Impact of Variations in the Nursing Care Supply-Demand Ratio on Postoperative Outcomes and Costs

Fabio Agri, MD, MBA,† Fabian Grass, MD, PD,* Sophie Kasmi, MD,* Nicolas Demartines, MD,* Markus Schäfer, MD,* and Marc-Olivier Sauvain, MD, PD*‡*

Introduction: Improving surgical outcomes is a priority during the last decades because of the rising economic health care burden. The adoption of enhanced recovery programs has been proven to be part of the solution. In this context, the impact of variations in the nursing care supply-demand ratio on postoperative complications and its economic consequences is still not well elucidated. Because patients require different amounts of care, the present study focused on the more accurate relationship between demand and supply of nursing care rather than the nurse-to-patient ratio.

Methods: Through a 3-year period, 838 patients undergoing elective and emergent colorectal and pancreatic surgery within the institutional enhanced recovery after surgery (ERAS) protocol were retrospectively investigated. Nursing demand and supply estimations were calculated using a validated program called the *Projet de Recherche en Nursing* (PRN), which assigns points to each patient according to the nursing care they need (*estimated* PRN) and the actual care they received (*real* PRN), respectively. The real/estimated PRN ratio was used to create 2 patient groups: one with a PRN ratio higher than the mean (PRN+) and a second with a PRN ratio below the mean (PRN−). These 2 groups were compared regarding their postoperative complication rates and cost-revenue characteristics.

Results: The mean PRN ratio was 0.81. A total of 710 patients (84.7%) had a PRN+ ratio, and 128 (15.3%) had a PRN− ratio. Multivariable analysis focusing on overall complications, severe complications, and prolonged length of stay revealed no significant impact of the PRN ratio for all outcomes ($P > 0.2$). The group PRN− had a mean margin per patient of U.S. dollars 1426 (95% confidence interval, 3 to 2903) compared with a margin of U.S. dollars 676 (95% confidence interval, −2213 to 3550) in the PRN+ group ($P = 0.633$).

Conclusions: A PRN ratio of 0.8 may be sufficient for patients treated following enhanced recovery after surgery guidelines, pending the adoption of an accurate nursing planning system. This may contribute to better allocation of nursing resources and optimization of expenses on the long run.

Key Words: nurse staffing, nursing care supply-demand ratio, Projet de Recherche en Nursing (PRN), enhanced recovery after surgery (ERAS), postoperative complications, cost-revenue analysis

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From the *Department of Visceral Surgery, Lausanne University Hospital CHUV, University of Lausanne (UNIL); †Department of Administration and Finance, Lausanne University Hospital, Lausanne; and ‡Department of Surgery, Neuchâtel County Hospital, Neuchâtel, Switzerland.

Correspondence: Nicolas Demartines, MD, Department of Visceral Surgery, University Hospital CHUV, Rue du Bugnon 46, 1011 Lausanne, Switzerland (e-mail: demartines@chuv.ch).

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Data availability: The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Improving surgical outcomes is a priority during the last decades because of the rising economic health care burden.[1–3] The emergence of minimally invasive approaches paired with perioperative care according to enhanced recovery after surgery (ERAS) principles had a substantial beneficial impact throughout different surgical specialties.[4,5] Nevertheless, postoperative morbidity remains a major issue that affects both quality of life and long-term outcome.[6,7]

Although most efforts to improve surgical outcomes focus on surgical innovation, ERAS programs target physiological changes and aim to minimize the perioperative stress response.[8,9] The ERAS concept revolutionized traditional practices, replacing them with evidence-based care. Identified key factors impeding hospital discharge of surgical patients include the need for parenteral analgesia, the need for intravenous fluids secondary to gut dysfunction, and impaired mobility caused by lack of postoperative mobilization.[10] These items are central elements targeted by ERAS pathways. The success of the program is based on multidisciplinary and multimodal care. The main philosophy behind ERAS is to bring together the various health care providers taking part of the patient journey allowing for patient-centered care. This multidisciplinary team includes surgeons, anesthetists, physiotherapists, nutritionists, and nursing staff as well as the actual patient. The aim is to prevent and manage postoperative complications using multiple therapeutic approaches, to avoid the adverse effects related to the exclusive use of a single measure. Multimodal, opioid-sparing analgesia to avoid the adverse effects inherent to opiates and multimodal management of paralytic ileus by stimulating early mobilization, limiting intravenous fluid intake, or using oral laxatives, among others, are 2 examples.[11,12] The key items of ERAS programs include preoperative counseling and optimization, fluid restriction, multimodal analgesia, and avoidance or early removal of tubes and drains, as well as both early postoperative nutrition and mobilization.[10] Compliance to both individual items and overall is audited to provide feedback on sustainability of the pathway and to identify areas of improvement.[13] High compliance has repeatedly been associated with decreased postoperative morbidity, length of stay (LOS), and, ultimately, costs.[14–17] Active participation of both patients and nursing staff is mandatory to achieve high compliance and the expected clinical benefit related to the pathway. Keys to success include sustained staff education before and after implementation of new ERAS programs, a dedicated ERAS coordinator, regular meetings, and external audit by expert centers as well as strong patient involvement.[18]

So far, only few studies have assessed the impact of nurse staffing on patient outcomes.[19–21] The latter association has been evaluated in some countries, including the United States, to set mandatory nurse patient ratios, but the expected benefits in terms of patient-related outcomes have not been realized.[19,22] Moreover, the economic impact of an adequate nurse-to-patient ratio is not well elucidated. This is even more surprising because nurses represent the largest group of caregivers in hospitals.[23] Furthermore, because patients require different amounts of care, the present study focused on the more accurate relationship between demand and supply of nursing care rather than the nurse-to-patient ratio.

Today, the value-based health care concept, aiming to maximize outcomes per unit of money spent, extends to the world.[24,25] In this context, quantifying the nursing supply-demand relationship has the potential to further enhance health care value and accurately guide resource allocation. The validated method used in this study is called the *Projet de Recherche en Nursing* (PRN) system.[26] The amount of required daily nurse staffing is calculated on the estimation of the workload needed to treat an individual patient. It predicts the time necessary for individual patient care. Therefore, the total of individual time spent on a specific ward provides an estimation of the equivalent full-time nurses required to deliver the corresponding amount of care. First, this demand is estimated at the patient entry and periodically reassessed. In parallel, nurses document daily and prospectively the amount of actual care delivered, the supply. Documentation of the estimate (demand) and the actual amount of care delivered (supply) allow the calculation of a ratio that should ideally reach the value of 1. However, in a stressed health care system facing a chronic shortage of caregiving resources, reaching a ratio of 1 increasingly represents a challenge.

The aim of this study was 2-fold: first, to assess the relationship between the daily nursing workload and the incidence of postoperative complications, and second, to investigate the direct economic impact of variations of the nursing care supply-demand ratio.

METHODS

Study Design, Database, and Patients

This is a retrospective study based on a prospectively held institutional online data registry called the ERAS Interactive Audit System (EIAS [ERAS Society, Stockholm, Sweden]). Postoperative complications were graded according to the validated Clavien complication scale, which grades complications according to the therapeutic measures needed to treat the complication.[27] The recording of 30-day complications along with their respective grade was prospective, and all complications were presented and discussed at weekly department meetings. Severe complications were defined as grade ≥IIIa, a grade V corresponding to postoperative death of the patient. Finally, more than 1 complication per patient was possible.

All adult (>18 years) patients undergoing elective and emergent (defined as surgery during unplanned hospital stay) colorectal and pancreatic surgery at the Department of Visceral Surgery, Lausanne University Hospital CHUV, between January 2014 and December 2016 were included. The Department of Visceral Surgery as ERAS-certified referral center prospectively collects a wide array of patient- and procedure-related data in the institutional ERAS database.[17]

The present study was approved by the Institutional Ethics Committee (CER-VD No. 2017-00601). Although all consecutive patients were included in the clinical ERAS program, only patients with a signed general consent form were eligible for research purposes.

Projet de Recherche en Nursing

The amount of required daily nursing staff was based on the estimation in advance of the workload needed to adequately treat a predefined number of patients on a particular ward. Since 1992, workload estimations throughout the hospital have been calculated using a validated program called the PRN.[26] The PRN method is widely used in many European countries, including Switzerland, France, Italy, Spain, and Luxembourg, and in North America especially Canada. It assigns points to each patient according to the type of care needed (basic care, technical care, or relational care), the category of care (hygiene, nutrition, or comfort), and the specific care (intravenous medication, wound compression, or rectal exam), resumed under the term of *factors*.[26,28] Adding the points for each factor and multiplying the sum by 5 minutes estimates the time needed to care for a specific patient over the next 24 hours. The sum of all *estimated* PRNs provides a prediction of the full-time equivalent nurses require to deliver the estimated amount of direct and indirect care over the next 24 hours; the estimated PRN is used to plan nurse staffing.

The *real* PRN is calculated using the effective nurse working time necessary for both direct and indirect nursing care each day. Practically, each nurse reported daily the amount of care provided to each patient under his or her responsibility. This nursing activity was prospectively collected in a database called the PRN system.

The ratio between the estimated and the real PRN was calculated to assess the accuracy of the predicted (demand) and the actually delivered (supply) workload.

The average real PRN to estimated PRN ratio was calculated for the study period from 2014 to 2016. The cohort was then dichotomized into 2 groups based on this mean PRN ratio: one with a PRN ratio (*real/estimated* PRN) equal or higher than the mean PRN value (PRN+) and a second with a PRN ratio below the mean (PRN−). In a first step, demographic and surgical specifics, and overall and specific postoperative 30-day complication rates were compared between these 2 groups. Complications have been previously defined,[29,30] and were graded according to their severity using the Clavien classification,[27] with severe complications defined as grade ≥IIIa. In a second step, multinominal logistic regression analysis was performed to identify independent risk factors for overall and severe complications and prolonged hospital LOS (defined as LOS > median LOS). For this analysis, PRN was integrated as a binary confounder (PRN <0.81 yes/no) along with clinically relevant demographic and surgical risk factors for postoperative adverse outcomes. By including PRN as a confounder, its independent impact as a potential risk factor could be assessed. Finally, a cost-revenue analysis of the groups was conducted.

Cost-Revenue Analysis

The anticipated work burden was quantified by means of the standardized and validated PRN point system.[23]

The cost-revenue analysis compared 2 groups of patients (PRN+ versus PRN−). Using the microcosting approach[31] to isolate nursing costs, the total and mean costs per patient were identified. Most countries around the world including Switzerland use a prospective payment system based on diagnosis-related groups (SwissDRG), and each DRG has its cost weight, calculated annually on the basis of updated hospital cost data per case. Because the considered payment system is a prospective one, the revenue corresponds to the fee actually received by the hospital for a patient in a specific SwissDRG. The gross margin represents the difference between total revenue and total costs, and the mean margin per patient is the average difference between costs and revenue per patient. The total revenue and the mean revenue per patient, as well as the gross margin and the mean margin per patient of each group were calculated and compared.

Costs were obtained in Swiss francs (CHF) and then converted to U.S. dollars (USD). The exchange rate used was USD 1 = 0.95 CHF, the official rate on August 16, 2022.

Statistics

Continuous variables were summarized as median (interquartile range) or mean ± SD and categorical variables as frequencies and percentages. The differences between groups were compared using χ^2 test for categorical variables and Mann-Whitney or independent-sample *t* test as appropriate for continuous variables. Multinominal regression analysis was performed including clinically relevant confounders to compute odds ratios (ORs) and 95%

confidence intervals (95% CIs) for the specific outcomes of interest (any and severe complication, prolonged LOS). Resampling via bootstrap *t* test was performed for cost analysis.

All tests were 2-sided, and an α level less than 0.05 was considered statistically significant. The analysis was conducted using the Statistical Package for Social Sciences (SPSS, version 25; SPSS, Inc, Armonk, New York).

RESULTS

Patient Characteristics

The final cohort included 838 patients. The mean (real/estimated) PRN ratio was 0.81 ± 0.13; 128 patients (15%) were above and 710 patients (85%) below this threshold. Demographic and surgical specifics of both groups are summarized in Table 1.

Postoperative Complications

Overall, 450 complications occurred in 423 of 838 patients, among which 54% (243 of 450) were severe complications in 232 patients. Surgical complications, infectious complications, and respiratory complications are detailed in Table 2. Overall, Clavien grade V complications (death) concerned 14 patients (1.7%).

All complication profiles but respiratory complications showed no difference between PRN+ and PRN− patients. Respiratory complications were more frequent in PRN− patients (Table 3). The results of multivariable analysis focusing on overall complications, severe complications, and prolonged LOS are presented in Figure 1, revealing no significant impact of PRN ratio for all outcomes ($P > 0.2$). Independent risk factors for any complication were emergency indication (OR, 1.73; 95% CI, 1.19–2.51; $P = 0.004$), American Society of Anesthesiologists (ASA) score ≥3 (OR, 1.87; 95% CI, 1.34–2.61; $P < 0.001$), and open approach (OR, 2.55; 95% CI, 1.91–3.39; $P < 0.001$); for severe complications, they were ASA score ≥3 (OR, 2.39; 95% CI, 1.61–3.54; $P < 0.001$) and open approach (OR, 2.55; 95% CI, 1.91–3.39; $P < 0.001$); and for prolonged LOS, they were emergency indication (OR, 1.96; 95% CI, 1.35–2.86; $P < 0.001$), ASA score ≥3 (OR, 2.63; 95% CI, 1.89–3.68; $P < 0.001$), and open approach (OR, 3; 95% CI, 2.22–4.05; $P < 0.001$).

Results of the Cost-Revenue Analysis

The mean costs per patient, the mean revenue per patient, and the mean margin per patient of each group are presented in Figure 2. Mean costs totaled USD 36,778 ± 35,692 for all patients. Cost comparison revealed total costs of USD 34,042 ± 27,848 for the group with a PRN+ ratio and USD 37,271 ± 36,926 for the group with a PRN− ratio ($P = 0.254$). The portion of the nursing costs per patient was 19.3% ± 0.1% in the group with a PRN+ and 19.1% ± 0.1% for the group with a PRN− ratio ($P > 0.2$).

The invoiced PRN+ group had a mean margin per patient of USD 676 (95% CI, −2213 to 3550), and the invoiced PRN− group had a margin per patient of USD 1426 (95% CI, 3–2903; $P = 0.633$).

DISCUSSION

Statement of Principal Findings

This study assessed the impact of nurse-delivered patient care on the incidence of postoperative complications in patients undergoing open and laparoscopic colorectal and pancreatic surgery in a high-volume institution within an established ERAS program. A cost-revenue analysis further elucidated the economic impact of variations of nursing care supply-demand ratio. The mean PRN

TABLE 1. Demographics

Item	Total (n = 838)	PRN ≥0.81 (n = 128)	PRN <0.81 (n = 710)	*P*
Age, mean ± SD, y	51.8 ± 20	51.8 ± 19.4	51.8 ± 20.1	0.985
≥70 y, n (%)	207 (24.7)	30 (23.4)	177 (24.9)	0.824
Sex (female), n (%)	390 (46.5)	66 (51.6)	324 (45.6)	0.248
BMI, mean ± SD, kg/m^2	24 ± 6	23.5 ± 6.4	24.1 ± 5.9	0.346
<18 kg/m^2, n (%)	104 (12.4)	19 (14.8)	85 (12)	0.382
ASA score (%)				
1	48 (5.7)	7 (5.5)	41 (5.8)	1.000
2	545 (65.1)	91 (71.1)	454 (63.9)	0.131
≥3	245 (29.2)	30 (23.4)	215 (30.3)	0.139
Type of surgery, n (%)				
Colectomy	382 (45.6)	52 (40.6)	330 (46.5)	0.248
Rectal resection	152 (18.1)	19 (14.8)	133 (18.7)	0.321
Stoma procedure	188 (22.4)	33 (25.8)	155 (21.8)	0.357
Pancreatic procedure	95 (11.3)	22 (17.2)	73 (10.3)	**0.033**
Other	21 (2.5)	2 (1.6)	19 (2.7)	0.757
Malignancy, n (%)	479 (57.2)	68 (53.1)	411 (57.9)	0.333
MIS, n (%)	421 (50.2)	56 (43.8)	365 (51.4)	0.124
Conversion	50 (11.9)	5 (8.9)	45 (12.3)	0.464
Emergency. n (%)	177 (21.1)	30 (23.4)	147 (20.7)	0.482

Baseline demographic and surgical parameters of patients with PRN ratios ≥0.81 (n = 128) and <0.81 (n = 710). Age and BMI are presented as mean ± SD. All others are frequencies with percentages.

Bold *P* values indicate statistical significance ($P < 0.05$).

BMI, body mass index; MIS, minimally invasive surgery; PRN, Projet de Recherche en Nursing (patient-to-nurse ratio).

TABLE 2. Detailed Complications

Complications	Total	Severe, n (%)
Surgical: anastomotic leak, urinary tract injury, mechanical bowel obstruction, postoperative paralytic ileus, deep wound dehiscence, intraoperative excessive hemorrhage, postoperative excessive hemorrhage, other surgical complication or injury, resection site hematoma	195	98 (50)
Infectious: wound, primary resection site, urinary tract, infected lymphocele, intraperitoneal or retroperitoneal abscess, sepsis, septic shock, infected graft or prosthesis, other infectious complications	168	93 (55)
Respiratory: lobar atelectasia, pneumonia, pleural fluid, respiratory failure, pneumothorax, other respiratory complications	87	52 (60)
Total	450	243 (54)

Severe corresponding to a Clavien grade ≥IIIa.

ratio of the present series was 0.81, which can be interpreted in 2 ways. Either the real workload was overestimated or the required nurse resources were not available. There was no difference between the group with a PRN ratio greater than (PRN+) and the group with a PRN ratio less than 0.81 (PRN−) regarding overall and most specific postoperative complications, suggesting this permissive target for efficient and secure patient care.

The preliminary cost-revenue analysis showed a potential positive impact of a permissive PRN− ratio. The greater positive margin for the group with a PRN− ratio may be driven by an increased revenue as well as reduced nursing costs. Although this preliminary cost analysis did not show statistically significant benefit, an indirect positive economic effect through outsourcing and redistribution of nursing workforce can reasonably be expected.

Strengths and Limitations

Patients need different amounts of care, limiting the precision of indicators such as the patient-to-nurse ratio. In the present study, we focused on the more accurate relationship between demand and supply of nursing care. Moreover, the aim of this study was 2-fold: first, to assess the relationship between the daily nursing workload and the incidence of postoperative complications, and second, to investigate the direct economic impact of variations of the nursing care supply-demand ratio.

The study has limitations related to the retrospective design and the lack of a predefined sample size. The series analyzed all-comers in the setting of evaluation of clinical practice without sample size calculation for a noninferiority design.

Moreover, the results are based on a prospective database and have to be interpreted considering the more than 10 years of ERAS experience of the local institution before extrapolating the findings to other institutions with less ERAS experience.

Importantly, the sample size of the PRN+ (PRN ratio ≥0.81) group was considerably smaller, which means that lower PRN was implicitly implemented over the study period as new standard of care. The groups were, however, similar (Table 1), except for pancreatic resections, which were more frequent in the PRN+ group. This may have contributed to increased complications in the PRN+ group.

Furthermore, the rather high event rate of all outcomes enabled a representative multivariable analysis with a limited number of confounders.

Patient and staff satisfaction is also an important metric to consider when it comes to value based health care, and this aspect needs further investigation to complete the overall equation.

Interpretation Within the Context of the Wider Literature

Nowadays, in chronically stressed health care systems, medical treatments have to be cost-effective.[32] ERAS programs allow for better coordination of care and patient preparation, ultimately leading to simplified and more efficient treatment. Previous series have shown the positive impact of ERAS on the nursing staff in

TABLE 3. Postoperative Complications and LOS

Complication	Total (n = 838), n (%)	PRN ≥0.81 (n = 128), n (%)	PRN <0.81 (n = 710), n (%)	*P*
Any (Clavien I–V)	423 (50.5)	59 (46.1)	364 (51.3)	0.292
Severe (Clavien IIIa–V)	145 (17.3)	21 (16.4)	124 (17.5)	0.899
Surgical	195 (23.3)	31 (24.2)	164 (23.1)	0.820
Infectious	168 (20)	22 (17.2)	146 (20.6)	0.404
Respiratory	87 (10.4)	6 (4.7)	81 (11.4)	**0.018**
Hospital readmission	50 (6)	8 (6.3)	42 (5.9)	0.840
Return to OR	94 (11.2)	14 (10.9)	80 (11.3)	1.000
LOS, d				
Median (IQR)	6 (4–12)	5 (4–13)	6 (4–12)	0.514
Prolonged >6 d	347 (41.4)	51 (39.8)	296 (41.7)	0.770

Postoperative complications within 30 days in patients with PRN ratios ≥0.81 (n = 128) and <0.81 (n = 710). Data are presented as frequencies with percentages. Length of stay is presented as median (IQR).

Bold *P* values indicate statistical significance ($P < 0.05$).

IQR, interquartile range; PRN, Projet de Recherche en Nursing (patient-to-nurse ratio).

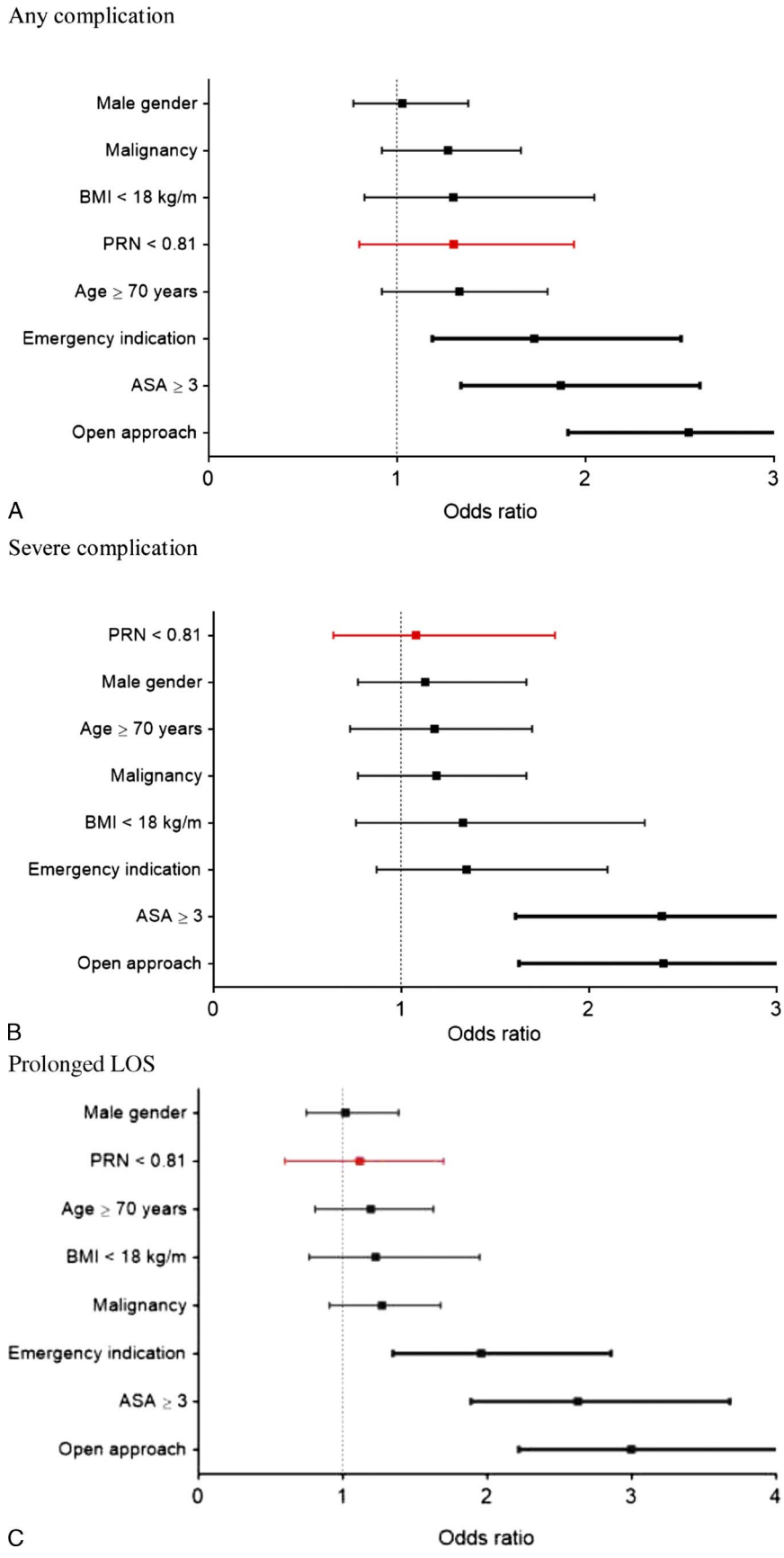

FIGURE 1. Multivariable analysis.

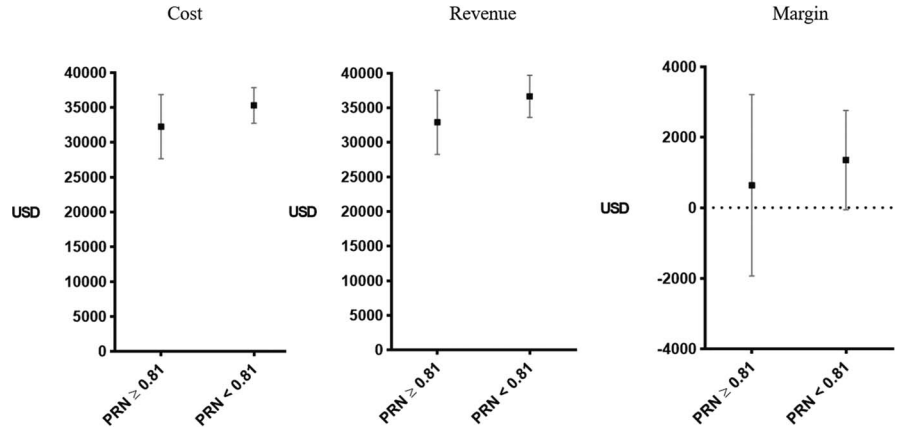

FIGURE 2. Cost analysis.

visceral[33] and gynecological surgical departments[34] resulting in significantly reduced workload after successful implementation.

The PRN ratio represents the ratio of available nursing working time to the estimated nursing working time by the PRN system. More specifically, this tool aims to anticipate the staff needed for the upcoming 24 hours, whereas the real/estimated PRN ratio indicates how these care needs were covered by the available nursing staff. A PRN ratio of <1 indicates that the estimated nursing care demand was higher than the available supply. In this case, patient care may potentially be compromised by understaffing as a result of a high patient-to-nurse ratio. It has been reported that an increased patient-to-nurse ratio may compromise patient safety.[35–37]

The present series revealed no significant differences regarding overall and most specific complications related to the PRN ratio. The well-established purpose of ERAS programs is to develop standardized perioperative care to improve postoperative recovery and outcomes. This potentially renders the PRN system obsolete for a correct assessment of the amount of care required per patient, or at the least, its application by caregivers needs to be reviewed. Today, a PRN ratio target <1 can be reasonable in this context. Through the focus on best possible compliance to ERAS protocols, patients are more engaged and proactive in their recovery process. Our group previously demonstrated the correlation between ERAS compliance and lower nursing workload.[33]

Interestingly, the present study revealed more respiratory complications in the PRN− group, emphasizing the important role of the nursing staff in preventing this frequent complication by promoting mobilization, physiotherapy, and breathing exercises.[29] This finding suggests that a PRN ratio less than 0.81 may increase complications in the situations where caregivers play an important supportive role.[38] If this situation is not avoidable because of understaffing, increased awareness and prevention of respiratory complications should become a priority. A dedicated prehabilitation program could be a valuable option.[39]

The present study did not demonstrate a significant cost-benefit associated with a decreased PRN ratio. However, this observation needs to be put into perspective of the DRG reimbursement policy, which is a dynamic prospective payment system. The fixed fee per case is set according to the consumption of resources of similar cases over the previous years and in different hospitals. Therefore, complex cases have a greater fixed fee than less complex cases. By extrapolating the complexity of the case based on the fixed fee (the revenue) the hospital received per case in the present study, it is reasonable to assume that more complex cases tend to have a ratio <0.81. Therefore, complex cases may have generated a high estimated PRN score but actually needed less care than anticipated. The population of challenging cases is probably the greatest beneficiary of the effects of an ERAS program, as are the finances of hospitals dealing with these patients. The PRN system was developed before the ERAS era, which makes it less accurate to predict the amount of care needed by patients treated according to ERAS guidelines, especially when dealing with highly complex patients and clinical situations. Therefore, the care needs for these patients are likely overestimated.

Implication for Policy, Practice, and Research

A permissive PRN ratio <1 implies that less nursing care should be planned for patients treated according to ERAS guidelines, with no negative impact on outcomes. This may result in higher financial margins for the hospital in the short term. Because of a mechanism of constant adjustment of the fee per case, which is based on the resources engaged and the costs generated by the past years, the positive margins will progressively reduce. On the long run, a reduction of the overall cost of care for the health care system through increased efficiency may contribute to a value-based competition.

However, staff reductions need to be carefully planned ahead considering several prerequisites before any hasty decision. In particular, stress or dissatisfaction of care teams could result in high turnover or absenteeism at work, loss of knowledge due to the lack of time for continuing education, and patient dissatisfaction.[10,40] This aspect must be integrated into the decision-making process and needs to be carefully monitored and studied in the future to find the most effective and efficient nursing care supply-demand ratio.

CONCLUSIONS

Planning nursing workforce through the PRN system may overestimate the care needs for patients, especially within established ERAS pathways. This seems to be even truer if the complexity of patients increases. A PRN ratio around 0.8 may be justified in this setting, pending the evolution of the PRN system or the adoption of a more accurate (currently not existing) nursing planning system. In an era where the health care cost burden steadily increases, this new target may contribute to better allocation of nursing resources while optimizing the expenses by adjusting the valuation of services.

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