The LACE+ Index as a Predictor of 30-Day Patient Outcomes in a Urologic Surgery Population: A Coarsened Exact Match Study

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OBJECTIVE To examine the potential of LACE+ scores, in patients undergoing urologic surgery, to predict short-term undesirable outcomes.

METHODS Coarsened exact matching was used to assess the predictive value of the LACE+ index among all urologic surgery cases over a 2-year period (2016-2018) at 1 health system ($n = 9824$). Study subjects were matched on characteristics not assessed by LACE+, including duration of surgery and race, among others. For comparison of outcomes, matched populations were compared by LACE+ quartile with Q4 as the referent group: Q4 vs Q1, Q4 vs Q2, Q4 vs Q3.

RESULTS Seven hundred and twenty-two patients were matched for Q1-Q4; 1120 patients were matched for Q2-Q4; 2550 patients were matched for Q3-Q4. Escalating LACE+ score significantly predicted increased readmission (2.86% vs 4.91% for Q2 vs Q4; $P = .012$) and Emergency Room (ER) visits at 30 days postop (5.69% vs 11.37% for Q1 vs Q4, 4.11% vs 11.45% for Q2 vs Q4, 8.29% vs 13.32% for Q3 vs Q4; $P < .001$ for all). Increasing LACE score did not predict reoperation within 30 days or rate of death over follow-up within 30 postoperative days.

CONCLUSION The results of this study suggest that the LACE+ index is suitable as a prediction model for important patient outcomes in a urologic surgery population including unanticipated readmission and ER evaluation. UROLOGY 134: 109–115, 2019. © 2019 Elsevier Inc.

Readmissions to the hospital are a major source of patient dissatisfaction[1-3] and a predominant driving force of healthcare expenditures, accounting for more than $12 billion per year.[4,5] The Center for Medicare & Medicaid Services (CMS) now oversees the financial penalty structure for readmissions related to numerous medical conditions in an effort to control healthcare spending.[6] Effective management of patient transitions of care is therefore an increasingly important benchmark for healthcare systems. By proactively identifying high-risk patients, physicians may be able to appropriately engage support resources to decrease preventable hospital readmissions.

Urology is an area of focus due to an increasing volume of procedures with rising readmission rates, secondary to the incorporation of early discharge pathways.[1] Complications following urologic procedures are varied and readmission rates have been shown to be as high as 28.5% within the first 30 days following radical cystectomy.[1,7-14] Leading causes for unplanned readmission in this population include sepsis, urinary tract infection, surgical site infection, acute renal failure, catheter related infection or obstruction, and various gastrointestinal issues.[9,13,15] Prior work by Leow et al found that patient factors (age, American Society of Anesthesiology score, and smoking status) and complications during the index admission (wound, renal failure, thromboembolic) significantly impact the risk of 30 day readmissions following urologic surgery.[11] However, there is currently no validated tool capable of encompassing the aforementioned factors to predict a patient's risk for readmission at the time of discharge.

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The LACE index (length of stay, acuity of admission, Charlson Comorbidity Index score, and emergency department visits in the past 6 months) was developed to help provide a simple metric to predict 30 day readmissions among medical patients/hospital discharges.[16] Previous studies have applied the LACE index in various surgical and disease-specific medical populations, such as congestive heart failure and chronic obstructive pulmonary disease, with varied results.[17-24] The original creators of the LACE index subsequently modified the tool to create the LACE+ index, which incorporates additional variables into the model such as age, gender, and previous hospital admission.[25] Neither the LACE or LACE+ indices have been assessed for association with readmission patterns in a urologic surgical population.

The study herein utilizes coarsened exact matching to create a "virtual randomized controlled trial"[26] to assess the predictive capacity of LACE+ for urologic surgery patients. The objective of this study is to assess and compare outcomes for patients from each LACE+ quartile against exact matched patients in the highest scoring quartile. Doing so will determine if a higher risk group of urological surgery patients can be identified using the LACE+ score, thus providing a guide for caregivers studying mechanisms to improve care and mitigate risk. This study seeks to compare consecutive patients undergoing urologic surgery over 2 years, with otherwise matched surgical experiences but differing LACE+ scores in order to study the capacity of LACE+ to predict adverse outcomes like early readmission.

MATERIAL AND METHODS

Sample Selection

In this Institutional Review Board approved study, 9824 consecutive patients undergoing urologic surgical intervention at a multihospital 1659 bed university health system were enrolled retrospectively over 2 years (January 01, 2016 to January 01, 2018). A waiver of informed consent was granted by the Institutional Review Boardas this study was considered to be minimal risk to patients. Key data were acquired using the EpiLog tool — a nonproprietary data acquisition system created by the senior author on the present paper. It was built and layered on top of the existing electronic health record architecture to enhance charting, workflow, quality improvement, and cost reduction initiatives.

Data Collection

Relevant patient information including sex, admission type, length of stay, Charlson Comorbidity Index Score, ALC status, recent ER visits, surgical history, and history of hospital admissions was scored and incorporated into a composite LACE+ index value (−2 to 90) (Fig. 1a). After calculating LACE+ scores for all patients, quartiles (Q1-Q4) were determined (Supplementary Fig. 1).

Patient characteristics not used for LACE+ score calculation were also documented, and served as matching criteria (Fig 1b). These included operative time, surgical cost, household income, insurance type, race, body mass index, patient class, and wound class. Data were binned ("coarsened") to create discrete categories within each matching criterion.

Occurrence of readmission, emergency department visit, reoperation, and mortality within 30 days were recorded. Patient Current Procedural Terminology billing code categories were also documented to describe the composition of case types in the cohort, although this information was not used for matching or data analysis (Supplementary Table 1).

Matching

Coarsened exact matching was performed (Fig. 2a). Matches were sought between patients with different LACE+ score quartiles but otherwise identical characteristics (matching criteria). During this process, patients with the highest LACE+ scores (Q4) were matched to patients with lower LACE+ scores (Q3, Q2, Q1). Unmatched patients from each LACE+ quartile were removed from the data set and not included in further analysis (Fig. 2b). The result was a series of matched groups (Q4-Q1, Q4-Q2, and Q4-Q3). Groups in these pairs differed only with respect to LACE+ score and had otherwise identical patient composition.

Finally, outcomes for patients in each quartile (eg, Q4 and Q1) were analyzed and compared for all matched groups (eg, Q4-Q1).

Statistical Analysis

Binning of the matching criteria and removal of missing values was performed using SAS Version 9.4 (SAS Institute Inc., Cary, NC). Matching was completed using the MatchIt programming package[27] in R Statistics (R Core Team, Vienna, Austria, 2017), with subsequent analysis executed through SAS Version 9.4.

Subsequent to identifying matched groups, comparison was made via the following: Q4 vs Q1, Q4 vs Q2, and Q4 vs Q3. McNemar's test was used to assess the ability of the LACE+ index and subsequent single variables to accurately predict the outcome measures by comparing the means between groups created via coarsened exact matching. Univariate analysis was performed with significance set as a P value <.05.

RESULTS

Patient Characteristics

The prematch sample included all consecutive patients undergoing urologic surgery over 2 calendar years (n = 9824). Median BMI was 27.75. Median total cost of surgical supplies and implants was $182.54. Median household income for patients was $70,568.00. Median age for all patients was 64 ± 15 years. 75.3% of patients were male (Table 1).

Patient Outcomes

Q1-Q4 Comparison. For Q1 to Q4 comparison, 722 patients were matched (n = 1444, a 30.5% match rate). Among matched patients, escalating LACE+ score significantly predicted increased ER visits at 30 days (5.69% vs 11.37%; P <.001, OR 2.17; 95% CI 1.46-3.24). Increasing LACE+ score did not predict higher rates of 30-day readmission, reoperation, or higher rates of early death over follow-up within 30 postoperative days (P = .077, OR 1.71; 95% CI 0.94-3.10 for readmission; P = .096, OR 2.60; 95% CI 0.87-9.32 for reoperation; P = 1.000, OR 0.50; 95% CI 0.01-9.61 for death over follow-up, respectively) (Fig. 3, Supplementary Table 2).

Q2-Q4 Comparison. For Q2 to Q4 comparison, 1120 patients were matched (n = 2240, a 51.6% match rate). Among matched

a

Predictor	Points
Male sex	3
Urgent admission	15
Discharge institution	
Teaching hospital /	
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 past 6 months	
0	0
1	3
> 1	6
No. of elective admissions in past year	
0	0
> 0	6
Interaction terms	
Age	
Charlson score	0-51
Previous urgent admissions	

	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	29	38	39	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

b

1. **Median Operating Time**
   a. Below Median (Time < 29 minutes)
   b. Above Median (Time > 29 minutes)
2. **Median Total Cost of Surgical Supplies and Implants**
   a. Below Median (Cost < $182.54)
   b. Above Median (Cost > $182.54)
3. **Median Household Income**
   a. Below Median (MHI < $70,568)
   b. Above Median (MHI > $70,568)
4. **Insurance Provider**
   a. Private = Commercial, Managed Care, Blue Cross
   b. Government = Medicare, Medicaid, Self-Pay, Other
   c. Worker's Comp = Worker's Comp
5. **Race**
   a. White
   b. Non-White = African American, Asian, Hispanic/Latino, American Indian, East Indian, Pacific Islander, Other, Unknown
6. **BMI**
   a. Cachexia = BMI < 18.5
   b. Normal = BMI between 18.5 and 30
   c. Obese = BMI > 30
7. **Patient Class**
   a. Inpatient
   b. Outpatient
8. **Wound Class**
   a. Clean
   b. Clean Contaminated
   c. Dirty

Figure 1. LACE+ score components and matching criteria. (**a**) LACE+ score components. Score sheet that demonstrates the components of the LACE+ index and their numerical weights. (**b**) Coarsened exact matching criteria. Details the specific variables used for match patients during coarsened exact matching.

patients, escalating LACE+ score significantly predicted increased 30-day readmission (2.86% vs 4.91%; $P = .012$, OR 1.77; 95% CI 1.13-2.77) and ER visits at 30 days (4.11% vs 11.45%; $P < .001$, OR 3.00; 95% CI 2.11-4.27). Increasing LACE+ score did not predict higher rates of reoperation or higher rates of early death over follow-up within 30 postoperative days ($P = .170$, OR 1.62; 95% CI 0.81-3.23 for reoperation; $P = .625$, OR 0.33; 95% CI 0.04-3.21 for death over follow-up, respectively).

Q3-Q4 Comparison. For Q3 to Q4 comparison, 1292 patients were matched ($n = 2584$, a 50.8% match rate). Among matched patients, escalating LACE+ score significantly predicted increased ER visits at 30 days (8.29% vs 13.32%; $P < .001$, OR 1.70; 95% CI 1.32-2.20). Increasing LACE+ score did not predict higher rates of 30-day readmission, reoperation, or higher rates of early death over follow-up within 30 postoperative days ($P = .861$, OR 1.03; 95% CI 0.73-1.45 for readmission; $P = .456$, OR 1.25; 95% CI 0.69-2.25 for reoperation; $P = .625$, OR 3.00; 95% CI 0.31-28.84 for death over follow-up, respectively).

DISCUSSION

The objective of the present study was to determine if the LACE+ index—a previously developed tool validated in other specialties—could be employed to predict outcomes in a mixed-procedure urologic surgery population. Successful application of the LACE+ index in this context would suggest that it may serve as a powerful tool for population management at the departmental level.

After comparing all quartiles, data reveal that increased LACE+ score is significantly predictive of higher rates of ER visits within 30 days of discharge. Patients with Q4 LACE+ scores were 2.2 times more likely to visit the ER than patients with a Q1 LACE+ score. Q4 patients also

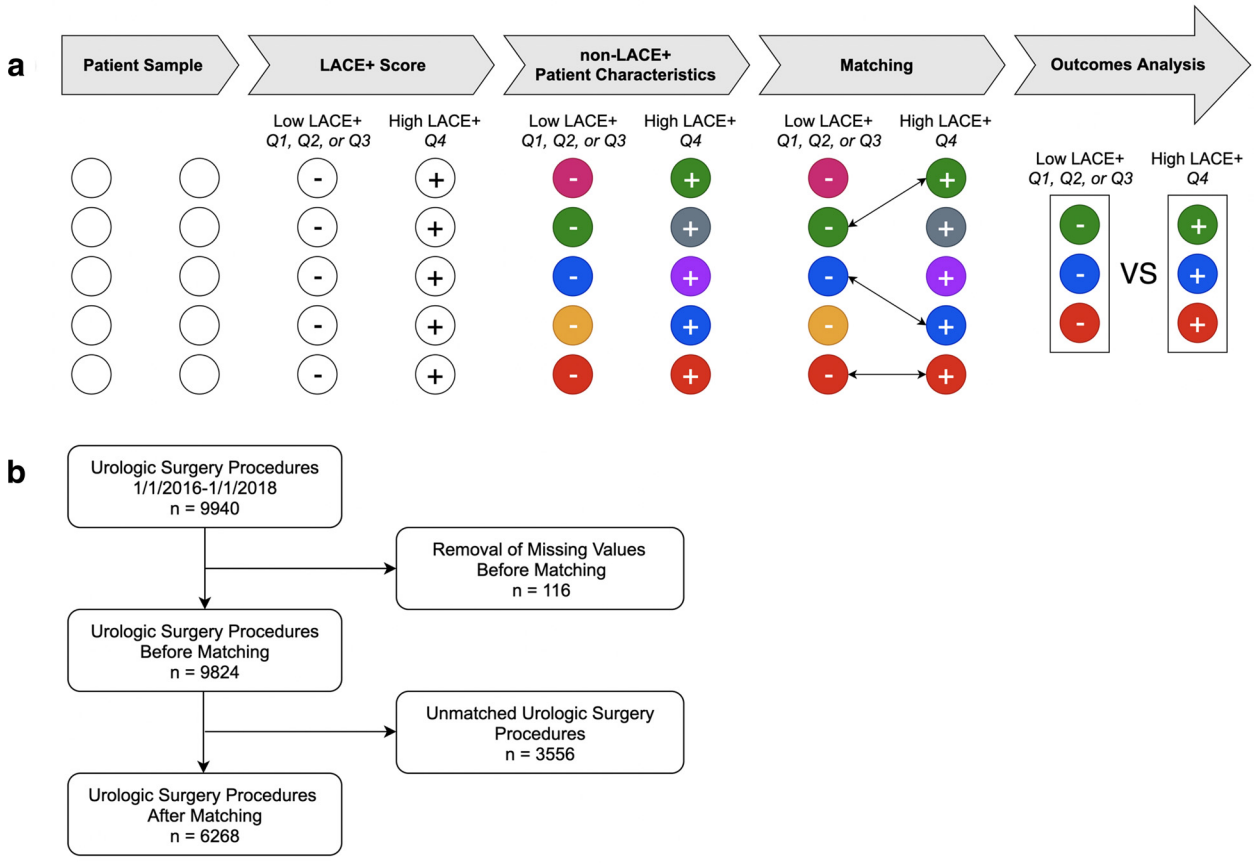

Figure 2. Matching and patient selection. (**a**) Coarsened exact matching process. Schematic overview of the process used for coarsened exact matching. (**b**) Flow chart of patient selection. Outlined are the number of patients included and excluded based on specific criteria. (Color version available online.)

had a 3.0-fold increased risk of ER visits than Q2 patients, and 1.7-fold increased risk compared to Q3 patients. Data also suggest that patients with higher LACE+ scores may experience higher rates of hospital readmission, although this finding should be subjected to further study. In the present study, Q4 patients were 1.8 times more likely to be readmitted more than patients with a Q2 LACE+ score. These results build upon prior work that reports upon the ability of the LACE+ index to predict outcomes within 30 days of discharge.[18,21,22,24]

The results of this study suggest that the LACE+ index may not be a suitable prediction model for all surgery outcomes. Increased LACE+ score was not found to significantly predict risk of reoperation or death after urologic surgery. It is important to note that these outcomes were relatively rare in the present cohort, with 99 reoperations (<2% of the matched sample) and 11 deaths (<<1% of the matched sample) occurring across all study groups during the 30-day period of interest. It is therefore possible that the present investigation did not have sufficient statistical power to assess LACE+ prediction of these outcomes. Reoperation and mortality should certainly be evaluated in future studies of the LACE+ index.

Although the present study did not definitively demonstrate LACE+ prediction of readmission, ER visits raise concerns similar to readmissions (cause, cost, and burden to patients) and return to the acute care setting through a visit to the ER is not captured within the CMS standard definition of readmission.[28,29] Readmissions have become a clear monetary priority for the CMS, insurers, and hospital administrators. For patients and their families, unplanned readmission can lead to emotional and financial stress, caused by unanticipated unpaid time off.

Multiple studies have noted that infection (surgical site and/or urinary tract) is the leading cause of 30-day readmission following urologic procedures.[14,15] James et al found that patients discharged to skilled nursing facilities had a higher rate of 30 day readmission comparted to patients discharged elsewhere.[30] Baack Kukreja et al suggest that prevention of readmissions following urologic procedures is achievable through improved discharge planning and transitions of care.[1] They suggest that follow-up care needs to focus on early identification of symptoms that may lead to readmission.[1] Several studies have found that these management strategies are particularly effective when applied to high-risk urologic surgery patients.[9,11-13] The implication of these results is evident: planning and providing adequate postoperative management of urologic surgery patients may have a significant impact on readmissions.

Table 1. Patient demographics and baseline characteristics. Overview of patient characteristics in each matched quartile group

Demographic/baseline Characteristic	Q1-Q4 Matched Patients *n* = 1444	Q2-Q4 Matched Patients *n* = 2240	Q3-Q4 Matched Patients *n* = 2584
Race, *n* (%)			
White	892 (61.77)	1648 (73.57)	1816 (70.28)
African American	408 (28.25)	450 (20.09)	598 (23.14)
Asian	37 (2.56)	50 (2.23)	52 (2.01)
Hispanic/Latino	62 (4.29)	31 (1.38)	54 (2.09)
American Indian	1 (0.07)	2 (0.09)	2 (0.08)
East Indian	4 (0.28)	1 (0.04)	7 (0.27)
Pacific Islander	0 (0.00)	1 (0.04)	1 (0.04)
Other	19 (1.32)	28 (1.25)	29 (1.12)
Unknown	21 (1.46)	29 (1.29)	25 (0.97)
Mortality during follow-up, *n* (%)	21 (1.45)	33 (1.47)	58 (2.24)
BMI, *n* (%)			
<18.5	10 (0.69)	12 (0.54)	28 (1.08)
18.5-29.9	876 (60.66)	1486 (66.34)	1784 (69.04)
≥30	558 (38.64)	742 (33.13)	772 (29.88)
Insurance type, *n* (%)			
Commercial	31 (2.15)	31 (1.38)	22 (0.85)
Medicare	403 (27.91)	1421 (63.44)	1788 (69.20)
Medicaid	219 (15.17)	99 (4.42)	188 (7.28)
Managed care	634 (43.91)	554 (24.73)	465 (18.00)
Self-pay	4 (0.28)	2 (0.09)	4 (0.15)
Blue cross	153 (10.60)	133 (5.94)	117 (4.53)
Admission type, *n* (%)			
Routine scheduled	1329 (92.04)	2095 (93.53)	2396 (92.72)
Emergency	104 (7.20)	136 (6.07)	169 (6.54)
Transfer	3 (0.21)	2 (0.09)	8 (0.31)
Routine unscheduled	8 (0.55)	7 (0.31)	10 (0.39)
Other	0 (0.00)	0 (0.00)	1 (0.04)
Charlson Comorbidity Index (CCI) Score, *n* (%)			
0	176 (12.19)	27 (1.21)	118 (4.57)
1	162 (11.22)	53 (2.37)	110 (4.26)
2	173 (11.98)	244 (10.89)	114 (4.41)
3	244 (16.90)	237 (10.58)	238 (9.21)
4	179 (12.40)	543 (24.24)	310 (12.00)
5	115 (7.96)	303 (13.53)	442 (17.11)
6	97 (6.72)	218 (9.73)	347 (13.43)
7	91 (6.30)	161 (7.19)	246 (9.52)
≥ 8	207 (14.35)	454 (20.25)	659 (25.52)
Number of other surgical intervention within 30 days prior to surgery, *n* (%)			
0	1360 (94.18)	2099 (93.71)	2366 (91.56)
≥ 1	84 (5.82)	141 (6.29)	218 (8.44)
Number of other lifetime surgical intervention prior to surgery, *n* (%)			
0	706 (48.89)	965 (43.08)	906 (35.06)
≥ 1	738 (51.11)	1275 (56.92)	1678 (64.94)
Incision site contaminant status, *n* (%)			
Clean	222 (15.37)	250 (11.16)	250 (9.67)
Clean contaminated	1206 (83.52)	1936 (86.43)	2282 (88.31)
Dirty	4 (0.28)	46 (2.05)	44 (1.70)
Surgery type, *n* (%)			
Elective	1370 (94.88)	2153 (96.12)	2466 (95.43)
Emergent	73 (5.06)	87 (3.88)	118 (4.57)
Urgent	1 (0.07)	0 (0.00)	0 (0.00)
Patient class, *n* (%)			
Inpatient	404 (27.98)	392 (17.50)	432 (16.72)
Outpatient	1040 (72.02)	1848 (82.50)	2152 (83.28)

The results of the present work suggest that the LACE+ index may be a valuable tool for identifying high-risk patients who might benefit most from optimized postdischarge management. Successful interventions might focus on reducing ER visits and improving patient care, such as in-home assistance or shorter intervals between follow-up appointments. For example, rather than sending in-home nursing care to Q1 and Q4 patients for an equivalent amount of time, nursing care could be sent more frequently to the Q4 cohort, shown to be at high risk for readmission and ER visits.

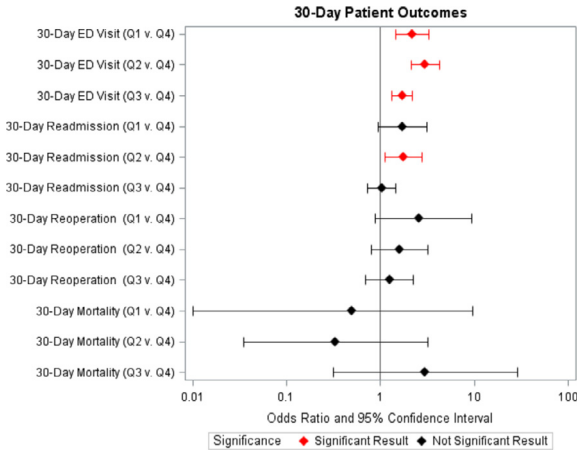

Figure 3. LACE+ score interquartile comparison. Odds ratios and 95% confidence intervals for patient outcomes at 30 days (significance set at $P = .05$). (Color version available online.)

The aim of this study was to elucidate the utility of an easily generated score for patient risk stratification. In order to perform a clinically meaningful assessment, patients were clustered together into score base quartiles, as can easily be performed in clinical practice. One can foresee segregating the urology population (or any clinical population) in the quartile subgroups and then applying measures, as outlined above, to the highest risk group to reduce adverse outcomes.

In the near future, risk prediction algorithms will likely become an increasingly important component of effective population health management. To this end, the LACE and LACE+ indices provide the ability to simplify abundant patient data into a single value, although their predictive value has fallen short in several studies.[17,19,23,24]

Overall, the results of the present work demonstrate that the LACE+ index is a good predictor of risk of ER visits within 30 days of discharge. Data also suggest that LACE+ may predict 30-day readmission risk, although this should be subjected to further study. Results do not support LACE+ prediction of reoperation or early death after urologic surgery.

Coarsened Exact Matching

The use of coarsened exact matching by the present study provides increased assurance that the predictive power of the LACE+ index is not the result of confounding variables. In the present study, matched patients, when compared by LACE+ quartile, had multiple outcomes that were significantly different both clinically and statistically.

In this study, analysis was performed after coarsened exact matching sought ideal matches for the highest quartile patients among lower quartile patients; conceptually a virtual randomized trial. The matching criteria employed in this work were selected based on their historical association with risk of undesirable outcomes. This statistical approach, coarsened exact matching, was undertaken in an attempt to reduce the confounding bias present in retrospective regression analyses.

The approach to matching which is more readily used in the medical/surgical literature is propensity score matching. Propensity score matching compacts many different data points (the covariates) down into 1 value, the PSM score. Matching is then performed based on that 1 value, ignoring the original covariates. This is suboptimal for several reasons. With this method, 2 patients with wildly disparate characteristics can be assigned the same PSM score. This inherently leads to poor match quality. The data compaction process also results in lost information. As additional covariates are included in the matching criteria, the compacting of data becomes increasingly pronounced, as more and more information is lost. Coarsened exact matching is advantageous in this regard as it uses the actual covariate values, which results in superior matches compared to those generated by propensity score matching. For coarsened exact matching, an exact match is defined as a match on every matching variable.[26]

Limitations

The study design is reliant on the index university hospital system as the recipient institution for the readmissions 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 enrolled patients visited the operative surgeon during the surgical follow-up period, at which time data on all clinical interactions in the perioperative time period were captured, regardless of location or hospital system. Potential inaccuracies in data recording may have also influenced analysis and contributed to inherent selection bias. However, one benefit of coarsened exact matching is that these hypothetical inaccuracies would be equally distributed between comparison groups. In addition, there is a slight limit in generalizability since this sample was selected from 1 institution.

The present study is a heterogeneous cohort of urologic surgical procedures, which introduces variability. Although attempts were undertaken to control for procedure type using variables such as operative time, length of stay, and patient class, there remains a distinct potential value to testing LACE+ in specific procedure types. Further, although patients were matched on many key criteria it is possible that in the population being studied there is/are additional criteria that might have resulted in more perfect matches.

Future studies should expand the use of the LACE+ index in a larger, perhaps multicenter, urologic surgery population that may prove robust enough for the accuracy of the LACE+ index to be definitively assessed. Additionally, a prospective trial using the LACE+ index to inform resource engagement could offer further conclusive results.

CONCLUSION

The results of the study herein are novel as this is the first report in the literature employing the LACE+ index in a

urologic surgery population. Our results suggest that the LACE+ index may be able to identify patients at risk of ER visits and readmission and facilitate interventions designed to reduce adverse outcomes after urologic surgery. The use of coarsened exact matching by the present study provide increased assurance that this predictive power is not the result of confounding variables. Future research should aim to expand the population analyzed by LACE+ and study its utility in a prospective manner.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.urology.2019.08.030.

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