## Title

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# Postoperative Admission of Adult Craniotomy Patients to the Neuroscience Ward Reduces Length of Stay and Cost

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**BACKGROUND:** The neurointensive care unit (NICU) has traditionally been the default recovery unit after elective craniotomies.

**OBJECTIVE:** To assess whether admitting adult patients without significant comorbidities to the neuroscience ward (NW) instead of NICU for recovery resulted in similar clinical outcome while reducing length of stay (LOS) and hospitalization cost.

**METHODS:** We retrospectively analyzed the clinical and cost data of adult patients undergoing supratentorial craniotomy at a university hospital within a 5-yr period who had a LOS less than 7 d. We compared those admitted to the NICU for 1 night of recovery versus those directly admitted to the NW.

**RESULTS:** The NICU and NW groups included 340 and 209 patients, respectively, and were comparable in terms of age, ethnicity, overall health, and expected LOS. NW admissions had shorter LOS (3.046 vs 3.586 d, $P < .001$), and independently predicted shorter LOS in multivariate analysis. While the NICU group had longer surgeries (6.8 vs 6.4 h), there was no statistically significant difference in the cost of surgery. The NW group was associated with reduced hospitalization cost by $3193 per admission on average ($P < .001$). Clinically, there were no statistically significant differences in the rate of return to Operating Room, Emergency Department readmission, or hospital readmission within 30 d.

**CONCLUSION:** Admitting adult craniotomy patients without significant comorbidities, who are expected to have short LOS, to NW was associated with reduced LOS and total cost of admission, without significant differences in postoperative clinical outcome.

**KEY WORDS:** Craniotomy postop, Neuroscience ward, Length of stay, Admission cost, Clinical outcome

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A major component of high-cost healthcare originates from patients who require hospitalization after a major surgery, and, in particular, from cost associated with utilization of the intensive care unit (ICU) in the postoperative period.[1,2] Recent data have linked ICU length of stay (LOS) to non-ICU[1] and overall hospital LOS.[2] The neurointensive care unit (NICU) is one of the costliest units[3] because of higher staff-to-patient ratio and additional neuromonitoring equipment necessary for patient care. Traditionally, patients undergoing craniotomies for tumor resection are admitted to the NICU after the surgery. However, there is no class I evidence demonstrating that patients perform better when they recover in the NICU as opposed to the neuroscience ward (NW). Conversely, the lack of evidence to the contrary limits a neurosurgeon's ability to justify admitting such patients to a non-ICU unit postoperatively.

Our department initiated a clinical pathway years ago that gave our neurosurgeons the flexibility to admit patients without significant medical comorbidities to the NW postoperatively after uncomplicated elective supratentorial craniotomies for brain tumor resection. Here, we present a retrospective cost-effectiveness analysis of our institutional experience over a 5-yr period

**ABBREVIATIONS: AIC,** Akaike Information Criterion; **APR-DRG,** All Patient Refined Diagnosis Related Group; **ED,** Emergency Department; **LOS,** length of stay; **MS-DRG,** Medicare Severity Diagnosis Related Group; **NICU,** neurointensive care unit; **NW,** neuroscience ward; **OR,** Operating Room; **PACU,** Post-Anesthesia Care Unit

Supplemental digital content is available for this article at www.neurosurgery-online.com.

to compare patients who recovered in the NICU vs the NW after elective craniotomy for tumor resection. This is the first time an analysis of a large series of patients, such as this one, has been reported.

## METHODS

### Patient Selection

We included all elective supratentorial craniotomy patients who were 18 yr or older with a LOS of 7 d or less who were admitted to our university hospital from March 2013 to April 2018. We excluded patients who underwent surgical procedures for shunts, Ommaya reservoirs, hemispherectomies, endoscopic transnasal approaches, external ventricular drains, stereotactic burr hole craniotomies, vascular and interventional radiology procedures, and any posterior fossa pathology. The decision to admit to the NW vs NICU was made by surgeon's practice preference.

### Data Collection

An institutional review board approval exempted us from patient consent because only de-identified information was collected for the purposes of quality improvement. We identified admissions based on a combination of International Classification of Diseases codes and procedure performed. The complete list of ICD9 codes is presented in **Supplemental Digital Content 1**, **Table 1**. The complete list of variables is listed in **Supplemental Digital Content 2**, **Table 2**. The variables analyzed are notable for patient demographics, financial information, admission data, predicting variables, LOS data, cost data, and any confounding variables. Medicare Severity Diagnosis Related Groups (MS-DRGs), MS-DRG weight, and All Patient Refined Diagnosis Related Group (APR-DRG) were collected for each admission to control for severity of illness and any comorbidities. The hospital financial decision team provided the calculated expected LOS based on the Vizient Clinical Data Base/Resource Manager model (Vizient Inc, Texas).

### Statistical Analysis

The RStudio (RStudio Inc, Version 1.1.453) software was used to perform statistical analyses. Qualitative and quantitative outcome variables between the 2 groups were compared with the Pearson's chi-squared test and the Wilcoxon-Mann-Whitney test, respectively. Multivariate linear and logistic regression models were constructed, starting with univariate regressions between the outcomes and every individual covariate to identify potential predictors for each outcome. Any variable with a *P*-value less than .10 was included in a bidirectional stepwise regression for each outcome. Through each stepwise model selection, the regression model with the lowest Akaike Information Criterion (AIC) was selected and used to identify and evaluate independent predictors of the outcomes of interest. The *P*-value for statistical significance was set at .05.

## RESULTS

### Admitting to the NW Is Associated With Reduced Overall LOS

Our analysis was limited to adult patients without significant comorbidities who were not expected to need prolonged recovery in the NICU. We retrospectively analyzed all patients 18 yr or older who underwent elective supratentorial craniotomy at our university's main medical center from March 2013 to March 2018, were hospitalized for 7 d or less, and stayed in the NICU for either 0 or 1 d, and assigned them to the NW and NICU groups, respectively. While most patients recover for at least 2 h in the Post-Anesthesia Care Unit (PACU) before transferring to either the NW or the NICU, some were directly admitted to the NICU from the Operating Room (OR) (Figure 1).

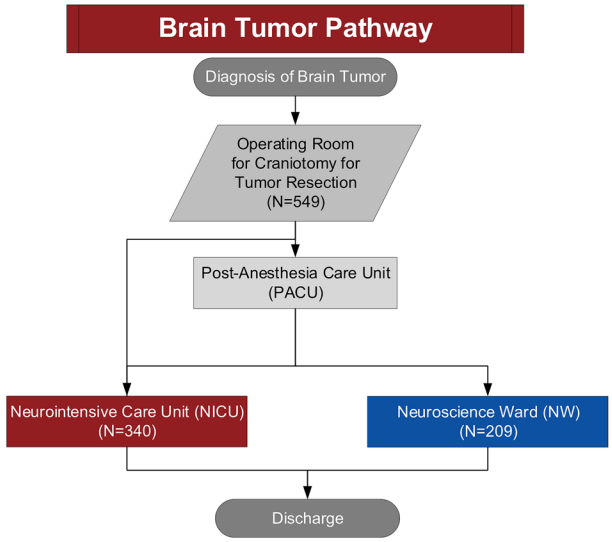


**FIGURE 1.** *Schematic diagram showing how the NICU and the NW pathways interact.*

A total of 209 patients were admitted to the NW, while 340 were admitted to the NICU. The patient characteristics that may be potential confounders were mostly comparable between the NW and NICU groups (Table 1), including age, MS-DRG, APR-DRG severity, ethnicity, insurance type, and cost of surgery. However, the NICU group had longer OR time usage, higher percentage of male patients, different discharge disposition, MS-DRG weight, and day of admission grouped by days of the week, when compared to the NW group.

The average LOS for the NW group was 3.046 d, compared to 3.586 d for the NICU group ($P < .001$) (Table 2). There was no difference in the expected LOS between the NW and NICU groups ($P = .184$) (Table 2, Table 3A).

In our multivariate analysis, postoperative stay in the NICU even for 1 night was independently associated with increased LOS ($P = .015$), but not with expected LOS (Table 3B). Additionally, MS-DRG weight, OR hours charged, day of admission, discharge disposition, and APR-DRG severity also independently predicted increased LOS (Table 3B).

Further subgroup analysis of those who stayed in the PACU past midnight on postoperative day 0 showed that it was

**TABLE 1. Patient Demographics and Univariate Analysis of Controlled Variables**

| | NW (n = 209) | NICU (n = 340) | |
|---|---|---|---|
| **Continuous variables** | **Average; 95% CI** | | **Mann-Whitney *P* value** |
| Age at discharge | 52.67; [50.76, 54.57] | 51.19; [49.63, 52.74] | .208 |
| MS DRG weight | 2.97; [2.85, 3.09] | 3.15; [3.05, 3.26] | .048* |
| OR hours charged | 6.43; [6.14, 6.72] | 6.83; [6.64, 7.01] | <.001*** |
| **Categorical variables** | **Frequency** | | **Pearson's chi-squared *P* value** |
| Sex | | | .038* |
| Female | 115 (55.0%) | 156 (45.9%) | |
| Male | 94 (45.0%) | 184 (54.1%) | |
| Ethnicity | | | .471 |
| Native American | 0 | 1 (0.3%) | |
| African American | 6 (2.9%) | 13 (3.8%) | |
| Asian | 26 (12.4%) | 34 (10.0%) | |
| Caucasian | 142 (67.9%) | 249 (73.2%) | |
| Pacific Islander | 0 | 1 (0.3%) | |
| Other | 35 (16.7%) | 42 (12.4%) | |
| Insurance | | | .461 |
| Commercial | 136 (65.1%) | 209 (61.5%) | |
| Group Health Plan | 1 (0.5%) | 4 (1.2%) | |
| International | 0 | 3 (0.9%) | |
| Medi-Cal | 5 (2.4%) | 6 (1.8%) | |
| Medicare | 42 (20.1%) | 79 (23.2%) | |
| Self-pay | 1 (0.5%) | 6 (1.8%) | |
| Tricare | 2 (1.0%) | 6 (1.8%) | |
| Managed care | 11 (5.3%) | 17 (5.0%) | |
| Worker's comp | 1 (0.5%) | 0 | |
| Other | 10 (4.8%) | 10 (2.9%) | |
| Day of admission | | | .019* |
| Monday | 44 (21.1%) | 72 (21.2%) | |
| Tuesday | 46 (22.0%) | 106 (31.2%) | |
| Wednesday | 22 (10.5%) | 16 (4.7%) | |
| Thursday | 61 (29.2%) | 103 (30.3%) | |
| Friday | 35 (16.7%) | 43 (12.6%) | |
| Saturday | 1 (0.5%) | 0 | |
| Discharge disposition | | | .005* |
| Acute care | 0 | 4 (1.2%) | |
| Deceased | 0 | 1 (0.3%) | |
| Home | 186 (89.0%) | 262 (77.1%) | |
| Inpatient rehab | 22 (10.5%) | 62 (18.2%) | |
| Psychiatric hospital | 0 | 0 | |
| Skilled nursing facility | 1 (0.5%) | 11 (3.2%) | |
| MS DRG | | | .133 |
| 23.00 | 4 (1.9%) | 7 (2.1%) | |
| 25.00 | 48 (23.0%) | 110 (32.4%) | |
| 26.00 | 49 (23.4%) | 73 (21.5%) | |
| 27.00 | 108 (51.7%) | 143 (42.1%) | |
| 41.00 | 0 | 3 (0.9%) | |
| 42.00 | 0 | 1 (0.3%) | |
| 54.00 | 0 | 2 (0.6%) | |
| 55.00 | 0 | 1 (0.3%) | |
| APR DRG severity | | | .125 |
| Minor | 77 (36.8%) | 100 (29.4%) | |
| Moderate | 109 (52.2%) | 184 (54.1%) | |
| Major | 23 (11.0%) | 54 (15.9%) | |
| Extreme | 0 | 2 (0.6%) | |

Symbols: *: $P < .05$; **: $P < .01$; ***: $P < .001$.

**TABLE 2. Comparison of Total Cost, Cost of Surgery, LOS, and Expected LOS Between NW and NICU**

| | NW | NICU | |
|---|---|---|---|
| | Average; 95%. CI | | Mann-Whitney *P* value |
| Total cost | $29 303.08; [27 613.00, 30 993.17] | $32 496.41; [31 411.09, 33 581.73] | <.001*** |
| Surgery cost | $6994.29; [6812.62, 7175.97] | $6833.52; [6698.91, 6968.13] | .327 |
| Length of stay | 3.046; [2.857, 3.235] | 3.586; [3.439, 3.733] | <.001*** |
| Expected length of stay | 3.936; [3.829, 4.043] | 3.889; [3.757, 4.022] | .184 |

Symbols: *: $P < .05$; **: $P < .01$; ***: $P < .001$.

**TABLE 3A. Univariate Linear Regression Analysis for LOS, Expected LOS, and Total Cost**

| | Length of stay *P* value | Expected length of stay *P* value | Total cost *P* value |
|---|---|---|---|
| Admitting unit | <.001*** | .628 | .001** |
| Age at discharge | .201 | .388 | .102 |
| MS DRG weight | <.001*** | <.001*** | <.001*** |
| OR hours charged | <.001*** | <.001*** | 0*** |
| Sex | .318 | .246 | .891 |
| Ethnicity | .921 | <.001*** | .070 |
| Insurance | .080* | .218 | .030* |
| Day of admission | <.001*** | .047* | .470 |
| Discharge disposition | 0*** | 0*** | 0*** |
| MS DRG | <0.001*** | <.001*** | 0*** |
| APR DRG severity | <.001*** | <0.001*** | <.001*** |

Symbols: *: $P < .05$; **: $P < .01$; ***: $P < .001$.

**TABLE 3B. Multivariate Linear Regression Analysis for LOS**

| Included variables | Coefficient | Wald *P* value |
|---|---|---|
| Admitting unit (NICU) | 0.235 | .015* |
| MS DRG weight (larger) | −0.147 | .028* |
| OR hours charged (more) | 0.172 | <.001*** |
| Day of admission | | <.001*** |
| Monday | – | – |
| Tuesday | 0.121 | .362 |
| Wednesday | 0.196 | .330 |
| Thursday | 0.681 | <.001*** |
| Friday | 0.284 | .071 |
| Saturday | −0.373 | .728 |
| Discharge disposition | | 0*** |
| Acute care | – | – |
| Deceased | 1.434 | .372 |
| Home | −0.151 | .779 |
| Inpatient rehab | 1.828 | .001** |
| Skilled nursing facility | 1.714 | .006** |
| APR DRG severity | | <.001*** |
| Minor | – | – |
| Moderate | 0.266 | .023 |
| Major | 0.885 | <.001*** |
| Extreme | 1.128 | .296 |

Symbols: *: $P < .05$; **: $P < .01$; ***: $P < .001$.

associated with longer LOS for the NW group, but not for the NICU group (Figure 2).

## Admitting to the NW Is Associated With Reduced Total Cost of Hospitalization

We compared the average total cost of hospitalization between the NW and NICU groups. The NICU group averaged $3193.33 more per admission ($32 496.41 vs $29 303.08; $P < .001$) (Table 2). There was no statistically significant difference in surgery cost between the 2 groups ($6833.52 (NICU) vs $6994.29 (NW); $P = .327$) (Table 2), suggesting that differences in costs incurred postoperatively.

To determine the specific cost components that contributed to the increased overall cost of the hospitalization, we compared 10 major components of cost between NW and NICU groups (Table 4A). The "room obs and overflow," "room routine," and "ICU room" categories correspond to the base cost of PACU, ward, and ICU equivalent levels of care, respectively. Notably, when examining the differences in component cost, the biggest difference was in the "ICU room" component, incurred by the NICU group. This difference in component cost is more than the increase the "room obs" and "room routine" components combined.

Multivariate analyses demonstrated that the admitting unit was not a significant independent predictor in the final model generated by stepwise regression. Variables independently associated with increased overall cost of hospitalization included OR hours charged, discharge disposition, MS-DRG, and APR-DRG severity (Table 4B). Interestingly, MS-DRG and APR-DRG severity were not significantly different between NW and NICU groups (Table 1).

In our post hoc analysis, however, the differences in cost between NW and NICU, when stratified by LOS, were the greatest when LOS was 1 d, and the effect diminishes with increasing LOS (**Supplemental Digital Content 3**, **Table 3**).

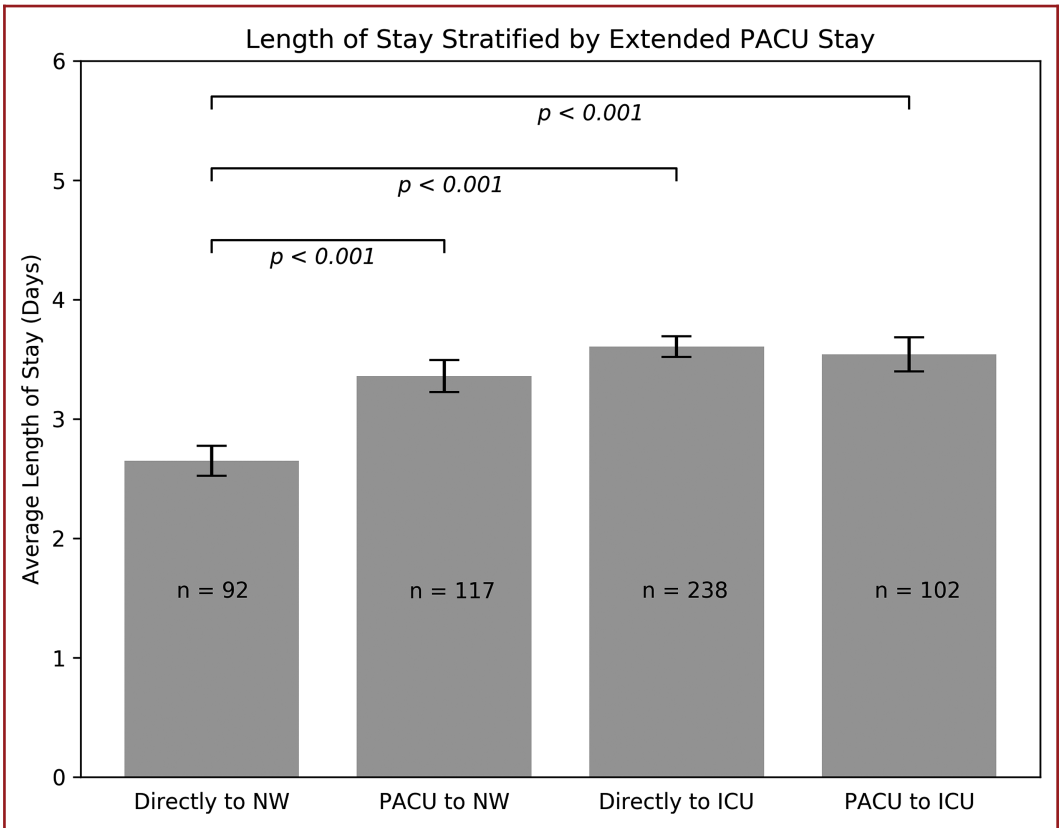


**FIGURE 2.** *LOS stratified by extended PACU stay. "PACU to NW" and "PACU to NICU" groups stayed in the PACU past midnight on postoperative day 0. Patients who were transferred from the OR directly to the NICU were in the "directly to NICU" group. Patients who were admitted to the NW from PACU within a few hours of surgery and did not stay past midnight were in the "directly to NW" group.*

In multivariate analyses, NW admission was a significant independent predictor for total cost when LOS was less than 2, 3, 4, and 5 d (**Supplemental Digital Content 4-5**, **Tables 4-5**), independent of MS-DRG weight. This suggests that for LOS <6 d, NW admission becomes a strong determinant of total cost irrespective of intrinsic patient factors.

Further post hoc analyses demonstrated that boarding in PACU past midnight on postoperative day 0 was associated with increased overall cost for both the NW and NICU groups (Figure 3).

### NW and NICU Admissions Have Similar Clinical Outcomes

We evaluated whether admission to the NICU yielded better clinical outcome compared to the NW and found no statistically significant differences in rates of return to OR, return to Emergency Department (ED), or readmission within 30 d (Table 5).

Univariate logistical regression analyses revealed that sex was a predictor of return to OR within 30 d, while MS-DRG weight, sex, and discharge disposition were predictors of readmission within 30 d (Table 6A). In multivariate analyses, male patients were found to be significantly more likely to return to the OR and be readmitted, while discharge disposition independently predicted whether a patient would be readmitted within 30 d (Table 6B). PACU boarding on postoperative day 0 was not associated with differential clinical outcomes for either cohort (**Supplemental Digital Content 6**, **Table 6**).

## DISCUSSION

The literature on the cost-effectiveness of neuroICU stay postoperatively for elective neurosurgical patients is scarce, in contrast to the existing literature on the benefits of NICU for brain and spinal cord injury patients.[4-9] Limited single institutional data from medical centers outside the United States have reported good outcomes with same day discharges for elective brain tumor craniotomy patients.[10] Despite the perceived clinical and economic benefits, however, outpatient craniotomies thus far have not gained widespread adoption.[11]

**TABLE 4A. Comparison of Cost Components Between NW and NICU**

| | NW | NICU | | |
|---|---|---|---|---|
| | Average; 95% CI | | Difference (NICU – NW) | Mann-Whitney *P* value |
| Blood bank | $166.95; [139.20, 194.70] | $201.35; [169.69, 233.01] | $34.40 | .013* |
| ICU room | $133.44; [51.89, 215.00] | $2209.12; [2057.15, 2361.09] | $2075.68 | 0*** |
| Implant supplies | $1806.61; [1477.36, 2135.85] | $1896.93; [1705.52, 2088.35] | $90.32 | .459 |
| Labs and pathology | $1913.94; [1719.25, 2108.62] | $2335.35; [2186.63, 2484.07] | $421.41 | <.001*** |
| Pharmacy | $2412.87; [1484.79, 3340.95] | $2223.42; [1766.95, 2679.89] | –$189.45 | <.001*** |
| Radiological imaging | $299.28; [276.29, 322.27] | $357.32; [330.44, 384.20] | $58.04 | <.001*** |
| Radiological processing | $201.10; [69.97, 332.22] | $279.55; [163.47, 395.63] | $78.45 | .346 |
| Room obs. and overflow | $1020.05; [897.55, 1142.56] | $538.22; [439.53, 636.91] | –$481.83 | <.001*** |
| Room rehab | $153.33; [120.47, 186.19] | $227.15; [198.25, 256.05] | $73.82 | <.001*** |
| Room routine | $2706.91; [2465.81, 2948.02] | $2310.14; [2090.27, 2530.02] | –$396.77 | <.001*** |

Symbols: *: $P < .05$; **: $P < .01$; ***: $P < .001$.
Room routine: cost of room and board in an NW equivalent room.
ICU room: cost of room and board in an ICU equivalent room.

**TABLE 4B. Multivariate Linear Regression Analysis for Total Costs**

| Included variables | Coefficient | Wald *P* value |
|---|---|---|
| Admitting unit (NICU) | 1047.30 | .126 |
| OR hours charged (more) | 2402.60 | 0*** |
| Discharge disposition | | <.001*** |
| Acute care | – | – |
| Deceased | 18 309.90 | .108 |
| Home | 1606.20 | .675 |
| Inpatient rehab | 8931.20 | .022* |
| Skilled nursing facility | 9253.50 | .035* |
| MS DRG | | 0*** |
| 23.00 | – | – |
| 25.00 | −34 027.30 | 0*** |
| 26.00 | −33 325.60 | 0*** |
| 27.00 | −32 824.50 | 0*** |
| 41.00 | −24 122.60 | <.001*** |
| 42.00 | −30 490.10 | <.001*** |
| 54.00 | −37 952.30 | <.001*** |
| 55.00 | −35 011.50 | <.001*** |
| APR DRG severity | | <.001*** |
| Minor | – | – |
| Moderate | 2618.60 | .004** |
| Major | 6824.70 | <.001*** |
| Extreme | 1880.50 | .806 |

Symbols: *: $P < .05$; **: $P < .01$; ***: $P < .001$.

## Key Results

We present here a large retrospective analysis of a single academic institution's experience with elective supratentorial craniotomies for adult brain tumor patients without significant comorbidities with a LOS of less than 7 d. NICU and NW patients were well matched with respect to age, ethnicity, MS-DRG, APR-DRG, and expected LOS, with the exception of MS-DRG weight, suggesting that most of the differences in outcome could be attributed to the relevant predicting variables we tested. Among those with LOS less than 5 d, even MS-DRG weight was well matched.

Our data suggest that even a single night stay in the NICU was associated with increased overall hospitalization cost and LOS, but with no difference in clinical outcome (return to ED, return to OR, and readmission within 30 d). The biggest contributor to this difference was the NICU's base cost. Our data imply that adult patients without significant comorbidities and with expected short LOS who undergo elective craniotomy for supratentorial lesions may be safely admitted to a NW unit without significant additional risks to the patient, while shortening their LOS and reducing hospitalization cost. Early recognition of this patient group and establishment of alternative pathways to ICU admission might decrease ICU utilization and the cost of hospitalization. NICU admission's independent effect on increased LOS could be explained by a variety of factors, including delayed mobilization, additional systemic barriers in multidisciplinary discharge planning, the lack of NW beds forcing a discharge directly from the NICU, and increased risk of ICU delirium.[12]

Our data also suggest that factors other than NICU admission can also contribute to longer LOS, given that the following variables were also independent predictors of LOS in our multivariate analysis: MS-DRG weight, OR hours charged, day of admission, discharge disposition, and APR-DRG severity. The longer surgery time (OR hours) and greater presence of comorbidities (APR-DRG severity) can explain a longer postoperative recovery time prior to discharge. Also, because discharging to a facility such as a skilled nursing facility or acute rehabilitation requires additional coordination and is dependent on the accepting facility's bed availability, it is not surprising that discharge disposition was a significant independent predictor of LOS.

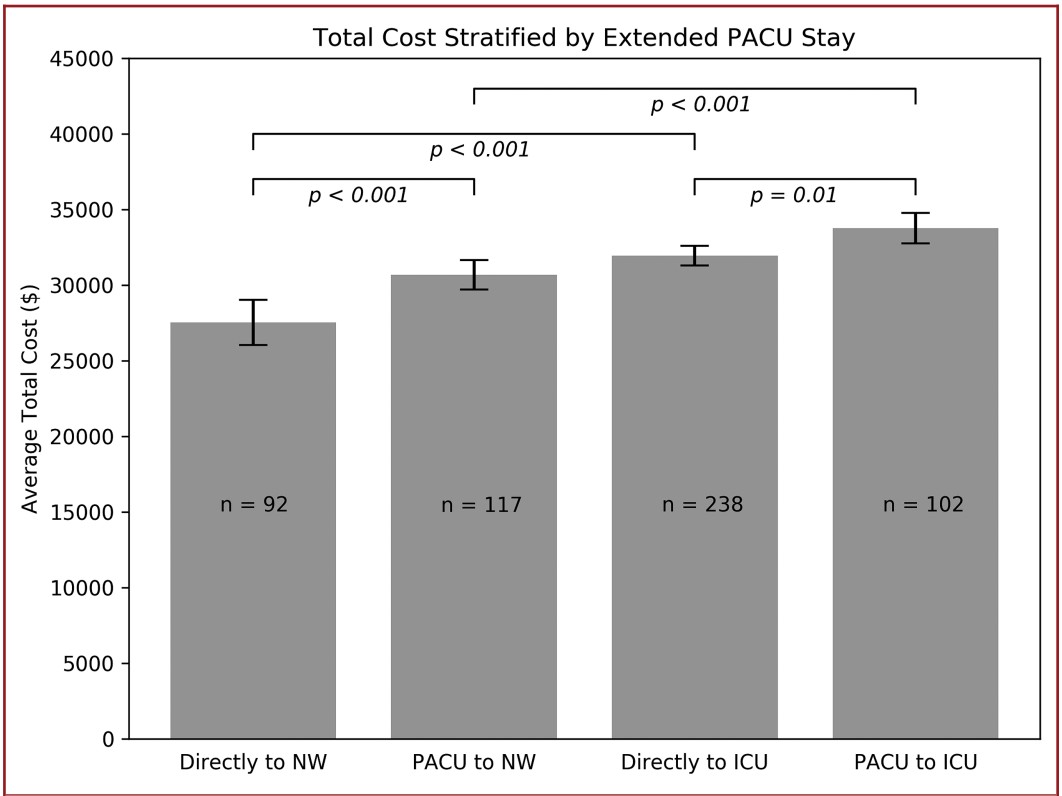


**FIGURE 3.** *Total cost stratified by extended PACU stay. "PACU to NW" and "PACU to NICU" groups stayed in the PACU past midnight on postoperative day 0. Patients who were transferred from the OR directly to the NICU were in the "directly to NICU" group. Patients who were admitted to the NW from PACU within a few hours of surgery and did not stay past midnight were in the "directly to NW" group.*

Interestingly, NICU admission was not an independent predictor of higher cost in the multivariate model, unlike MS-DRG, APR-DRG severity, and discharge disposition. This suggests that the cost difference between the NW and the NICU groups could be better explained by differences in the presence of other comorbidities and where the patient was discharged than where they were admitted postoperatively. APR-DRG severity in particular as a potential confounder of NICU admission's effects on total cost implies that perhaps some neurosurgeons admitted patients who might benefit more from being in the ICU given their medical comorbidities, and the result of that was overall higher cost of hospitalization.

However, our subgroup analysis stratified by overall LOS found that the cost difference was greatest when LOS was short, and the effect diminishes as LOS lengthens. Because all patients in the NICU group only stayed in the NICU for 1 night, the diminishing effect with increasing LOS further highlights the need to identify patients who are otherwise healthy and expected to have shorter LOS, whose NW admission can potentially yield the greatest cost savings without affecting clinical outcome. This was supported by our finding that for the subgroup of patients with LOS less than 5 nights, NW admission independently predicted lower total cost on multivariate analysis (**Supplemental Digital Content 4**, **Table 4**). Moreover, among those patients there were no significant differences in MS-DRG weight that would explain differences in cost due to the presence of higher level of comorbidities (**Supplemental Digital Content 5**, **Table 5**).

The subgroup analysis showing that extended PACU-stay past midnight increased LOS NW but not NICU admission can be due to the lack of a multidisciplinary team facilitating discharge in the PACU. The increased cost from extended PACU stay can be due to its higher staffing ratio, the anesthesia team, and higher resource utilization.

## Limitations

The limitations of our study include the retrospective nature of analysis, the lack of randomization to either the NW vs NICU group, the lack of multi-institutional data to reduce institutional bias, and the lack of more detailed data assessing the comorbidities of our patients which might affect their LOS. We also restricted our cohort of NICU patients to those who stayed in the NICU for 1 night. While this helped to ensure that most likely our NICU patient cohort had uneventful NICU recovery, it excluded those

**TABLE 5. Comparison of Clinical Outcomes Between NW and NICU**

| | NW | NICU | |
|---|---|---|---|
| | Frequency | | Pearson's chi-squared *P*-value |
| Return to OR | | | .867 |
| Yes | 8 (3.8%) | 14 (4.1%) | |
| No | 201 (96.2%) | 326 (95.9%) | |
| Return to ED | | | .757 |
| Yes | 21 (10.0%) | 37 (10.9%) | |
| No | 188 (90.0%) | 303 (89.1%) | |
| Readmission | | | .398 |
| Yes | 22 (10.5%) | 44 (12.9%) | |
| No | 187 (89.5%) | 296 (87.1%) | |

Symbols: *: $P < .05$; **: $P < .01$; ***: $P < .001$.

**TABLE 6A. Univariate Logistic Regression Analysis for Return to OR, Return to ED, and Readmission Within 30 Days**

| | Return to OR *P* value | Return to ED *P* value | Readmission *P* value |
|---|---|---|---|
| Admitting unit | .866 | .757 | .399 |
| Age at discharge | .592 | .534 | .498 |
| MS DRG weight | .908 | .514 | .009** |
| OR hours charged | .970 | .879 | .409 |
| Sex | .041* | .651 | .006** |
| Ethnicity | .998 | .380 | .998 |
| Insurance | .067 | .560 | .800 |
| Day of admission | .870 | .950 | .380 |
| Discharge disposition | .390 | .850 | <.001*** |
| MS DRG | .580 | .920 | .062 |
| APR DRG severity | .950 | .730 | .880 |

Symbols: *: $P < .05$; **: $P < .01$; ***: $P < .001$.

**TABLE 6B. Multivariate Logistic Regression Analysis for Return to OR and Readmission Within 30 Days**

| Included variables | Odds ratio | Wald *P* value |
|---|---|---|
| Return to OR | | |
| Sex (male) | 2.697 | .041* |
| Readmission | | |
| Sex (male) | 2.190 | .008** |
| Discharge disposition | | |
| Acute care | – | – |
| Deceased | 0 | .988 |
| Home | 0.299 | .305 |
| Inpatient rehab | 2.607 | .418 |
| Skilled nursing facility | 1.424 | .793 |

Symbols: *: $P < .05$; **: $P < .01$; ***: $P < .001$.

who stayed longer in the NICU but also had uneventful recoveries. Consequently, we may have artificially reduced the degree of differences that can be seen between NW and NICU group analyses both in terms of LOS and from a cost perspective. It would not be surprising to see a trend toward continued increase in LOS and hospitalization cost by including those who stayed in the NICU more than 1 night, on a per nightly basis.

### Interpretation and Generalizability

Our analysis demonstrated that even a 1-night stay in the NICU was sufficient to see an increase in costs. A potential limitation of our study is its generalizability given our practice setting of an academic center. In our university hospital, the NW is staffed with nurses who have undergone rigorous training under a preceptor and a 6-mo probationary period prior to independent patient care. Additionally, the nurse to patient ratio is either 1:3 or 1:4 allowing for neurological assessments every 2 h. This in conjunction with telemetry monitoring allows for the NW to serve as a neurological surgery stepdown unit in a way that may not be replicable at other centers. However, given the appropriate institutional setting, our study supports the creation of postoperative pathways that allow for select patients without significant medical comorbidities for admission to a neurosurgical ward.

## CONCLUSION

Admitting adult elective craniotomy patients without significant medical comorbidities who are expected to have a short LOS to the NW is independently associated with reduced LOS compared to admitting to the NICU for 1 night prior to the NW. The severity of comorbidities and discharge disposition are independent predictors of total cost. In patients with LOS < 5 d, direct postoperative NW admission may even be an independent predictor of reduced hospitalization costs, without significant differences in clinical outcomes.

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**Supplemental Digital Content 1. Table 1:** List of ICD codes.
**Supplemental Digital Content 2. Table 2:** List of variables.
**Supplemental Digital Content 3. Table 3:** Mean total cost between NW and NICU stratified by total LOS.
**Supplemental Digital Content 4. Table 4:** NW admission was an independent predictor of total cost in shorter LOS subgroups.
**Supplemental Digital Content 5. Table 5:** Mean MS-DRG weight between NW and NICU in shorter LOS subgroups.
**Supplemental Digital Content 6. Table 6:** Comparison of clinical outcomes stratified by extended PACU stay. "PACU to NW" and "PACU to NICU" groups stayed in the PACU past midnight on postoperative day 0. Patients who were transferred from the OR directly to the NICU were in the "directly to NICU" group. Patients who were admitted to the NW from PACU within a few hours of surgery and did not stay past midnight were in the "directly to NW" group. Symbols: *: $P < .05$; **: $P < .01$; ***: $P < .001$.