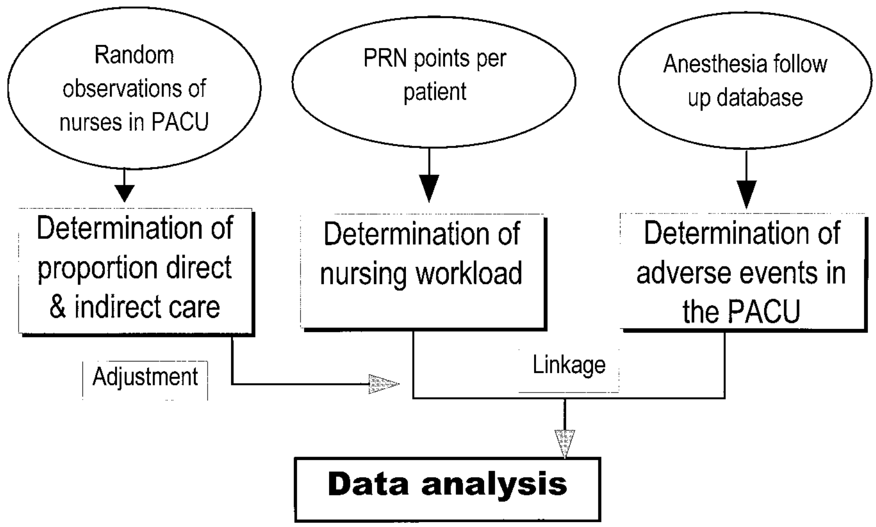

Fig. 1. Steps in data collection and analysis.

adverse postoperative events. Our approach to estimate the cost of anesthesia care in the PACU used a nursing workload measurement system. This differs from previous methods in that a workload approach measures patients' requirements for nursing care (nursing intensity) and provides an estimate of the number of nursing care hours (workload) required to meet these needs.

The objective of this research was to use a nursing workload system to measure the activities of nurses in the PACU. The Project Research in Nursing (1980 version; PRN 80), a nursing task inventory system, is a Canadian information system for the management of nursing staff in hospitals and homes for the aged.[6] We then used the points per task derived from the PRN system to determine workload and costs of nursing care for patients with and without adverse postoperative events. The secondary objective was to use the parameters from a regression to model the number of nursing personnel required for differing rates of occurrence of postoperative adverse events.

Methods

Two data sources were used in this research, the ongoing anesthesia follow-up database from St. Michael's Hospital in Toronto (preoperative, intraoperative, and postoperative information on all patients who were attended by an anesthetist) and that from a nursing workload study in the PACU at the same hospital (April 1996 to September 1996).

The anesthesia database has been previously described.[7] For each patient undergoing surgery at the hospital (PACU admissions only), a special form with definitions for adverse events was completed by PACU nurses and recorded demographics, length of stay, and any adverse postoperative events. All forms were retrieved by a research assistant who checked them against operating room records. A clinical anesthesiologist or research nurse checked each form for accuracy and completeness. All data were entered into a database that included further checks on accuracy. An extensive pilot study and pretest on the form were conducted before its institution in the PACU; all PACU nurses received in-service training on its application. Length and type of operation, anesthesia technique and drugs, and other intraoperative information obtained by the attending anesthesiologist were also available from the anesthesia database.

The second source of study data related to nursing workload measurement. For this part, nursing workload in the PACU was determined using the PRN system.[8] We selected the PRN because it is the workload system that has been most extensively used and validated in previous studies[8,9] (additional details on the PRN system are presented in appendix 1).

The initial phase of the study consisted of determination of the actual tasks performed by PACU nursing staff (registered nurses and registered practical nurses). Because the PRN system measures direct care (*i.e.*, activities related to hands-on care), we first needed to ascertain what proportion of a nurse's time was spent in direct patient care *versus* indirect and nonpatient activities (fig. 1). To do this, we used a work sampling technique (see appendix 1). Two trained observers made random observations of all nursing activities during six day shifts (8:00 A.M. to 4:00 P.M.) and five evening shifts (3:30 P.M. to 11:30 P.M.). The observers watched each nurse working in the PACU at randomly selected times on each shift and identified all activities during that shift. Work sampling was performed using observation times randomly generated at 10-min intervals. The work sampling technique, involving a large number of randomly selected observations, is therefore representative of the entire shift. Ten days of observation yielded 1,605 random observations for all nursing staff on day and evening shifts. Of these, it was found that 72.5% of PACU nursing time, excluding personal time, was spent in direct patient care.

The next step involved classification and collection of all direct-care nursing activities using the PRN point system (fig. 1). Here each patient was observed, and each task/activity (*e.g.*, intravenous medications, pain medication) related to patient care was recorded on a predefined form listing the PACU activities. The PRN system assigns a value for each direct-care item delivered by nurses. Each value assigned in the PRN system weights task intensity as well as time factor. For example, vital signs measured one to three times yield a PRN value of 1, vital signs measured 4–14 times gives a PRN value of 3, and assisting with a physician intervention gives a PRN value of 8. Using this system, we collected patient-specific PRN data for 2,031 consecutive patients over a 3-month weekday period (63 days).

To perform the calculations necessary to determine a unit of nursing service, we sampled the specific data from 6 of the study days (n = 227). These days were chosen as representative of the PACU activities with full staff compliments and a full roster of postoperative patients. Thus, values derived from these calculations would represent optimal PACU staffing and patient service. We calculated the time value associated with each PRN point in the PACU by summing the total time (total length of PACU stay for the 227 patients) and dividing this by the total PRN points for the 6 specific days. This resulted in a time of 2.11 min of direct care per PRN point. We next adjusted this figure upward to account for the proportion of indirect nursing care time. Thus, for each PRN unit value, the total nursing care time (direct and indirect) was 2.92 min.

At this stage, we merged the PRN values for each patient with his/her data from the anesthesia database. Because patient chart numbers were on both files, we used this variable to link the two databases. This allowed us to determine if specific patients had experienced an adverse event in the PACU.

Statistical Analysis

We determined the PRN points for all 2,031 patients and the mean (and SD) and median (and 25th–75th percentiles) number of PRN points by patient characteristics such as age, sex, American Society of Anesthesiologists (ASA) physical status score, duration of surgery, and anesthetic technique were determined for all patients, and for patients with and without an adverse event. Because the number of some adverse events was low, we grouped similar events (see appendix 2 for definition of postoperative events). Adverse events were described for patients using both hierarchical and mutually exclusive categories, *e.g.*, any admission to the intensive care unit (ICU), any critical respiratory event but no ICU admission, only nausea and vomiting but no ICU admission or respiratory event, only nausea and vomiting, and desaturation but no ICU or respiratory event, *etc.* For each event, we calculated the proportion of total nursing workload (and 25th–75th percentiles) represented by that event.

We next determined which factors were associated with increased PACU workload (*i.e.*, increased PRN points). We used a linear regression model with PRN points as the dependent variable and age, sex, ASA patient status, anesthesia technique, duration of surgery, and adverse postoperative events as independent variables. Age (< 50 yr, 50–64 yr, and 65+ yr) and duration of operation (< 1 h, 1–2 h, > 2 h) were entered into the analysis as categoric variables, physical status was grouped as 1–2 and 3–4, and anesthesia technique was entered as a series of dummy variables. This analysis allowed us to determine a value for each independent variable, and these values represented the additional PRN points for each variable over that of the baseline (intercept). Because the data for PRN points were somewhat skewed, we eliminated the 10 largest outlying values before running the regression. To account for multiple comparisons, parameter coefficients (how much values of the dependent variable change for each unit change in values of the independent variables) were considered statistically significant at $P < 0.01$.

To assess the effect of patient case-mix differences on the number of nursing personnel, we created three theoretical PACU models. For each model, the number of patients was kept at 2,031 over a 3-month period, but

Table 1. PRN Points by Number of Postoperative Events

Number of Events	Number of Patients	PRN Points Mean ± SD	PRN Points Median	25–75th percentile
None	1,220	29.0 ± 13.8	26	20.0–35.0
1	487	40.4 ± 17.2	36	27.0–51.0
2	202	47.9 ± 18.7	46	32.0–60.0
3	81	54.6 ± 24.8	56	36.0–66.0
4	20	72.7 ± 22.4	65.5	56.5–81.0
5	16	79.9 ± 35.7	76.5	53.5–94.5
6	5	144.0 ± 60.8	155	80.0–198.0

PRN = Project Research in Nursing.

the rate of postoperative events was varied. Model A represents a PACU in which the rate of adverse events was 50% that of our study population. Model B has the same PACU patient case-mix as the present study, and Model C represents the PACU in which the rate of adverse events was twice that of Model B. We used the parameter estimates from the regression to determine the number of PRN points required for each patient in the theoretical PACU (*i.e.*, the number of patients with a particular adverse event was multiplied by the value of the parameter estimate for that event). The total number of PRN points was then summed for all patients and added to the baseline rate to determine the adjusted number of PRN points. We then determined the number of nursing personnel required over 3 months for each PACU by multiplying the adjusted number of PRN points by 2.92 min per PRN point and dividing by 360 min per nursing personnel (this assumes a shift of 8 h with 1 h for meals and two half-hour breaks for 3 months in the summer, consisting of 5 days per week plus three statutory holidays).

Results

Of the 2,031 PACU patients, 56.1% were female, 80% were ASA health status 1 or 2, and 60% had received general anesthesia with mechanical ventilation. For the 2,031 PACU patients, the mean number of PRN points per patient was 35.7 (SD = 19.6), and the median number of points was 31 (25th–75th percentile = 22–46).

The number of PRN points varied with the number of postoperative events experienced by patients (table 1). Patients with more postoperative events had a higher number of PRN points. However, the relationship was not linear, and there was much overlap in the number of PRN points. Patients without any events had, on average, 29.0 PRN points (SD = 13.8) with a median number of points of 26.

In addition, the number of PRN points varied by patient characteristics (table 2). Patients who were women, had an ASA physical status score of 1–2, had surgeries that lasted < 1 h, and those who received neurolept anesthesia required the lowest amount of nursing services (*i.e.*, had the lowest PRN points). The number of PRN points also varied by type of postoperative event (table 3). The highest value was for the 10 patients who experienced multiple problems (number of problems ranged from 2 to 10), leading to an unanticipated ICU admission (mean PRN value, 119.0; median, 95.5). Patients who experienced a critical respiratory event (n = 21) also had high PRN values (mean, 62.7; median, 54). Isolated nausea and vomiting was the most frequently observed postoperative adverse event (n = 121 for patients experiencing nausea and vomiting but no other problems).

Nausea and vomiting combined with other events increased the workload but not in an additive fashion. For example, patients with nausea and vomiting alone had a mean PRN value of 36.7, and those who experienced desaturation alone had a value of 39.0. When the two events occurred in the same patient, the mean value was 46.8 PRN points. However, not all multiple problems

Table 2. PRN Points by Patient Characteristics and Modes of Anesthesia

Characteristic	Number of Patients	PRN Points Mean ± SD	PRN Points Median	25–75th Percentile
All patients	2,031	35.7 ± 19.6	31	22–46
Women	1,140	33.7 ± 17.4	29	22–42
Men	891	38.2 ± 21.8	32	23–50
Age				
<50 yr	1,131	35.0 ± 19.3	30	22–44
50–64 yr	408	37.0 ± 18.4	33	22–49
65+ yr	492	35.7 ± 20.9	31	20–48
ASA physical status				
I	808	32.7 ± 16.7	29	22–40
II	817	36.6 ± 20.0	32	22–49
III	348	39.5 ± 22.4	33	23–52
IV	58	39.2 ± 26.2	32	25–47
Duration of operation				
<1 h	485	25.1 ± 12.9	24	19–30
1–2 h	862	33.0 ± 17.1	29	22–42
2+ h	684	45.9 ± 21.5	44	30–59
GA, spontaneous ventilation	401	28.8 ± 12.5	26	20–34
Monitored anesthesia care	362	22.5 ± 16.7	19	13–28
Regional	50	37.7 ± 24.1	34.5	20–48
GA mechanical ventilation	1218	41.8 ± 19.5	37	27–54

ASA = American Society of Anesthesiologists; GA = general anesthesia; PRN = Project Research in Nursing.

Table 3. PRN Points and Proportion of Total Nursing Workload for PACU Postoperative Events

		PRN Points		% Workload	
Event	Number of Patients (%)	Mean ± SD	Median	Mean	25–75th Percentile
Unplanned admission to ICU	10 (0.5)	119.0 ± 62	95.5	1.6	0.8–2.6
Critical respiratory event	21 (1.0)	62.7 ± 24.0	54	1.9	1.4–2.3
Desaturation	70 (3.4)	39.0 ± 15.2	36.5	3.8	2.6–4.8
Arrived intubated	47 (2.3)	51.6 ± 16.8	50	3.3	2.5–4.0
Excessive pain	72 (3.5)	44.1 ± 16.3	42	4.4	3.1–5.7
Agitation	31 (1.5)	43.4 ± 14.9	43	1.8	1.3–2.2
Excessive pain and agitation	16 (0.8)	56.8 ± 23.9	56	1.3	0.9–1.4
Shivering/hypothermia	69 (3.4)	38.9 ± 17.1	33	3.7	2.5–4.8
Shivering and excessive pain	16 (0.8)	44.6 ± 12.8	47.5	1.0	0.7–1.2
Cardiac-related	71 (3.5)	42.7 ± 21.2	37	4.2	2.5–5.8
Nausea/vomiting	121 (6.0)	36.7 ± 16.3	33	6.1	4.2–6.9
Nausea/vomiting and desaturation	13 (0.6)	46.8 ± 12.4	47	0.8	0.8–1.0
Other events	254 (12.5)	49.2 ± 22.8	47	17.3	10.9–22.4
No events	1,220 (60.1)	29.0 ± 13.8	26	48.8	33.7–59.0

ICU = intensive care unit; PACU = postanesthesia care unit; PRN = Project Research in Nursing.

resulted in an increase in the number of PRN points. If a patient experienced excessive pain (mean PRN, 44.1) and shivering/hypothermia (mean PRN, 38.9), the effect of the combination of the two adverse events did not seem to add much additional workload (mean PRN, 44.6).

The frequency and mean PRN points affected the proportion of the total workload for each postoperative event or combination of events (table 3). For example, patients who had an unplanned ICU admission represented 0.5% of the 2,031 patients but 1.6% of the total workload (25th–75th percentile, 0.8–2.3%). In contrast, patients with nausea and vomiting and no other problem represented 6.0% of the patients and 6.1% of the costs (25th–75th percentile, 4.2–6.9%). Patients with no adverse events comprised 60.1% of the patients and used 48.8% of the PACU costs (25th–75th percentile, 33.7–59.0%).

Factors associated with increased or decreased PACU workload are listed in table 4. After controlling for other factors affecting PACU workload, female patients were associated with significantly lower workload than males, as were patients whose physical status score was 1 or 2. Patients aged $\leq$ 50 yr had significantly decreased workload compared with those aged 50–64 yr. Compared with patients without any postoperative adverse events, patients who needed to be transferred to an ICU contributed an additional 37.3 PRN points ($P < 0.0001$). Surgery that lasted $>$ 2 h contributed an additional 10.60 PRN points ($P < 0.0001$) to nursing workload. In addition, patients who underwent monitored anesthesia care or general anesthesia with spontaneous ventilation contributed less to workload compared with general anesthesia with mechanical ventilation.

The three theoretical PACU models are shown in table 5. The number of nursing staff required was related to the rate of postoperative adverse events. For Model A (the PACU in which patients had half the rate of adverse events), the adjusted number of PRN points was 78,505, and the number of nursing personnel needed to meet this workload was 637, or 10.1 nurses per day. In contrast, in Model C, in which patients had twice the rate of adverse events, the same number of patients would require 733 nursing personnel, or 11.6 nurses per day.

Discussion

This study examined the requirements for nursing services in the PACU using a nursing workload measurement system. This allowed us to consider the nursing workload for patients with and without postoperative events and to examine more fully where most nursing attention is given. We found that for patients without adverse events in the PACU, the average number of PRN points was 29.0, which still represents a significant workload and cost for PACU nursing staff. As the number of postoperative events increased, so did the associated nursing resources. The relationship was not linear because the resource needs were very dependent on the specific PACU adverse events experienced by patients. Multiple problems, such as those leading to an unanticipated ICU admission or major respiratory events, contributed disproportionately to workload. Nausea and

Table 4. Factors Associated with Nursing Workload (Linear Regression Results)

Factor	Reference	Parameter Estimate*	SD	*P* Value
Women	Men	−2.68	0.6	0.0001
Age				
<50 yr	50–64 yr	−2.76	0.8	0.0006
65+ yr		−0.50	0.9	0.5926
Physical status score 1–2	3–4	−4.39	0.8	0.0001
Duration of operation				
1–2 h	<1 h	3.78	0.9	0.0001
>2 h		10.60	1.0	0.0001
General anesthetic spontaneous ventilation	GA mechanical ventilation	−5.62	0.9	0.0001
Monitored anaesthesia care		−16.07	0.9	0.0001
Regional		−4.83	2.0	0.015
Cardiac	No event	9.27	1.7	0.0001
Critical respiratory event		18.63	3.4	0.0001
Desaturation		3.77	1.7	0.025
Arrived intubated		13.59	2.0	0.0001
ICU admission		37.30	5.5	0.0001
Excessive pain		11.60	1.6	0.0001
Agitation		8.62	2.5	0.0005
Pain and agitation		17.43	3.5	0.0001
Shivering/hypothermia		3.19	1.7	0.064
Shivering and pain		9.37	3.4	0.0075
Nausea/vomiting		3.69	1.3	0.0048
Nausea/vomiting and desaturation		7.84	3.8	0.041
Other events		13.10	1.0	0.0001
Intercept		36.68	1.4	0.0001

$R^2 = 0.423$.

* Parameter estimate: how much values of the dependent variable change for each unit change in values of the independent variable.

ICU = intensive care unit.

vomiting occurred with the highest frequency, but its contribution to overall workload was in proportion to its prevalence: isolated nausea/vomiting occurred in 6.0% of patients and contributed 6.1% of the total workload.

There are few details provided in previous studies on how nursing workload is actually determined. This is of considerable importance given that nursing costs contribute markedly to overall costs of anesthesia. The concept of case costing, the determination of patient-specific costs by episode of patient care, uses a sophisticated management information system to assign costs to various cost centers within a hospital (*e.g.*, nursing, pharmacy, and so forth). However, within this cost center (*i.e.*, the PACU), the assignment of costs to individual cases may not account for key factors determining patients' predicted (and actual) use of resources.

For example, Broadway and Jones[4] provided a detailed determination of how they assessed costs (not charges) for personnel in one hospital in Cambridge, United Kingdom. For the PACU, the sum of all salaries for recovery nurses was divided by the number of patients attended, and an average cost per patient was derived. This method is similar to that used by some management information systems in that nursing costs are treated as average (standard) cost per case or per minute. This implicitly assumes that all patients have the same characteristics and require the same level and type of nursing care. The *per diem* method, although simple and straightforward, does not permit us to estimate the intensity or complexity of nursing functions in the PACU, nor does it allow us to examine actual variations in nursing care for different types of patients. Our theoretical models suggest that requirements for nursing services varied considerably according to the rate of postoperative adverse events. A *per diem* approach would have predicted the same nursing requirements for each model. Furthermore, previous studies[10–13] have demonstrated that the *per diem* methodology is not reliable or valid. Only an examination of actual nursing functions and the complexity of the patient situation will allow us to determine where efficiencies can be optimized. Thus, our use of the PRN system allowed us to examine in more detail the components of nursing time and their relation to patient condition in the PACU.

Patient characteristics such as age and sex increased PACU nursing workload, and thus costs, but in essence

Table 5. Rate of Adverse Events and Number of Nursing Personnel Required for 3 Months of PACU Care (N = 2,031 Patients)

	Model A* (low rate)			Model B			Model C† (high rate)		
	N	%	PRN Points	N	%	PRN Points	N	%	PRN Points
ICU admission	5	(0.3)	187	10	(0.5)	373	20	(1.0)	746
Central respiratory event	11	(0.5)	205	21	(1.0)	391	42	(2.0)	783
Desaturation	35	(1.7)	132	70	(3.5)	264	140	(6.9)	528
Arrived intubated	24	(1.1)	326	47	(2.3)	639	94	(4.6)	1278
Excessive pain	36	(1.8)	418	72	(3.6)	835	144	(7.1)	1670
Agitation	16	(0.8)	138	31	(1.5)	267	62	(3.1)	534
Pain and agitation	8	(0.4)	139	16	(0.8)	279	32	(1.6)	558
Shivering/hypothermia	35	(1.7)	112	69	(3.4)	220	138	(6.8)	440
Hypothermia and pain	8	(0.4)	75	16	(0.8)	150	32	(1.6)	300
Cardiac-related	36	(1.8)	334	71	(3.5)	658	142	(7.0)	1316
Nausea/vomitting	61	(3.0)	225	121	(6.0)	447	242	(12.0)	893
Nausea/vomitting and desaturation	7	(0.3)	55	13	(0.6)	102	26	(1.3)	204
Other events	127	(6.3)	1664	254	(12.5)	3327.4	508	(25.0)	6654.8
Total PRN points (baseline and adverse events)			78.506			84.449			90.401
Number of minutes of PACU care‡			229,236			240,752			263.972
Number of nursing personnel§	636.8			668.8			733.3		

* Model A: rate of adverse events is one half that of Model B.

† Model C: rate of adverse events is twice that of Model B.

‡ Total PRN points × 2.92 min/PRN point

§ Number of minutes of PACU care divided by 360 min.

ICU = intensive care unit; PACU = postanesthesia care unit; PRN = Project Research in Nursing.

added less to overall workload as compared with adverse postoperative events. For example, fewer nursing interventions were given to women rather than men, and patients aged 50–64 yr required more nursing resources than patients aged < 50 yr. Surgical time and anesthetic technique were also major contributors to PACU workload. In contrast, even minor postoperative events such as hypothermia added to nursing interventions. However, our theoretical PACU models illustrate that changing rates of adverse events can have an impact on the number of nursing personnel required to provide services to patients. Given the same time period and the same number of patients, the requirements for nursing resources varied considerably when the rate of adverse events was increased or decreased.

Eliminating or reducing postoperative adverse events should theoretically have a significant impact on reducing the nursing workload in the PACU. In reality, unpredictable events such as critical respiratory events or unanticipated ICU admissions added disproportionately to workload (*i.e.*, the proportion of total workload was greater than the prevalence of these conditions). More predictable events such as nausea and vomiting contributed in proportion to their occurrence. The relatively low costs for nausea and vomiting may be because they are easily treatable and that they are anticipated; few nursing resources were tied up in dealing with these problems. In contrast, perhaps minor problems such as nausea and vomiting are not perceived to be important to warrant a lot of nursing attention as compared with other events. This requires further investigation.

Interestingly, excessive pain, although a common problem, required a relatively high amount of nursing care, especially when combined with agitation. Given that routine orders are typically available for analgesics, this high use of nursing time is surprising. Although medication is one means of controlling pain and agitation, simple acts of being with and soothing the patient may be other important nursing interventions in pain management. Perhaps more could be done to prevent the problem before PACU admission. The goal may be to anticipate pain and the subsequent agitation before the pain cycle peaks and patients become severely uncomfortable.

The relatively low resource requirement for cardiac problems may be reflective of the patient population of general surgical cases in that patients with major cardiac problems are admitted directly to the ICU. With regard to anesthetic technique, patients who received a general anesthetic with mechanical ventilation required the most nursing attention. In addition, patients who received a regional technique had high PACU nursing requirements. The numbers of patients that received a regional block are too few for detailed analysis but may represent a high-risk patient population or could be related to the type of regional block or its duration.

Despite the comprehensiveness of this study, the methods used have some limitations. The study did not attempt to measure optimal or efficiencies of PACU nursing care. The study was observational in that we measured what interventions and treatments the patients received without making a judgment as to whether an intervention was necessary. Therefore, we cannot draw any conclusions from the study about the optimal use of nursing resources. Second, the study observed nurses and patients over a 3-month period in the summer, and, although unlikely, it is possible that different results may have been observed if the study had been conducted at another time. A third limitation is that the PRN system has not been used previously to study nursing workload in the PACU. However, the PRN system has been widely used and has been well validated in other settings. Finally, it should be noted that the relationship between nursing workload and costs can vary depending on the type of nursing personnel employed. In this study, the PACU nursing staff was comprised of registered nurses and registered practical nurses; differing complements of nursing personnel or differing remuneration might result in differing costs per PRN point, but the requirement for nursing care (total PRN points) would be similar. On the other hand, we do not know if the same number of less-skilled personnel could meet these patient needs.

Given the results of our study, would it be possible to estimate the amount of nursing resources for the PACU? It would seem that infrequent problems such as critical respiratory events are associated with an increased workload requirement greater than their rate of occurrence. Although the incidence of such problems may be estimated from the literature, such events will likely continue to be a feature of postoperative care. More predictable but more frequent events such as nausea and vomiting or hypothermia add relatively little extra to nursing time, and good methods exist to reduce the rate of these problems.[13–15] Given their high frequency, there is only limited potential for reducing nursing workload by reducing the incidence of these events. Nursing staff complements will need to be maintained at high levels to deal with the 40% of patients (accounting for 51.2% of nursing care workload) who experienced an adverse event in the PACU so that, again, there is limited scope for reducing workload, particularly around unpredictable events.

In summary, this study used a sophisticated workload tool (PRN) to measure the intensity of nursing care in the PACU and to estimate the workload associated with this care. If there were a greater proportion of very ill patients or the frequency of postoperative adverse events had been higher, our model predicts a need for additional nursing resources.

Appendix 1

Time Lines

All work sampling data collection was conducted over a 2-month period followed by PRN data collection in July through September of the same year. The time frame between the two series of data collection was < 1 month, with the interim month being used to train data collectors for the PRN arm of the study. No unusual changes in practices occurred in this time frame. Therefore, the work sampling data time frame was considered an accurate estimate of direct- and indirect-care time for use with the PRN system.

Calculation of Sample Size for Work Sampling Validation: Direct and Indirect Care

An objective of work sampling technique was used to estimate the percentage of time spent in direct care (care that occurs in the presence of the patient) *versus* indirect care (activities directed at maintaining the patient and unit environment) for each staff group for each shift. Work sampling is a statistical estimate of workload based on a random sampling technique, and a number of observations of the variable of interest are recorded. From these data, a number of statistical inferences can be made about the true nature of the underlying population.[16,17]

In our study, 2,016 random observations of direct/indirect-care time were made on day shifts, and 1,440 random observations were made on evening shifts. Inter-rater reliability between data collectors was maintained at $> 85\%$ throughout the work sampling phase. This sample was more than adequate to reflect the actual split between direct and indirect care on both day and evening shifts where all registered nursing staff were observed at 10-min intervals.

PRN Workload Measurement Tool

PRN 80 is a Canadian information system for the management of nursing staff in hospitals and homes for the aged.[6] The primary objective of the PRN 80 system is to measure the quantity of nursing care required by all patients. This instrument lists 214 indicators or tasks that nurses complete on behalf of patients during a 24-h period. Each indicator or task is a assigned a point value that represents the time to complete a specific nursing intervention as well as the number of times the task will be completed on a shift. For example, vital signs measured 1–3 times yields a point value of 1, and vital signs measured 4–14 times gives a PRN point value of 3. Assisting the physician with an intervention gives a PRN point value of 8. In the usual application, a PRN point value is equal to 5 min in the 24-h ward setting.

The PRN methodology has undergone extensive testing and several iterations since it was first developed in 1972.[6] Since that time, nurse experts and experienced staff have been involved in ongoing content validation of the PRN system. Using a nominal group technique, clinical consultation and review of some 2,300 nursing care plans by nurse experts, the initial items and time vales were established for the PRN system.[6]

At the time of instrument development, the construct and predicative validity[18] of the PRN system was established. Construct validity was measured by comparing the degree of occupation of nursing staff to the PRN estimate of staff required on the shift on one medical and one surgical unit. The correlation coefficients were large at 0.77–0.90 and 0.60–0.80, respectively. The results suggest that the time estimates from PRN tool correspond to the degree of work actually performed by nursing staff.[8]

Developing PRN Points

Patients do not remain in the PACU over a 24-h period; thus, the researchers needed to revise the point value for each item to reflect time per PACU visits. To do this, we took a representative sample of 10% of the patients for whom full classification data were available. The sample of 227 patients represented days on the unit that were representative of normal PACU activities with a full roster of patients and a full complement of nursing staff. Thus, the values derived from these calculations would represent the optimal PACU staffing and patient service. We examined the total amount of time (derived from work sampling study) that nurses were engaged in direct-care activity over the 6 days when the 227 patients were in the PACU (relative to the total PRN points) to determine the time value per PRN point in PACU. This is considered a valid approximation of the PRN system in the PACU given the close time line between the work sampling data collection and the original PRN classification. The method for determining time per point closely approximated the methods reported by Chagnon *et al.*[6,8]

Appendix 2: PACU Adverse Outcomes

Agitation: unable to be settled or calmed down by verbal reassurance
Critical respiratory event: hemoglobin saturation $< 90\%$ or hypoventilation or obstruction requiring major intervention (drug reversal, jaw manipulation, airway insertion, manual ventilation, or reintubation)
Arrived intubated: endotracheal tube present on arrival in the PACU
Unanticipated ICU admission: problem or problems identified in the PACU leading to an unexpected ICU admission
Nausea and vomiting: any volunteered complaint of nausea, observed active retching, requiring antiemetics
Cardiac related
Hypertension/hypotension: $>$ or $<$ 20% preoperative systolic blood pressure for $>$ 15 min, or $>$ or $<$ 50% preoperative systolic pressure for one reading
Tachycardia/bradycardia: heart rate $>$ 120 beats/min or $<$ 50 beats/min for $>$ 15 min; new dysrhythmia or ischemia
Excessive pain: moaning or writhing in pain at any time or initial nursing care dominated by pain control
Desaturation: oxygen saturation as measured by pulse oximetry $< 90\%$, cyanosis or arterial oxygen partial pressure $<$ 60 mmHg
Shivering or hypothermia: shivering on arrival in the PACU resulting in failure to obtain vital signs or lasting $>$ 15 min; skin temperature $<$ 35°C

References

1. Watcha MF, White PF: Economics of anesthetic practice. ANESTHESIOLOGY 1997; 86:1170–96
2. Macario A, Vitez TS, Dunn B, Mc Donald T: Where are the costs in perioperative care? Analysis of hospital costs and charges for in patient surgical care. ANESTHESIOLOGY 1995; 83:1138–43
3. Dexter F, Tinker JH: Analysis of strategies to decrease postanesthesia care unit costs. ANESTHESIOLOGY 1995; 82:94–101
4. Broadway PJ, Jones JG: A method of costing anesthetic practice. Anaesthesia 1995; 50:56–63
5. Apfelbaum JL, Grasela TH, Walawander CA: Benchmarking data to modify practice reduces ambulatory surgical center expenses (abstract). ANESTHESIOLOGY 1997; 87:A963
6. Chagnon M, Audette LM, Lebrun L, Tilquin C: Validation of a patient classification tool through evaluation of nursing staff degree of occupation. Med Care 1978; 16:465–75 7 Rose DK, Cohen MM, Wigglesworth DF, Yee D: Development of a computerized database for the study of case-mix, process and outcome of anaesthesia care. Can J Anaesth 1992; 39:716–23
8. Chagnon, M, Audette L, Lebrun L, Tilquin C: A patient classification system by level of nursing care requirements. Nursing Res 1978; 27:107–12
9. O'Brien-Pallas L, Leatt P, Deber R, Till J: A comparison of workload estimates using three methods of patient classification. Can J Nurs Admin 1989; 2:16–23
10. O'Brien-Pallas L: An analysis of the multiple approaches to measuring nursing workload. Can J Nurs Admin 1988; 5:12–6
11. O'Brien-Pallas L, Irvine D, Peereboom E, Murray M: Measuring nursing workload: Understanding the variability. Nurs Econ 1997; 15:171–82
12. Prescott PA, Ryan JW, Soeken KL, Castor AH, Thompson KO, Phillips CY: The patient intensity for nursing index: A validity assessment. Res Nurs Health 1991; 14:213–21
13. Beattie WS, Lindblad T, Buckley DN, Forrest JB: The incidence of post-operative nausea and vomiting in women undergoing laparoscopy is influenced by the day of menstrual cycle. Can J Anaesth 1991; 38:298–302
14. Desilva PHDP, Darvish AH, McDonald SM, Cronin MK, Clark K: The efficacy of prophylatic ondansetron, droperidol, perphenazine, and metoclopramide in the prevention of nausea and vomiting after major gynecologic surgery. Anesth Analg 1995; 81:139–43
15. Rowbotham DJ: Current management of postoperative nausea and vomiting. Br J Anaesth 1992; 69(suppl 1):46S–59S
16. Niebel B: Motion and Time Studies, 7th Edition. Chicago, Irwin Publishing Co., 1982, pp 533–65
17. Cockerill R, O'Brien-Pallas L, Bolley H, Pink G: Measuring nursing workload for case costing. Nurs Econ 1993; 11:342–9
18. Nunnally JC, Bernstein IR: Psychometric Theory, 3rd Edition. New York, McGraw Hill, 1994, pp 84–100