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Research paper

The impact of the addition of nurse practitioners to surgical intensive care units: A retrospective cohort study

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ABSTRACT

Background: Demand for surgical critical care is increasing, but work-hour restrictions on residents have affected many hospitals. Recently, the use of nurse practitioners (NPs) as providers in the intensive care unit (ICU) has expanded rapidly, although the impacts on quality of care have not been evaluated.
Objectives: To compare the outcomes of critically ill surgical patients before and after the addition of NPs to the ICU team.
Methods: We conducted a retrospective cohort study in a Taiwanese surgical ICU. We compared the outcomes of patients admitted to ICU during the 2-year period before and after the addition of NPs to the ICU team. Patients admitted in the 1-year transition phase were excluded from comparisons. The primary endpoint was ICU mortality. Secondary endpoints included ICU length of stay and incidence of unplanned extubation.
Results: A total of 8747 patients were included in the study. For all eligible admissions, primary and secondary outcomes did not differ significantly between the two groups. For scheduled ICU admissions, ICU mortality was significantly lower after the addition of NPs (2.2% before vs. 1.1% after addition of NPs, $p = 0.014$). For unscheduled ICU admissions, ICU mortality did not differ significantly between the two groups. In the multivariate analysis, admission after the addition of NPs was associated with significantly reduced ICU mortality (odds ratio = 0.481; 95% confidence interval = 0.263–0.865; $p = 0.015$) among scheduled admissions.
Conclusion: Incorporating NPs in the ICU team was associated with improved outcomes in scheduled admissions to surgical ICU when compared with a traditional, resident-based team.

1. Introduction

More than 310 million people undergo surgery worldwide each year.[1] With the ageing of the global population, the number of patients with advanced age and multiple chronic diseases receiving surgical interventions is increasing. As a result, the demand for surgical critical care services is rising rapidly.[2] However, in Taiwan, the staffing in surgical intensive care units (ICUs) has decreased due to recently implemented work-hour restrictions on physicians-in-training. Many teaching hospitals that rely on residents as a significant part of the workforce are seeking feasible solutions to meet the increasing demand for surgical critical care services.

Non-physician healthcare providers, in most cases nurse practitioners (NPs), have been added into the mix of healthcare providers to address the issue. Over the past decade, NPs have been increasingly employed to provide direct patient care in the ICU due

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to physician shortages and the prioritisation of education over service delivery in residency education.[3] However, data evaluating the outcomes of patients cared for by NPs in the ICU are limited. Previous studies conducted in medical ICUs or trauma units show no difference in mortality between patients cared for by NP teams and resident-based teams.[4–6] However, it remains unclear how NPs affect the quality of care in a heterogeneous population of surgical intensive care patients.

To evaluate the quality, efficiency, and safety of the NP-staffed ICU care model, we examined the outcomes of patients admitted to surgical ICUs before and after the addition of NPs to supplement residents in delivering direct patient care.

2. Material and methods

2.1. Study design

We conducted a retrospective observational cohort study in the surgical ICUs of the National Cheng Kung University Hospital in Taiwan. The hospital began to incorporate NPs into the ICU care delivery team in early 2013, and the transformation was complete by the end of 2013. We gathered data from patients admitted to surgical ICUs from 2011 to 2015 and compared the outcomes of patients admitted during 2-year period before the transformation (2011 and 2012) and after the transformation (2014 and 2015). Patients admitted to ICU during the transition phase (2013) were excluded from comparison because the bed numbers were not consistent and the NPs were still in training. Because of the observational design of the study, which incorporated normal clinical management, the protocol was approved by the Institutional Review Board of National Cheng Kung University Hospital (Approval No.: B-ER-106-084) with a waiver of informed consent.

2.2. The addition of NPs to the ICU care delivery team

The surgical ICUs in the hospital take care of critically ill patients encompassing all surgical subspecialities, including cardiovascular surgery, thoracic surgery, general surgery, neurosurgery, plastic surgery, and traumatology. Patients admitted to the ICUs include scheduled and unscheduled admissions. If the ICU admission is requested before a scheduled surgical procedure by the surgeon or anaesthesiologist during preoperative assessment, the admission is classified as a scheduled admission. Other admissions are unscheduled admissions. These ICUs operate as semi-closed units, and clinical management is provided collaboratively by an intensivist and a surgeon.

Before 2013, there were a total of 34 beds in the ICUs, and daytime staffing (8:00 AM-5:00 PM) consisted of three rotating residents. These residents took care of all patients admitted to the ICUs, and each resident took care of 10–12 patients. Overnight (5:00 PM–8:00 AM), the ICUs were covered by one intensivist and one resident. To meet increasing critical care demands, the hospital began a project to expand the number of ICU beds at the beginning of 2013. Owing to the expansion of beds, shortage of surgical residents, and work-hour restrictions on residents, the hospital decided to develop NP roles to supplement residents in ICU daytime staffing from 2013.

In Taiwan, people who want to become NPs must complete a hospital-based government-accredited NP training program—which includes at least 6 months' clinical training—and then pass national certification exams. They are required to be registered nurses and have at least 3 years' clinical experience before undergoing a NP training program. People may work as NPs while they are still in training, but they are required to pass the national certification examinations within 2 years. The hospital began the NP training program in 2006. NPs have worked in general wards and in emergency department since 2006, but not in the ICU.

At the beginning of 2013, the hospital employed 8 persons as NPs in the surgical ICU. All have Bachelor's degree in Nursing, and none had a master's or a doctoral degree. Two had NP licences and had worked as NPs in other hospitals. One had worked in the medical ICU, and the other had worked in a neurosurgical ward. The other six did not have NP licences at that time but were qualified for NP training. Three of them had prior experience as registered nurses in the ICU. They began working as NPs to learn how to integrate into the ICU care delivery team and to participate in the NP training program, which was held by the hospital Department of Nursing, at the same time.

By the end of 2013, the transformation was complete; there were 44 beds in surgical ICUs and daytime staffing consisted of NPs and residents. One or two residents rotated to ICU each month, and each surgical resident took care of 8 patients. Residents were also responsible for conducting certain invasive procedures during regular working hours for all patients. NPs were responsible for care of the remaining patients, and each NP managed 4–6 patients. Attending physicians did rounds with residents and NPs twice a day during weekdays and were onsite most of each day. Activities and procedures performed by NPs included obtaining histories, conducting physical examinations, prescribing medications, initiating and adjusting intravenous fluids and enteral feedings, ordering and interpreting routine clinical laboratory tests and radiographs, initiating speciality consultation, inserting nasogastric feeding tubes and Foley catheters, removing invasive medical devices, managing wounds, and discussing care issues with patient's family members. All of the orders, prescriptions, and medical documentations have to be countersigned by the attending physicians. Night-time staffing includes either two residents plus one intensivist or one resident plus two intensivists. The number of ICU nurses increased proportionally with a constant patient-to-nurse ratio before and after the addition of NPs, as did other healthcare workers in the ICU.

Before the addition of NPs to the ICU team, daytime staff solely consisted of residents, and each resident took care of 10–12 patients. After transition, the daytime staff includes residents plus NPs. Each resident took care of a fixed number of 8 patients, and each NP took care of 4–6 patients.

2.3. Study population

All adult patients admitted to the surgical ICUs during the 5-year study period were eligible for inclusion in the study. For multiple ICU admissions during the same hospitalisation, all ICU admissions were included in the analysis. We divided patients into 3 groups according to admission date: before the addition of NPs (before NPs) (2011/1/1–2012/12/31), transition phase (2013/1/1–2013/12/31), and after the addition of NPs (after NPs) (2014/1/1–2015/12/31). Because the bed number was not consistent and the NPs were still learning in the transition phase, data from patients admitted to ICU during the transition phase were excluded from the outcome analysis.

2.4. Data collection

All of the study ICUs are equipped with electronic patient monitoring and recording systems (Philips IntelliVue Clinical Information Portfolio, Philips Medical Systems, Andover, MA 01810, USA). Data associated with clinical care, such as vital signs, cardiac rhythms, laboratory results, central venous pressure, intravenous fluid content and amount, urine output, and parameters of mechanical ventilation are all entered prospectively into this clinical

information system by nurses, doctors, NPs, clinical pharmacists, nutritionists, or respiratory therapists. Clinical data during the ICU stay were collected retrospectively from the clinical information system, and demographic data were retrieved from the hospital administrative database. Confidentiality was maintained using approved practices.

Severity of illness is routinely assessed within the first 24 h of admission and before discharge according to the Acute Physiology and Chronic Health Evaluation (APACHE) II score.[7] The nurses caring for the patients are required to calculate APACHE II scores and enter the results into the information system. Comorbidities were identified according to the diagnostic codes of the respective hospitalisation, and the corresponding International Classification of Diseases (9th edition) codes of comorbidities were presented in Supplementary Table S1.

2.5. Study outcomes

The primary endpoint was ICU mortality. Secondary endpoints included ICU length of stay and incidence of unplanned extubation. We compared the clinical outcomes of patients admitted before and after the addition of NPs. Because the risk profiles are distinct between scheduled and unscheduled admissions in the surgical ICUs,[8,9] we further divided these patients according to the urgency of admission in subsequent analyses.

2.6. Statistical analysis

We used descriptive statistics to describe the characteristics of the study population. Continuous variables were summarised as means and standard deviations; categorical variables as frequency and percentage. Values were compared between groups using Student *t* test for continuous variables and using χ^2 test with Yates' correction or Fisher's exact test, as appropriate, for categorical variables.

Logistic regression using general linear models and stepwise regression with backward elimination were used to investigate independent predictors of ICU mortality. Only variables with a *p*-value <0.05 on univariate analysis were entered into a stepwise multiple logistic regression. In multivariate logistic regression, variables are presented as odds ratios (ORs) and 95% confidence intervals (CIs). All tests were two sided, and *p*-values <0.05 were considered statistically significant. Data collection and management was performed using Excel (Microsoft; Redmond, Washington). Statistical analyses were performed using open source R statistical software.

3. Results

We screened all consecutive admissions to the SICU over a 5-year period from January 2011 to December 2015. There were 8747 eligible SICU admissions during the study period. Of these, 3006 patients were admitted before the addition of NPs, 1778 during transitional phase, and 3963 after the addition of NPs (Fig. 1). With the increase in bed number (from 34 to 44), the number of ICU admissions increased proportionally (from 3006 to 3963). Of all eligible admissions, the mean age was 62 years, and 5500 (62.9%) were male. The overall ICU mortality rate was 9.1% (Table S2).

We compared the characteristics of patients before and after the addition of NPs (Table 1). There was no significant difference with respect to age, gender, and initial APACHE II scores between the two groups. The proportion of scheduled admissions was significantly higher after the addition of NPs (45.5% before NPs vs. 48.6% after NPs, $p = 0.012$). Patients admitted after the addition of NPs had a higher proportion of malignancy and lower proportions of coronary artery disease, congestive heart failure, and chronic kidney disease.

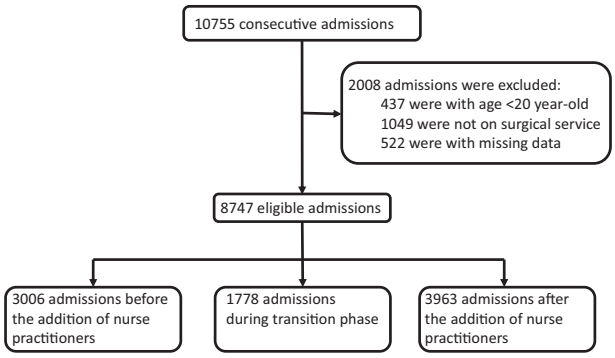

Fig. 1. Flow chart of the study.

For all eligible admissions, clinical outcomes were compared in Table 2. There was no significant difference in ICU mortality (9.4% before NPs vs. 8.7% after NPs, $p = 0.36$), ICU length of stay ($p = 0.07$), and incidence of unplanned extubation ($p = 0.25$). Because the difference in the proportions of scheduled admissions might confound the analysis of outcome, we divided patients into scheduled and unscheduled admissions in subsequent comparisons. Among unscheduled admissions, there was no difference in ICU mortality (15.7% before NPs vs. 15.9% after NPs, $p = 0.75$), but the ICU mortality of scheduled admissions after the addition of NPs was significantly lower than the ICU mortality of scheduled admissions before the addition of NPs (2.2% before NPs vs. 1.1% after NPs, $p = 0.014$).

In univariate analysis (Table 3), factors significantly associated with ICU mortality were APACHE II scores ($p < 0.001$), admission after the addition of NPs ($p = 0.014$), existence of cerebrovascular disease ($p = 0.044$), existence of chronic kidney disease ($p < 0.001$), and existence of severe liver disease ($p < 0.001$). Then we

Table 1
Comparison of patient characteristics before and after the addition of NPs.

Characteristics	Before NPs (n = 3006)	After NPs (n = 3963)	*p*-value
Admission time	2011/1/1–2012/12/31	2014/1/1–2015/12/31	
Age, year	61.9 ± 16.2	61.9 ± 16.2	0.94
Male	1884 (62.7%)	2484 (62.7%)	0.99
APACHE II score	16.4 ± 8.2	16.3 ± 7.5	0.65
Scheduled admission	1368 (45.5%)	1925 (48.6%)	0.012
Comorbidity			
Malignancy	778 (25.9%)	1144 (28.9%)	0.006
Metastatic tumour	378 (12.6%)	548 (13.8%)	0.13
Diabetes mellitus	777 (25.8%)	995 (25.1%)	0.49
Coronary artery disease	333 (11.1%)	373 (9.4%)	0.025
Congestive heart failure	297 (9.9%)	332 (8.4%)	0.031
Cerebrovascular disease	510 (17%)	634 (16%)	0.28
Chronic lung disease	156 (5.2%)	177 (4.5%)	0.17
Chronic kidney disease	349 (11.6%)	368 (9.3%)	0.002
Severe liver disease	55 (1.8%)	82 (2.1%)	0.49
AIDS	0 (0)	0 (0)	
Subspeciality			
Thoracic surgery	303 (10.1%)	339 (8.6%)	<0.001
General surgery	853 (28.4%)	1244 (31.4%)	
Neurosurgery	1019 (33.9%)	1329 (33.5%)	
Plastic surgery	64 (2.1%)	161 (4.1%)	
Traumatology	168 (5.6%)	230 (5.8%)	
Cardiovascular surgery	599 (19.9%)	660 (16.7%)	

APACHE = Acute Physiology and Chronic Health Evaluation; NP = nurse practitioner.

Table 2
Comparison of patient outcomes before and after the addition of NPs.

Outcomes	Before NPs (n = 3006)	After NPs (n = 3963)	*p*-value
ICU mortality	287 (9.4%)	352 (8.7%)	0.36
ICU stay, day	7.6 ± 13.1	7.1 ± 12.2	0.07
Unplanned extubations per 100 ventilator-days	0.104 (20/19202)	0.149 (36/24202)	0.25

ICU = intensive care unit; NP = nurse practitioner.

Table 3
Univariate analysis of ICU survivors and non-survivors among scheduled admissions.

Characteristics	Survivors (n = 3242)	Non-survivors (n = 51)	*p*-value
Age, year	61.1 ± 15.2	62.9 ± 13.9	0.37
Male	2012 (62.1%)	37 (72.5%)	0.15
APACHE II score	14.1 ± 6.3	23.2 ± 8.6	<0.001
After the addition of NP	1904 (58.7%)	21 (41.2%)	0.014
Comorbidity			
Malignancy	1328 (41%)	24 (47.1%)	0.39
Metastatic tumour	641 (19.8%)	9 (17.6%)	0.86
Diabetes mellitus	830 (25.6%)	18 (35.3%)	0.14
Coronary artery disease	394 (12.2%)	10 (19.6%)	0.13
Congestive heart failure	348 (10.7%)	8 (15.7%)	0.25
Cerebrovascular disease	288 (8.9%)	9 (17.6%)	0.044
Chronic lung disease	175 (5.4%)	2 (3.9%)	0.99
Chronic kidney disease	263 (8.1%)	15 (29.4%)	<0.001
Severe liver disease	53 (1.6%)	8 (15.7%)	<0.001

APACHE = Acute Physiology and Chronic Health Evaluation; ICU = intensive care unit; NP = nurse practitioner.

performed stepwise multiple logistic regression to identify independent risk factors of ICU mortality (Table 4). Independent risk factors included in the final model were admission after the addition of the NP phase (OR = 0.481, 95% CI = 0.263–0.865, $p = 0.015$), admission APACHE II score (OR = 1.186, 95% CI = 1.143–1.233, $p < 0.001$), and existence of severe liver dysfunction (OR = 16.507, 95% CI = 6.18–40.02, $p < 0.001$).

4. Discussion

In this large retrospective cohort study of surgical patients requiring intensive care, we found that incorporating NPs in the ICU care delivery team was associated with similar outcomes for unscheduled admissions and slightly improved outcomes for scheduled admissions when compared with a traditional, resident-based team. These findings are important given the ongoing physician shortage and increasing use of non-physician healthcare providers in surgical critical care.

Although NPs were first introduced to the healthcare workforce in the 1960s, the use of NPs as healthcare providers in the ICU has become increasingly common during the past decade. More hospitals are employing NPs under the supervision of attending physicians to augment or to partially replace residents in the ICU. Although previous studies show that the integration of NPs in critical care is safe and effective, most of these studies are performed in medical ICUs or trauma units.[6,10] Few were carried out in the cardiovascular surgical ICU.[11,12] Our study is the first to examine the safety and efficacy of the addition of NPs to the ICU care delivery team that takes care of critically ill patients encompassing all surgical subspecialities.

Table 4
Multivariate logistic regression analyses for ICU mortality among scheduled ICU admissions: results of stepwise selection procedures.

Independent variables	Odds ratio	95% confidence interval	*p*-value
Admission the addition of NP	0.481	0.263–0.865	0.015
APACHE II score	1.186	1.143–1.233	<0.001
Severe liver disease	16.507	6.18–40.02	<0.001

APACHE = Acute Physiology and Chronic Health Evaluation; ICU = intensive care unit; NP = nurse practitioner.

Our primary results showed that ICU mortality was comparable between all patients admitted to ICU before and after the addition of NPs in care delivery team. However, the proportion of scheduled admissions was significantly higher after the addition of NP because more ICU beds (from 34 beds to 44 beds) were available. Therefore, we separated our patients according to the urgency of admission in subsequent analysis.

Among unscheduled admissions, all of the patient characteristics and clinical outcomes were similar between two groups. These results suggest that incorporation of NPs into ICU care delivery team is safe. In scheduled admissions, ICU mortality rate was significantly lower after the addition of NPs. In multivariate analysis, admission after the addition of NP is still significantly associated with reduced mortality. These findings may suggest that adding NPs to supplement critical care provide improved quality of care for patients admitted to ICU after undergoing scheduled surgery. However, owing to the observational nature of this study, our results should be interpreted with caution. The decision to request ICU admission prior to undergoing scheduled surgery is subjective, and variation in the indications for ICU care may exist among surgeons and anaesthesiologists. It is possible that surgeons and anaesthesiologists requested ICU admission more frequently after the addition of NPs because of the increased number of available ICU beds. As a result, scheduled admissions after the addition of NPs were possibly associated with inherently lower risk; such a difference in risk profile between two groups cannot be completely reflected by adjusting age, admission APACHE II score, and comorbidities in our multivariate analysis. Overall, our findings support that incorporating NPs into daytime ICU staffing provides similar, if not improved, clinical outcomes in surgical ICU patients.

Although NPs are not able to replace residents entirely in clinical care because they are not permitted to perform certain invasive procedures, they may provide certain positive influences that residents are lacking. First, surgical residents have to rotate among wards and units in the hospital, and they have to learn different routines in different places. In contrast, NPs always work in the ICU and do not have to rotate, so they are more familiar with ICU care routines than residents are. Second, NPs spend less time in non-unit activities such as conferences, teaching, and reading and spend more time interacting with patients, families, nurses, and other medical staff.[4] As a result, the presence of NPs enhances collaboration and teamwork and has positive effects on residents and other members of the ICU care delivery team.[13] Previous surveys have demonstrated that the majority of residents believed that the addition of NPs reduced their individual workloads and enhanced their education.[14,15] In our study, the addition of NPs effectively reduced the case load of each resident from 10–12 patients to 8 patients. The addition of NPs also enhances interprofessional education, improves satisfaction of individual team members, and improves nursing retention.[6,16] However, because we did not routinely measure the attitudes and perceptions among team members in our ICU, we were not able to examine the effects of NPs on other healthcare workers in our study.

In our study, ICU mortality rates were 9.4% before NPs (2011–2012) and 8.7% after NPs (2014–2015). According to data

from Taiwan Clinical Performance Indicator (TCPI), the overall ICU mortality rates were 11.5% (14011/122287) in 2011–2012 and 10.8% (15798/146139) in 2014–2015 in the medical centres participating in TCPI. The ICU mortality rates in our study were lower than the data from TCPI. However, such a comparison may not be appropriate because our study was performed in surgical ICUs and TCPI's data included medical and surgical ICUs.

Although the role of NPs has been expanding rapidly in recent years, there is wide variation in the education, training, and scope of NPs across the globe.[17–19] A master's degree is required for NPs in many countries, including Australia, the Netherlands and the United States, and a post basic academic certificate is required in some countries. However, a master's degree is not mandated in Taiwan.[17] The scopes of practice of critical care NPs around the world share common roles, including patient assessment and examination, diagnostic management, coordination of patient care, initiating consultation, and discussing care with family members. However, the authority to prescribe medication and to perform invasive procedures differs between countries. While independent prescribing by a NP is a key element of scope of practice for NPs in the United States, NPs are not able to prescribe medication without physicians' supervision in Taiwan.[18] In addition, critical care NPs in the United States are involved in procedural medical roles, such as chest tube insertion, central line replacement, and endotracheal intubation.[19] In contrast, NPs in Taiwan are not permitted to perform invasive procedures other than nasogastric tube placement and urinary catheter placement.

Compared to previous studies, our study has several strengths. First, this is a large study with comprehensive patient inclusion. Rather than limiting the patients to a specific surgical subspeciality, we included all adult ICU patients receiving surgical services in the study, including general surgery, cardiovascular surgery, thoracic surgery, neurosurgery, plastic surgery, and traumatology. Second, although the study is retrospective in design, the data were retrieved from a prospectively maintained ongoing clinical database. Third, we excluded the data from a transition phase from outcome analyses, and this should make our data more comparable.

5. Limitations

There are several limitations in this study. First, this is a single-centre observational study, and all data were collected from one institution. Wide variability of NP privileges, roles, and responsibilities exists in various countries and institutions; thus, generalisation of our results is limited. Second, the causes of death were not specified and may be unrelated to ICU care. Third, the night-time staffing pattern also changed during the study period. Fourth, historical events occurred between data collection times, so there may have been factors influencing patient outcomes that may not have been identified in our study. Fifth, we did not collect data about the proportion of scheduled admissions cared for by residents or NPs. However, since we never assigned a specific resident or NP to take care of a specific patient, we believe that NPs and residents were equally involved in scheduled admissions.

6. Conclusions

Our study demonstrates that incorporation of NPs in surgical ICU team is associated with improved outcomes in scheduled admissions and similar outcomes in unscheduled admissions. Our study adds further evidence that NPs can render safe and effective care in the surgical ICU.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.aucc.2018.05.004.

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