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The LACE+ index fails to predict 30–90 day readmission for supratentorial craniotomy patients: A retrospective series of 238 surgical procedures

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ABSTRACT

Objective: The LACE + index (Length of stay, Acuity of admission, Charlson Comorbidity Index (CCI) score, and Emergency department visits in the past 6 months) is a tool utilized to predict 30–90 day readmission and other secondary outcomes. We sought to examine the effectiveness of this predictive tool in patients undergoing brain tumor surgery.

Patients and methods: Admissions and readmissions for patients undergoing craniotomy for supratentorial neoplasm at a single, multi-hospital, academic medical center, were analyzed. Key data was prospectively collected with the Neurosurgery Quality Improvement Initiative (NQII)-EpiLog tool. This included all supratentorial craniotomy cases for which the patient was alive at 90 days after surgery (n = 238). Simple logistic regression analyses were used to assess the ability of the LACE + index and subsequent single variables to accurately predict the outcome measures of 30–90 day readmission, 30–90 day emergency department (ED) visit, and 30–90 day reoperation. Analysis of the model's or variable's discrimination was determined by the receiver operating characteristic curve as represented by the C-statistic.

Results: The sample included admissions for craniotomy for supratentorial neoplasm (n = 238) from 227 patients, of which 50.00% were female (n = 119). The average LACE + index score was 53.48 ± 16.69 (Range 9–83). The LACE + index did not accurately predict 30–90 day readmissions (P = 0.127), 30–90 day ED visits (P = 0.308), nor reoperations (P = 0.644). ROC confirmed that the LACE + index was little better than random chance at predicting these events in this population (C-statistic = 0.51 − 0.58). However, a single unit increase in LACE + leads to a 0.97 times reduction in the odds of being discharged home with fair predictive accuracy (P < 0.001, CI = 0.96 − 0.98, C-statistic = 0.69).

Conclusion: The results of this study show that the LACE + index is ill-equipped to predict 30–90 day readmissions in the brain tumor population and further analysis of significant covariates or other prediction tools should be undertaken.

1. Introduction

Healthcare quality and outcome measures are continuing to drive private and government reimbursement for medical services. Total expenditures in 2004 for the readmission of Medicare and Medicaid patients reached $17.4 billion dollars and 34% of Medicare patients were readmitted within 90 days [1]. The Center for Medicare & Medicaid Services (CMS) now oversees the financial penalty structure for readmissions related to pneumonia, myocardial infarction, and heart failure in order to reduce readmissions rates [2]. The neurosurgical population undergoing supratentorial craniotomy for tumor is not directly affected by these CMS penalties, unless patients are readmitted for the three diagnoses listed above. Yet the readmission rate for these patients has been reported to be as high as 17% in 30-days and 25% by 90-days

Abbreviations: CCI, Charlson comorbidity Index; LOS, Length of stay; LACE, Length of stay, Acuity of admission, Charlson comorbidity Index (CCI) score, and emergency department visits in the past 6 months; RAPT, Risk assessment prediction tool

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[3,4]. The emphasis on readmission rates has become a marker of a hospital's quality of care and necessitates improvements in the continuity of care and prevention of readmissions for both patients and hospitals alike [5,6]. For neurosurgeons, providing a technically superb resection is no longer the sole indicator of quality care.

The ability to concentrate resources on reducing readmissions depends on the ability identify which patients are at the highest risk for readmission. The LACE index (Length of stay, Acuity of admission, Charlson Comorbidity Index (CCI) score, and Emergency department visits in the past 6 months) is a validated prediction tool that integrates patient data to assist in stratifying patients' risk of readmission [7]. Van Walraven et al. modified the tool to create the LACE + index which incorporates more variables into the model such as age and gender [8]. There have been investigations using these prediction models in a number of patient populations with varying success [9–13]. Therefore, we used the LACE + index in a retrospective analysis of supratentorial brain tumor cases to assess the ability of the LACE + index to predict 30–90 day readmission and other secondary outcomes.

2. Materials and methods

2.1. Sample selection

In this Institutional Review Board approved study, patients undergoing surgical intervention across a large academic medical center were enrolled retrospectively from June 1, 2017 to June 01, 2018. Key data were prospectively collected with the Neurosurgery Quality Improvement Initiative (NQII)-EpiLog tool and included all supratentorial craniotomy cases for brain tumor for which the patient was alive at 90 days after surgery (n = 238). The EpiLog tool is a non-proprietary clinical research and quality improvement architecture that was built and overlaid onto the electronic health record system, which enables prospective data collection.

2.2. Data collection

The NQII EpiLog tool prospectively captured patient age, gender, LACE + index score measured from -2 to 90, the Risk Assessment Prediction Tool (RAPT), a 6 question preoperative questionnaire resulting in a score from 0 to 12 where low scores predict non-home discharge disposition [14], discharge disposition, and mean operative time (MOT) as a proxy for surgical complexity. The LACE + components and their correspondent point values, which were used for calculating an index score, are provided in Fig. 1. Other comorbidities were recorded such as body mass index (BMI), tobacco use, and American Society of Anesthesiologists (ASA) score that rates perfect health as a 1 and moribund as a 5. Lastly, occurrence of 30–90 day readmission, 30–90 day emergency department (ED) visit, and 30–90 day reoperation were also recorded (Tables 1–3).

2.3. Statistical analysis

The study sample was not always evenly distributed across each predictor variable used, therefore Wilcoxon Rank Sum Tests and Fisher's exact tests applied where appropriate. Both non-linear logistic regressions and generalized linear regressions were used to assess the ability of the LACE + index and subsequent single variables to accurately predict the outcome measure of 30–90 day readmission, 30–90 day reoperation, and 30–90 day ED visit. Goodness of fit was defined as $P > 0.05$ as assessed with the deviance statistic or Hosmer-Lemeshow test for categorical and continuous variables, respectively. All models met criteria for acceptable goodness of fit. Data are presented as odds ratios compared to the alternative outcome for binary variables or in reference to single unit variation in a continuous scale. A significant result was defined as $P < 0.05$. Analysis of the model's or variable's discrimination was determined by the receiver operating characteristic (ROC) curve as represented by the C-statistic, with corresponding 95% confidence intervals to assess reliability of fit. Evaluation of a model's predictive accuracy is as follows; a C-statistic ≤ 0.5 is equivalent to chance, a C-statistic between 0.7 and 0.8 defines a good fit, and a C-statistic greater than 0.8 indicates an excellent fit [15].

3. Results

3.1. Patient characteristics

The sample included admissions for craniotomy for supratentorial neoplasm (n = 238), of which 50.00% were female (n = 119). The mean age of the population was 62.29 ± 13.09 years old. Average LOS was 136.42 ± 70.89 h and average LACE + index score was 53.48 ± 16.69 (Range 9–83).

The 30–90 day readmission rate was 13.03% (n = 31). Women accounted for 41.94% of all readmissions (n = 13) and the non-readmitted group was composed of 51.21% women (n = 106, P = 0.381). The average age of the readmitted population was older, but not significantly (61.62 ± 10.75 v. 55.53 ± 16.10 years, P = 0.053).

There was no observed difference in LOS between the readmitted and not readmitted cohorts (151.05 ± 98.32 v. 144.52 ± 107.76 h, P = 0.507) or in LACE + index scores (55.82 ± 15.03 v. 50.51 ± 20.50, P = 0.119).

3.2. Univariate analysis

The LACE + index did not accurately predict 30–90 day readmissions (OR = 1.01, CI = 1.00–2.03, P = 0.127), 30–90 day ED visits (OR = 1.01, CI = 0.99–1.03, P = 0.308), nor reoperations (OR = 1.01, CI = 0.98–1.04, P = 0.644). ROC confirmed that the LACE + index was little better than random chance at predicting these events in this population (C-statistic = 0.51 – 0.58). However, a one-unit increase in LACE + led to a 0.97 times reduction in the odds of being discharged home with fair predictive accuracy ($P < 0.001$, CI = 0.96 – 0.98, C-statistic = 0.69).

Component pieces of the LACE + index were analyzed as single variable predictors of 30–90 day readmission within this population. Men were no more likely than women to be readmitted and the model did not have prediction accuracy better than chance (OR = 0.73, CI = 0.37–1.47, P = 0.382, C-statistic = 0.54). A one-year increase in age led to a 1.06 fold reduction in 30–90 day readmission risk (P = 0.045, CI = 1.01–1.11, C-statistic = 0.60). For CCI scores less than or equal to 4, there was a 1.86 fold increase (CI = 1.16–3.00) in 30–90 day readmissions for a unit higher CCI score and a 0.46 times reduction in readmission (CI = 0.25 – 0.85) for CCI scores greater than 4 (P = 0.025, C-statistic = 0.65).

Additional covariates were used to assess their ability to predict 30–90 day readmission within this supratentorial brain tumor population. High ASA class did not independently predict readmission (OR = 0.09, 0.52, CI = 0.01–1.33, 0.05–5.51, P = 0.571). Likewise, tobacco use was not associated with any change in readmission risk (OR = 0.92, CI = 0.35–2.79, P = 0.993). A one-unit increase in BMI less than or equal to 25 kg/m^2 was associated with a 0.76 times decrease (CI = 0.65 – 0.89) in 30–90 day readmission risk and a 1.54 fold increase in readmission risk with BMI's greater than 25 kg/m^2 (CI = 1.25–1.89, $P < 0.001$, C-statistic = 0.71). The RAPT index showed a 0.83 times decreased risk (CI = 0.75 – 0.92, $P < 0.001$) when RAPT scores were less than or equal to 10, but an increase in RAPT over 10 had no significant effect (OR = 1.29, CI = 0.71–2.35) and the prediction accuracy was no better than chance (C-statistic = 0.62). A longer MOT did not affect 30–90 day readmission status (OR = 0.99, CI = 0.99–1.00, P = 0.353). Patients with public health insurance experienced a 2.01 times increased risk of 30–90 day readmissions compared to patients with private insurance that nearly approached significance (P = 0.050, CI = 1.00–4.04, C-statistic = 0.59).

Predictor	Points
Male sex	3
Urgent admission	15
Discharge institution	
Teaching hospital or small nonteaching hospital*	0
Large nonteaching hospital†	−1
Length of stay (days)	
< 1	0
1	2
2	3
3	4
4	5
5–6	6
7–10	7
> 10	9
No. of days on ALC status	
0	0
> 0	−1
No. of ED visits in previous 6 months	
0	0
1	3
> 1	6
No. of elective admissions in previous year	
0	0
> 0	6

	Previous urgent admissions = 0			Previous urgent admissions > 0		
Age (years)	Charlson 0	Charlson 1	Charlson > 1	Charlson 0	Charlson 1	Charlson > 1
< 32	0	10	30	25	33	48
32–40	2	12	31	26	34	48
41–46	5	15	34	27	35	49
47–52	7	16	34	28	35	48
53–58	9	17	35	29	35	48
59–64	12	20	38	30	36	49
65–69	15	23	40	32	38	50
70–75	18	26	42	33	39	50
76–80	20	27	42	35	40	50
> 80	27	33	47	38	42	51

Fig. 1. LACE + Index.

Table 1
Patient Demographics.

	Index Admission	Not Readmitted	Readmitted	P Value
Total, n (%)	238 (100.00)	207 (86.97)	31 (13.03)	
Sex, n (%)				0.381
Male	119 (50.00)	101 (48.79)	18 (58.06)	
Female	119 (50.00)	106 (51.21)	13 (41.94)	
Age (years), mean (SD)	62.29 (13.09)	55.53 (16.1)	61.62 (10.75)	0.053
LOS (hours), mean (SD)	136.42 (70.89)	144.52 (107.76)	151.05 (98.32)	0.507
LACE+, mean (SD)	53.48 (16.69)	50.51 (20.50)	55.82 (15.03)	0.119

Table 2
Post-surgical outcomes with increasing LACE + score.

	Odds Ratio	Confidence Interval	C-statistic	P Value
30–90 Day Readmission	1.01	1.00–1.03	0.58	0.127
30–90 Day ED Visit	1.01	0.99–1.03	0.56	0.308
30–90 Day Reoperation	1.01	0.98–1.04	0.51	0.644
Home Discharge	0.97	0.96–0.98	0.69	< 0.001

Table 3
Individualized LACE + components and alternative predictors of 30–90 day readmission.

	Odds Ratio	Confidence Interval	P Value	C-statistic	Confidence Interval
Male sex	0.73	0.37–1.47	0.382	0.54*	0.45–0.62
Age	1.06	1.01–1.11	0.045	0.60	0.51–0.68
CCI Score			0.025	0.65	0.56–0.74
≤4	1.86	1.16–3.00			
< 9	0.46	0.25–0.85			
RAPT			< 0.001	0.62*	0.46–0.78
≤10	0.83	0.75–0.92			
> 10	1.29*	0.71–2.35			
BMI			< 0.001	0.71	0.62–0.80
≤25	0.76	0.65–0.89			
> 25	1.54	1.25–1.89			
ASA Class			0.571	0.63	0.57–0.68
2	0.09	0.01–1.33			
3	0.52	0.05–5.51			
4	Reference				
Tobacco Use	0.92	0.35–2.79	0.993	0.50*	0.44–0.55
MOT	0.99	0.99–1.00	0.353	0.52*	0.42–0.63
Discharge Home	0.17	0.11–0.27	< 0.001	0.54*	0.46–0.63
Insurance Type			0.050	0.59	0.50–0.67
Public	2.01	1.00–4.04			
Private	Reference				

* Denotes a result that is not significantly different than chance.

4. Discussion

The results of this study show that the LACE + index is ill-equipped to be used for 30–90 day readmissions in the brain tumor population and further analysis of significant covariates or other prediction tools should be undertaken. The Hospital Readmission Reduction Program, which initiated the reimbursement reductions for Medicare patients, and the CMS's National Strategy for Quality Improvement in Health Care have placed a spotlight on the need to reduce readmission throughout hospitals [2,5]. An analysis of the readmissions for brain tumor patients in California estimated that each readmission costs the health system $20,296 and a reduction of 40% of these 30-day readmissions would net the state $12 million in savings [16].

The LACE indices have been used successfully in very large sample sizes with relatively heterogenous populations [7,8,12,17,18]. Yet other studies have found problems using the LACE index in congestive heart failure and chronic obstructive pulmonary disease populations as well as in older populations [9–11, 19]. The population in this study and the original validation population from van Walraven et al. do not differ much in age, but the brain tumor population likely carries a heavier disease burden which can be seen by the elevated mean LACE + index score of 53 compared to 30–39 [8]. LACE + index calculations incorporate age and CCI score in a combined variable in such a way that older and sicker populations quickly will be designated with very high LACE + scores. This discrepancy in the sample's disease burden goes to show that the LACE + index is not well suited for older and sicker populations, because it loses discriminative ability when the median score increases.

Our results demonstrate that the individual constituents of the LACE + index have varying ability to predict 30–90 day readmission. Increased age confers a statistically significant 6% increased risk of readmission, albeit with predictive accuracy only slightly greater than chance. CCI scores follow the pattern of the LACE index when scores are less than or equal to 4, but paradoxically any increase in CCI score above 4 leads to a 0.46 times reduction in readmission risk. This is a curious finding considering a one-unit increase in CCI score, in intracranial meningioma patients, correlates with an 12–18% increased risk of inpatient mortality and a 20–30% increased risk of complications [20,21]. The counterintuitive reduced risk of 90-day readmission at very high CCI scores is not a product of increased mortality risk, this is prevented by the study design. However, it is possible that varying pathology impacts readmission to a greater degree than the LACE + index. This study is not powered to analyze individual pathology types. The underlying cause of this paradoxical result will be pursued in future investigations.

Alternate variables such as BMI and ASA class, which have been associated with increased readmissions in a similar population [22,23], show mixed results. ASA class does not significantly predict readmission in our study population. Increasing BMI scores equal to or less than 25 kg/m^2 have a 0.76 times reduction in odds of readmission, while increasing BMI with scores greater than 25 kg/m^2 lead to a 1.54 times increased risk of readmission. This non-linear logistic regression has good predictive accuracy, indicating that only BMI over 25 kg/m^2 confer increased risk of readmission.

Further investigations into the effect of insurance type showed publicly insured patients were 2.01 times more likely to be readmitted, which substantiates results from other studies [4,24,25]. This result narrowly fell short of significance and is indicative of the underlying socioeconomic differences between these populations. Medicare and Medicaid patients are likely representative of the older, sicker, and less economically advantaged individuals that encounter the healthcare system. The difference in 30–90 day readmission rate could be attributed to the patients themselves due to the possibility of decreased access to care or increased comorbid conditions, resulting in increased hospital visits and readmissions. Or this could be a result of inferior care delivery to the publicly insured population, which Jencks et al. demonstrated by showing that Medicare beneficiaries are subject to variable care during inpatient admissions [26]. Furthermore, Sharma et al. showed that private insurance, young age (≤65 years old), male sex, and white race all independently associated with home discharge status [27]. The multitude of socioeconomic factors are not specifically addressed in this study, but future investigations should control for these variables and specifically study how these systemic factors impact patient outcomes.

The inefficiency of the LACE + index raises the question of whether the readmission rate is truly predictable or even reducible in these patients. One study found that 70.4% of readmissions in a cohort of glioblastoma patients were preventable, meaning unrelated to the progression or treatment of their cancer, and those readmitted patients had a shorter mean survival time than non-readmitted patients [28,29]. The motivations for reducing readmission rates are both in the interest of the healthcare system and the patient; there are clear incentives to reallocate resources to readmission reducing programs such as shorter intervals between follow-up [6] or in-home assistance [30], but these can only be resources well spent if they are focused on the sub-group of patients who are at the highest risk for readmission.

This study was limited by the retrospective nature and the patient sample chosen for the analyses. We intentionally limited the study to a patient group with elevated readmission rates, in a time frame infrequently studied 30–90 days post-op [4], but that resulted in a small sample size (n = 238) in comparison to other studies investigating the utility of the LACE indices. There is selection bias due to incomplete records that lead to cases being removed from the sample. Readmission to the index hospital system was required for the readmission to be recorded in the electronic health record. This means there is a potential under reporting of the true readmission rate and could create challenges for the LACE + index to accurately fit the sample. However, all patients in this study had follow-up of greater than 90 days within the neurosurgery department at which time it is noted if any evaluations occurred in the index center, or elsewhere. Future studies should define a larger sample of brain tumor patients and look to delineate a prediction tool that can be properly weighted for a sicker population than for what the LACE + index was originally designed.

5. Conclusion

Reduction of costly hospital readmissions is a target for health care quality improvement, and brain tumor patients are a population with historically high rates of readmission. Having the tools to predict readmissions would provide hospitals and surgical teams the ability to reallocate resources towards the patients who will likely need the most support in order to improve outcomes and decrease costs. Unfortunately, the LACE + index, as applied here, does not provide the necessary accuracy for 30–90 day readmissions in this setting and future work is needed to fill this gap in predicting patient readmissions.

Disclosures

The authors have no personal or institutional interest with regards to the authorship and/or publication of this manuscript.

Ethics committee approval

This study was approved by the IRB at the Hospital of the University of Pennsylvania. IRB number for this study is: 831,722. All ethical guidelines and rules were followed to protect patient privacy.

Contributorship statement

IFC and NRM involved in the design and conception of this manuscript. IFC and NRM performed the literature review and compiled the primary manuscript. IFC, PZS, BO and SG collected and analyzed data. IFC and PZS compiled the figures and tables. IFC, PZS, GG, DK, DMO, OC, BO, SG, SDM and NRM critically revised the manuscript. All authors approved the manuscript as it is written.

Declaration of conflicting interests

The Authors declare that there is no conflict of interest.

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