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RESEARCH ARTICLE

Identification of high-risk patients for early death or unplanned readmission using the LACE index in an older Portuguese population [version 1; peer review: 1 approved, 1 approved with reservations]

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Abstract

Background: Unplanned readmissions are frequent, associated with high costs and potentially preventable. Pre-discharge risk screening is a crucial step to prevent hospital readmissions. This study evaluates the LACE index as a tool capable of identifying patients with high risk of early readmission or death in an older Portuguese population.

Methods: We performed a retrospective study in a tertiary care hospital in Portugal. All acute patients, aged ≥ 65 years, discharged from the Internal Medicine Service between 1 January and 30 June 2014 were included. Data was collected from hospital records. The LACE index was calculated for each patient. A comparative analysis was performed based on a cutoff of 10 (≥ 10 indicates a high-risk population) for the LACE score.

Results: 1407 patients were evaluated, with a mean age of 81.7 ± 7.6 years; 41.2% were male, 52.2% were dependent for ≥ 1 activities of daily living, the average Charlson comorbidity index was 3.54 ± 2.8 . There were 236 (16.8%) readmissions, 132 (9.4%) deaths and 307 (21.8%) patients were dead and/or readmitted within 30 days of discharge. At 90 days, 523 (37.2%) patients were dead and/or readmitted. The LACE score was higher in patients who died or were readmitted within 30 days compared with those who were not (13.2 ± 2.7 versus 11.5 ± 3.0 , $p < 0.0001$). Patients with LACE score ≥ 10 had significantly higher mortality and readmission rates compared to those with LACE score < 10 : at 30 days, 25.5% versus 9.3% (OR 3.34, 95% CI 2.24-4.98, $p < 0.0001$); at 90 days, 43.4% versus 16.2% (OR 3.98, 95% CI 2.89-5.49, $p < 0.0001$). However, the discriminative capacity of LACE index assessed by C-statistic was relatively poor: 0.663 (95% CI 0.630-0.696) and 0.676 (95% CI 0.648-0.704), respectively.

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Approval Status

	1	2
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Any reports and responses or comments on the article can be found at the end of the article.

Conclusions: This study shows that the LACE index should be used with reservations for predicting 30 and 90-day readmission or death in complex elderly patients.

Keywords

hospital readmissions, elderly, LACE index

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Introduction

Unplanned hospital readmissions are frequent^{1,2}, particularly in elderly patients with comorbidities^{3,4}. These are associated with high costs and a poor global prognosis¹⁻³. Portugal is no different from other Western countries, in which there is a rapid ageing of the population. As a consequence, the number of complex elderly patients with multiple diseases requiring hospitalisation has increased in the last two decades, similarly to the readmission rate⁵.

The problem of hospital readmissions has gained great interest from the medical community and the governments of most developed countries^{1,2}. Several studies suggest that rehospitalizations are potentially preventable^{6,7}, and the ratio of readmissions is now seen as a quality benchmark for health care systems⁸⁻¹¹. There have been a large number of publications in recent years on this subject, and some countries have made efforts to cultivate programs to reduce the impact of this major problem^{2,12,13}.

A pre-discharge risk screening is the first crucial step in any model that attempts to prevent unplanned hospital readmissions. Several readmission screening tools have been created^{14,15}, such as the LACE index¹⁶, PARR-30¹⁷, 8Ps¹⁸, and HOSPITAL score¹⁹. However, none prove to be completely adequate^{14,15}.

The LACE index was first presented in 2010, by Van Walraven *et al.* This is a simple, quick and inexpensive tool that includes length of stay, acuity of the admission (emergency), comorbidities (measured with the Charlson comorbidity index [CCI]) and previous emergency department visits before readmission. It was designed to predict early death or unplanned readmission after discharge from hospital to the home setting¹⁶ (Table 1). However, subsequent studies have failed to obtain consistent results²⁰⁻²⁴.

The original LACE index was based on a middle-aged population living in Canada, with good functional status and few comorbidities¹⁶. This population is not representative of the kind of patient usually observed in acute care facilities in Portugal. Further research is essential to clarify whether the LACE index is a useful tool in predicting the risk of readmission in elderly patients with multiple diseases.

The aim of this study was to assess the ability of the LACE index to predict the risk of readmission or death within 30 and 90 days after discharge in elderly patients at a Portuguese tertiary hospital.

Methods

Study population

We performed a retrospective study in Coimbra Hospital and University Centre, a tertiary care hospital in Portugal. The study included all acute patients aged ≥ 65 years, who were discharged from the Internal Medicine Service between 1 January and 30 June 2014 ($n=1619$). The first hospitalisation during the study period was established as the index admission, and we counted no more than one readmission for each patient. Exclusion criteria were planned admission, discharge to

Table 1. The LACE index (adapted from van Walraven C *et al.* 2010¹⁶, reproduced with permission).

Variable	Value	Points
Length of stay (days)	<1	0
	1	1
	2	2
	3	3
	4–6	4
	7–13	5
	≥ 14	7
Acute admission (emergency)	Yes	3
	No	0
Charlson comorbidity index score	0	0
	1	1
	2	2
	3	3
	≥ 4	5
Emergency department visits during previous 6 months	0	0
	1	1
	2	2
	3	3
	≥ 4	4

Note: The LACE score is calculated by summing the points attributed to the 4 variables.

rehabilitation or continuing care facility, transfer to another acute care hospital, leaving the hospital against medical advice, or death. A total of 1407 patients were eligible for analysis (Figure 1).

Data collection

Medical and demographic data were collected from hospital records, including age, gender, residence, functional status, comorbidities (CCI), reason for admission, medications, length of stay and healthcare utilisation in the previous 6 months (emergency department visits and number of hospital admissions). Readmissions and mortality at 30 and 90 days since the indexed admission were also obtained.

Instrument

The LACE index was calculated for each patient. The LACE score ranges from 0 to 19 - higher scores are related to increased risk of readmission or death after discharge¹⁶. Previous investigations have failed to reach an optimal cut-off for defining high-risk populations. Therefore, we decided to establish 10 as the cutoff, considering that it has already been used in some publications²⁰⁻²². For a more accurate interpretation of the data obtained, we also found it useful to divide patients into three risk groups: low (0–7), moderate (8–13), and high (≥ 14) risk.

Figure 1. Flow chart of patient inclusion, with reasons for exclusion, and total study population.

Statistical analysis

We compared the characteristics of patients with or without 30-day readmission or death using Chi-square for categorical variables and Student's t-test for continuous variables. The area under the receiver operating characteristic (ROC) curve C-statistic (ROC area) was estimated to assess the discriminating ability of the LACE index to predict: (1) readmission, (2) death, and (3) readmission or death within 30 and 90 days. Statistical significance was set at $p < 0.05$. Descriptive and statistical analysis were performed in SPSS v.23.0 (IBM Corp., Armonk, NY, USA). Data are presented as the mean $\pm$ standard deviation.

Results

A total of 1407 patients were evaluated. Their demographic and clinical baseline characteristics are shown in Table 2, as well as the comparison between patients with and without readmission or death after 30 days of discharge. The age of patients ranged from 65 to 104 years (mean 81.7 ± 7.6); 41.2% were male, 52.2%

were dependent on one or more activities of daily living (ADL), the average CCI score was 3.54 ± 2.8 , and 23.2% of patients had a hospital admission in the previous 6 months. Admissions were predominantly emergencies (99.6%), and the most common reasons included pneumonia, urinary tract infection, chronic obstructive pulmonary disease, and heart failure. The patients were hospitalised for 9.5 ± 8.9 days, discharged with 7.53 ± 3.4 different medications, and the average LACE index score was 11.8 ± 3.0 . The median time to complete the LACE index was 44 seconds for each patient.

In the overall cohort, there were 236 (16.8%) readmissions, 132 (9.4%) deaths and 307 (21.8%) patients were dead and/or readmitted within 30 days of discharge. At 90 days there were 404 (28.7%) readmissions, 255 (18.1%) deaths, and 523 (37.2%) patients were dead and/or readmitted (Table 3).

The group of patients with 30-day events (death or readmission) were slightly older and had a higher percentage of men compared to non-event patients (Table 2). In the comparison of these two groups, dependence for one or more ADL, CCI, hospital admission in the previous 6 months, length of initial hospital stay, and number of medications at discharge showed statistically significant differences (Table 2). The LACE score was also significantly higher in patients with death or readmission within 30 days compared with non-event patients (13.2 ± 2.7 versus 11.5 ± 3.0 , $p < 0.0001$).

LACE scores ranged between 4 and 19. There were no patients with a LACE score of ≤ 3 . As seen in Figure 2 and Figure 3, those with a higher LACE score presented with an increased risk of readmission or death. The 30-day death or readmission ranged from 0.0% for a LACE score of 4–5 to 30.0–44.4% for a LACE score of 18–19. The same pattern was found at 90 days, with the risk of death or readmission ranging between 0.0% for a LACE score of 4, and 60.0–67.7% for a LACE score of 17–19.

Patients with a LACE score ≥ 10 represented 77.1% (1085) of the sample. In this group, we observed significantly higher mortality and readmission rates compared to patients with LACE score < 10 (Table 3): 30-day readmission, 19.8% versus 6.5% (OR 3.54, 95% CI 2.22–5.65, $p < 0.0001$); 30-day death, 11.1% versus 3.7% (OR 3.21, 95% CI 1.75–5.89, $p < 0.0001$); 30-day death or readmission, 25.5% versus 9.3% (OR 3.34, 95% CI 2.24–4.98, $p < 0.0001$); 90-day readmission, 33.7% versus 11.8% (OR 3.80, 95% CI 2.65–5.46, $p < 0.0001$); 90-day death, 21.5% versus 6.8% (OR 3.73, 95% CI 2.36–5.89, $p < 0.0001$); 90-day death or readmission, 43.4% versus 16.2% (OR 3.98, 95% CI 2.89–5.49, $p < 0.0001$).

The ROC curves of the LACE index as a predictor of readmission, death, and readmission or death within 30-days are displayed in Figure 4. The C-statistics associated with the LACE index were 0.652 (95% CI 0.615–0.689), 0.672 (95% CI 0.625–0.718),

Table 2. Patient characteristics, and comparison of groups with and without readmission or death within 30 days.

Patient variable	Overall cohort (n=1407)	Death or unplanned readmission within 30 days		
		No n=1100 (78.2)	Yes n=307 (21.8)	p value
Age (years), mean (SD)	81.7 (7.6)	81.6 (7.4)	82.1 (7.7)	0.3073
Gender (male), n (%)	579 (41.2)	435 (39.5)	144 (46.9)	0.0243
Residence, n (%)				
Assisted-living facility	210 (14.9)	158 (14.4)	52 (16.9)	0.2635
Home	1197 (85.1)	942 (85.6)	255 (83.1)	
Dependent for one or more ADL, n (%)	734 (52.2)	517 (47.0)	217 (70.7)	<0.0001
Charlson comorbidity index score, mean (SD)	3.54 (2.8)	3.24 (2.7)	4.62 (3.2)	<0.0001
Hospital admission in previous 6 months, n (%)	326 (23.2)	227 (20.6)	99 (32.2)	<0.0001
Length of stay in days, mean (SD)	9.5 (8.9)	8.87 (7.7)	11.51 (12.2)	<0.0001
Number of medications at discharge, mean (SD)	7.53 (3.4)	7.38 (3.4)	8.1 (3.5)	0.0026
LACE score, mean (SD)	11.8 (3.0)	11.5 (3.0)	13.2 (2.7)	<0.0001

Table 3. The role of the LACE index in predicting events after hospital discharge.

Outcome	Total, n (%)	Discrimination	LACE <10, n (%)	LACE ≥10, n (%)	Odds ratio	p value
	n=1407	C statistic (95% CI)	n=322 (22.9)	n=1085 (77.1)	(95% CI)	
30-day readmission only	236 (16.8)	0.652 (0.615-0.689)	21 (6.5)	215 (19.8)	3.54 (2.22-5.65)	<0.0001
30-day death only	132 (9.4)	0.672 (0.625-0.718)	12 (3.7)	120 (11.1)	3.21 (1.75-5.89)	<0.0001
30-day death and/or readmission	307 (21.8)	0.663 (0.630-0.696)	30 (9.3)	277 (25.5)	3.34 (2.24-4.98)	<0.0001
90-day readmission only	404 (28.7)	0.649 (0.619-0.680)	38 (11.8)	366 (33.7)	3.80 (2.65-5.46)	<0.0001
90-day death only	255 (18.1)	0.678 (0.644-0.713)	22 (6.8)	233 (21.5)	3.73 (2.36-5.89)	<0.0001
90-day death and/or readmission	523 (37.2)	0.676 (0.648-0.704)	52 (16.2)	471 (43.4)	3.98 (2.89-5.49)	<0.0001

and 0.663 (95% CI 0.630-0.696), respectively (Table 3). However, the highest C-statistic achieved was relative to mortality at 90 days (0.678, 95% CI 0.644-0.713). The discriminative capacity of the LACE index as assessed by C-statistic was relatively poor in all outcomes evaluated, and tended to be a better predictor for evaluating death than for readmissions. These results are consistent with those found in other works^{21,22}.

We performed an additional descriptive analysis, dividing patients into three risk groups: 122 patients (8.7%) were at low risk (LACE 0-7); 873 (62.0%) were at moderate risk (LACE 8-13), and 412 (29.3%) were at high risk (LACE ≥14). As we see in Figure 5, in the high-risk group, a third (33.7%) of patients were readmitted or died 30 days after discharge, and more than a half (54%) had an event at 90 days. In contrast, individuals defined

Figure 2. LACE score and the risk of death or readmission within 30 days.

Figure 3. LACE score and the risk of death or readmission within 90 days.

Figure 4. ROC curves for the LACE index within 30 days. Note: ROC curves for the LACE index as a predictor of readmission (left), death (middle) and readmission or death (right) within 30 days.

Figure 5. Readmission, death and readmission or death according to risk group, as defined by LACE index score.

as low and moderate risk had a much lower event rate (5.7% and 18.4% at 30 days, 13.1% and 32.8% at 90 days, respectively).

Dataset 1. Demographic and clinical data for all 1407 patients

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The data file contains the main medical and demographic variables collected for all 1407 patients, including: age, gender, residence, functional status, number of medications at discharge, length of stay, CCI score, hospital admission in the previous 6 months, LACE index score, readmissions and mortality at 30/90 days, and risk group categorization.

Discussion

It is now clear that unplanned readmissions are associated with high costs and avoidable health risks for patients^{1,2}. This major problem is even greater in countries such as Portugal, where

most of patients are elderly with complex and multiple comorbidities. Available data confirm that this is an increasing problem in Portuguese hospitals⁵, but the annual cost of readmissions is unknown.

In the US, about 17% (US\$17.4 billion) of total hospital payments by Medicare in 2004 were related to readmissions¹. Previous studies have shown that a significant portion of early readmissions can be prevented^{6,7}. The implementation of the Affordable Care Act's Hospital Readmission and Reduction Program reinforced this idea. This program, which economically penalises US hospitals with high readmission rates, is associated with a significant decline in the number of rehospitalizations¹³.

The development of readmission prevention programs should be a priority for hospital and health system leaders. Unplanned hospital readmissions and early death after discharge can be taken

as markers of health care quality^{8–10}. However, considering these events as a direct consequence of inadequate care or premature discharge is simplistic and reductive^{11,12}. Hospital readmissions are still difficult to predict, resulting from the complex relationship between multiple factors.

Prevention strategies and the implementation of a post-discharge plan requires the identification of individuals at a high risk of readmission, which depends on prediction tools¹². There are not predictors of hospital readmission validated for the Portuguese population. For this study, the LACE index was chosen as it is a simple, quick and easy instrument created to predict the risk of readmission and early death at 30 days¹⁶. The predictive capability of LACE has shown tremendous inconsistency in different populations^{20–24}. However, attempts to improve the LACE index through the incorporation of other variables have resulted in more complex and time-consuming models without showing any significant advantage^{24–27}.

This single-center retrospective study was based on a population of elderly people with significant comorbidity, polypharmacy, and usually compromised functional status. These baseline characteristics are representative of the general reality of the Portuguese Internal Medicine wards. This is in contrast to the much younger, independent and “relatively healthy” Canadian population used to derive the original LACE index¹⁶.

As expected, the hospital readmission rate and mortality were elevated, with 21.8% of patients experiencing readmission or death at 30 days, and 37.2% at 90 days after discharge. Most patients had a high LACE score (77.1% had LACE score ≥ 10), due to high CCI, prolonged hospitalisations, and almost all admissions were emergencies.

In the study population, those with a LACE score ≥ 10 had a 3-fold increased risk of being readmitted or dead at 30 days, and this risk was even higher at 90 days - almost 4 times compared to the group of patients with a LACE score < 10 . However, the LACE index had a relative poor discriminative ability in predicting 30-day readmissions alone (c-statistic 0.652), and only a slightly better performance in 30-day mortality prediction (c-statistic 0.672). A similar pattern was obtained at 90 days. This performance was poorer than the findings in the original study by Van Walraven *et al.*¹⁶, but very consistent with other studies conducted in similar populations (UK²¹ and Singapore²²).

Despite these results, we found it interesting to classify patients into three risk groups. With this approach, we obtained interesting results. In the high-risk group (LACE score 14–19), more than half of the patients were readmitted or died at 90 days; therefore, making this a hypothetical perfect target to integrate a structured post-discharge preventive plan. This strategy may be more advantageous in clinical practice than defining low- and high-risk patients based on a single cutoff. Further research is required to determine if a specific post-discharge intervention in this group

(LACE score 14–19) may decrease the number of early deaths and readmissions.

Limitations

Our study has some limitations. First, this single-center study was based on a relatively small sample of patients. Second, as a retrospective study, only the variables usually collected were evaluated. Characteristics such as economic status and frailty were not assessed. Third, the causes of unplanned readmission and death were not analysed. Fourth, patients readmitted in hospitals other than ours were not included. This may have led to an underestimated readmission rate in this study. Fifth, the outcomes related to 90 days after discharge were never validated and were mentioned in a very few studies, which limits the comparative analysis of our findings. The same is true for the risk stratification in three groups.

Conclusions

This study shows that the LACE index should be used with reservations for predicting 30 and 90-day readmission or death in complex elderly patients. Further research is needed to determine an effective way to stratify patients at risk of readmission according to the LACE index and to clarify the real impact of post-discharge intervention in these patients.

Data availability

Dataset 1: Demographic and clinical data for all 1407 patients. The data file contains the main medical and demographic variables collected for all 1407 patients, including: age, gender, residence, functional status, number of medications at discharge, length of stay, CCI score, hospital admission in the previous 6 months, LACE index score, readmissions and mortality at 30/90 days, and risk group categorization. doi, [10.5256/f1000research.11315.d176755](https://doi.org/10.5256/f1000research.11315.d176755)²⁸

Ethical approval

This study was conducted according to the principles expressed in the Declaration of Helsinki. The study was approved by the Ethics Committee of Coimbra Hospital and University Centre. The need for written informed consent from the participants was waived by the committee due to the retrospective nature of the study based only on data from medical records.

Author contributions

All authors have contributed equally to the preparation of the paper and study design; JF and FC collected the majority of data. MV and AC were responsible for the critical revision of the article and the final approval of the version to be published.

Competing interests

No competing interests were disclosed.

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[Data Source](#)

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Robert Robinson

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This article is well written and explores the utility of the LACE index in a different setting than other published studies - A tertiary care center in Portugal.

The background is well written, citing relevant articles and explaining the limitations in the ability to identify patients at highest risk of hospital readmission with various systems. Differences in the study population and the derivation and validation studies for the LACE index is discussed. Consider including the references listed below in the introduction to include literature since the publication of the first version of this paper.

Methods are conventional. Inclusion of a Brier score and a Hosmer-Lemeshow goodness of fit score for each of the three outcomes (mortality, 30 day readmission, and 90 day readmission) is essential for a better understanding of the significance of the AUC values for the ROC curves and will allow a more detailed understanding of the value of the scores in this population.

The Brier score will evaluate the accuracy of the LACE index in predicting outcomes in this study, and the Hosmer-Lemeshow test will evaluate test calibration in the patient population. The full inclusion and exclusion criteria (including definitions) for this study should be described in detail, in addition to the figure showing the reasons for patient exclusion from analysis.

The percentages in axis labels for Figures 2 and 3 do not need numbers to the right of the decimal point (100% instead of 100.00%).

Discussion and conclusions are well written, framing the results of this study in the current knowledge at the time of initial release of this paper regarding the LACE index as a predictor of mortality and readmission. Additional publications on this topic since the release date would not change the conclusions drawn by the authors. The inclusion of the Brier score and Hosmer-Lemeshow test results in the discussion and contrasting the results against other studies would be appropriate.

These methodological concerns limit the rating of this interesting and potentially useful article to "Approved with Reservations."

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Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Hospital readmissions

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 09 October 2017

<https://doi.org/10.5256/f1000research.12211.r26621>

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Nan Liu

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Thanks for the opportunity to review. In this manuscript, the authors validated the LACE index on identifying high risk elderly patients in a selected Portuguese population. 1407 patients were retrospectively recruited to evaluate the performance of LACE on its associations with the risk of readmission or death in 30 days and 90 days. The results were consistent with several similar international studies and the authors suggested that the LACE index should be used with reservations.

The study is well designed and the manuscript is clearly written. The methods are reported in a standard approach and the results are sufficient in supporting the conclusions. One suggestion: since 90-day outcome is studied, the authors are suggested to add in the results on 90-day readmission or death into Table 2 and Figure 4.

In Methods (study population subsection, first paragraph second sentence), the authors mentioned that they included all "acute" patients, so please define "acute" and explain why these patients from the Internal Medicine Service were studied (for example, are they are subset of all internal medical patients?). As shown in the results that "admissions were predominantly emergencies (99.6%)", the authors need to clarify the actual inclusion criteria.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

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