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Association of neutrophil-to-lymphocyte ratio with outcomes after elective abdominal aortic aneurysm repair

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Data are lacking regarding real-time prediction of postoperative complications after elective aneurysm repair. The neutrophil-to-lymphocyte ratio (NLR) has been evaluated as a predictor of outcomes after cardiac and infrapopliteal interventions and is associated with poor outcomes for critical limb ischemia. We examined NLR and outcomes after abdominal aortic aneurysm (AAA) repair. Inpatients undergoing elective AAA repair (2008 to 2015) were selected from the Cerner Health Facts database using International Classification of Disease (9th edition) procedure codes. Postoperative outcomes were identified using data from patient records within 1 week after surgery. NLR was calculated by dividing the absolute neutrophil count by the absolute lymphocyte count. The receiver operating characteristic curve was analyzed to define low and high postoperative NLR groups. Chi-square analysis and multivariable logistic regression models were used to identify characteristics (demographics, diagnoses, postoperative NLR) associated with postoperative complications.

Elective AAA repair occurred in 5,655 patients. Of these, we could calculate postoperative NLR for 1,908 (34%), with 1,529 undergoing endovascular repair and 379 undergoing an open repair. Compared with patients with low postoperative NLR, patients with high postoperative NLR experienced longer hospital stays (5.7 vs 2.6 days, P < .0001); higher rates of in-hospital death (2.9% vs 1.4%, P = .002); higher rates of renal failure (11.6% vs 3.9%, P < .0001); cardiac problems or myocardial infarction (3.8% vs 1.2%, P = .0002); respiratory problems (13.3% vs 5.8%, P < .0001); and infection (8.9% vs 2.9%, P < .0001). The association between high postoperative NLR and adverse postoperative outcomes persisted on multivariable analysis. This included infection (odds ratio [OR], 2.59; 95% confidence interval [CI], 1.65–4.07), renal failure (OR, 2.19; 95% CI, 1.45–3.31), cardiac events (OR, 2.41; 95% CI, 1.21–4.77), and respiratory problems (OR, 1.73; 95% CI, 1.22–2.45).NLR was associated with adverse outcomes after elective endovascular and open AAA repair. An elevated NLR within 1 week after surgery was strongly associated with postoperative complications, and may identify at-risk patients who require closer follow-up. Given the perilous nature of vascular surgery and the risk-benefit ratio for prophylactic aneurysm repair, future study of postoperative outcome and preoperative NLR is needed to provide clinically important risk profiles before treatment decisions. (J Vasc Nurs 2019;37:213-220)

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Support from the Agency for Healthcare Research and Quality was used to fund the research reported in this publication (R24HS022140). The authors take sole responsibility in the content of this report, which does not necessarily represent the official views of the Agency for Healthcare Research and Quality.

Presented at the Midwestern Vascular Surgery Society 42nd Annual Meeting, September 13th-15th 2018, St. Louis, Missouri.

Conflicts of interest: The authors declare no conflicts of interest.

1062-0303/$36.00

https://doi.org/10.1016/j.jvn.2019.06.001

INTRODUCTION

Selecting patients for elective aneurysm repair has become a more complex clinical dilemma with the advent of endovascular aortic repair (EVAR). Elective open aortic aneurysm repair was historically reserved for patients who would experience long-term survival benefit and who were good-risk surgical candidates.[1] Endovascular repair has expanded the pool of appropriate candidates because of reduced perioperative surgical stress, shorter recovery time, and early survival advantage.[2,3] There are concerns, however, that the rate of rupture after EVAR and long-term survival may not be as favorable as for open repair, with mortality rates equalizing after 3 years.[3–5]

Appropriate selection of patients who will derive sustained benefit from elective aneurysm repair is of paramount importance in this endovascular era. Clinical frailty scores have shown good discrimination for mortality after open aneurysm repair and for life-threatening complications after both open and endovascular aneurysm repair.[6–8] Although biomarkers have been studied as prognostic indicators for outcomes in oncologic and cardiovascular disorders,[9–12] they have not been as widely evaluated in vascular disorders. The neutrophil-to-lymphocyte

ratio (NLR) has been reported as a strong marker for cancer-specific survival, overall survival, and recurrence-free survival in urothelial cancer,[13] and breast,[14] colorectal,[15] gastric,[16] and non–small-cell lung cancer[17] outcomes now appear to be well founded with a robust body of literature to support the association. The overarching mechanistic principle of using the NLR for cancer surveillance and progression of disease is based on the imbalance of neutrophils and lymphocytes in patients with cancer and systemic inflammation that arises thereof.[18] Systemic inflammation has been previously shown to play a key role in disease progression in cancer by promoting tumor angiogenesis, encouraging tumor metastasis and proliferation of cancer cells. In addition, a proinflammatory balance affects the response of tumors to different systemic chemotherapy agents.[19] Neutrophils, specifically, have been shown to act as "tumor-promoting" leukocytes with the ability to stimulate and suppress antitumor immune responses, promote tumor cell leakage and metastasis, and secrete vascular endothelial growth factor that stimulates tumor angiogenesis.[20]

The NLR and platelet-to-lymphocyte ratio have been increasingly recognized as systemic markers of overall inflammation, and an association between atherosclerosis and NLR has been proposed.[21–23] Despite mounting evidence associating elevated NLR with poor outcomes in these disease processes, the mechanism of action resulting in those observations remains unknown. The pathology of atherosclerosis is driven by inflammation, in turn regulated by white blood cells. Even when the white blood cell count is normal, a higher NLR has been associated with a larger atherosclerotic burden.[24] No clear consensus exists, however, for what constitutes a normal NLR or platelet-to-lymphocyte ratio. The NLR is easily obtainable from the complete blood count with differential and has been associated with adverse outcome in vascular disorders morbidity in a few preliminary studies of ruptured abdominal aortic aneurysm (AAA)[25] and elective major vascular surgery.[26] The understanding of the role of NLR in vascular disorders is still largely in a nascent stage, and the potential of this novel biomarker has yet to be realized or studied.

AAA disease affects approximately 12.5% of men and 5.2% of women older than 74 years and is responsible for over 10,000 deaths annually in the United States.[27] As the size of an aneurysm increases, so does the rupture risk with mortality rates for ruptured AAA estimated to be approximately 90%.[28] Due to the increasing perioperative benefits of endovascular aneurysm repair (EVAR) over traditional open aneurysm repair with a reduction in perioperative mortality of 1.4% after EVAR and 4.2% after open repair, over 80% of aneurysm repairs are now performed endovascularly.[29]

With this goal in mind, we undertook a national database study of the association of the NLR with adverse outcome after elective AAA repair.

METHODS

Data source

International Classification of Disease (9th edition) (ICD-9)-CM diagnosis and procedure codes were used to identify patients who underwent elective (nonruptured) open or EVAR repair between September 2008 and October 2015 from the Cerner Health Facts database.[30] Health Facts is a proprietary database comprising electronic medical records from hospitals and hospital systems that use Cerner Corporation's electronic health record (EHR). It includes EHR data from over 400 acute-care hospitals and contains detailed information on diagnoses, procedures, laboratory studies, medications, patients, and encounters. Cerner applies rigorous validity checks to the data, removes identifiers, and standardizes data before including them in Health Facts using methods compliant with the Health Insurance Portability and Accountability Act.

We used these data to identify patients who had elective AAA procedures, determine surgical outcomes after each procedure, and evaluate patient and procedural characteristics that are associated with outcomes. We used the Agency for Healthcare Research and Quality's Clinical Classifications Software to group diagnosis codes into clinically relevant groups. Because Health Facts data are deidentified, informed patient consent was not needed. The Health Sciences Institutional Review Board at the University of Missouri deemed our study exempt.

Study population

We included patients who underwent an open (procedure codes: 38.44 or 39.25) or EVAR (procedure codes: 39.71) procedure for a

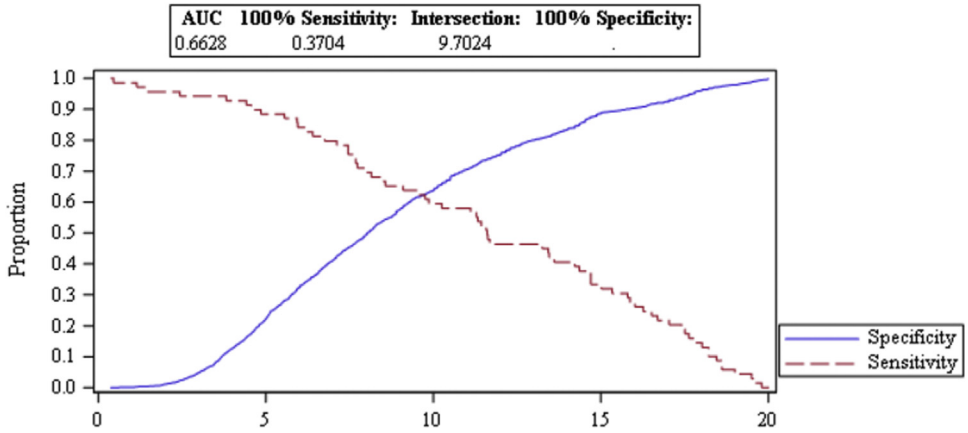

Figure 1. *ROC curve analysis of postoperative NLR. NLR = neutrophil-to-lymphocyte ratio; ROC = receiver operating characteristic.*

TABLE 1

CHARACTERISTICS OF PARTICIPANTS (N = 1,908)*

Patient and procedure characteristics	*N (%)*	*Low NLR N (%)*	*High NLR N (%)*	P-*value*
Age (mean, SD)	72.2 (8.7)	72.0 (8.7)	72.7 (8.6)	.11
Gender				.14
Female	451 (23.6)	264 (22.5)	187 (25.4)	
Male	1,457 (76.4)	909 (77.5)	548 (74.6)	
Race				.38
Caucasian	1,682 (88.2)	1,040 (88.7)	642 (87.4)	
Other race	226 (11.8)	133 (11.3)	93 (12.6)	
Charlson Index (mean, SD)	2.1 (1.3)	2.1 (1.2)	2.3 (1.5)	.0004
Procedure type				<.0001
Endovascular	1,529 (80.1)	1,040 (88.7)	489 (66.5)	
Open	379 (19.9)	133 (11.3)	246 (33.5)	
NLR (mean, SD)	9.0 (4.6)	5.93 (2.1)	13.8 (2.9)	<.0001
Low NLR	1,173 (41.5)	—	—	
High NLR	735 (38.5)	—	—	
Pre-existing conditions				
Chronic heart disease	885 (46.4)	551 (47.0)	334 (45.4)	.51
Chronic kidney disease	234 (12.3)	128 (10.9)	106 (14.4)	.02
Diabetes	386 (20.2)	234 (19.9)	152 (20.7)	.69
Outcomes				
Renal failure	131 (6.9)	46 (3.9)	85 (11.6)	<.0001
Cardiac problems/myocardial infarction	42 (2.2)	14 (1.2)	28 (3.8)	.0002
Respiratory problems	166 (8.7)	68 (5.8)	98 (13.3)	<.0001
Infection	100 (5.2)	34 (2.9)	66 (8.9)	<.0001
In-hospital death	37 (1.9)	16 (1.4)	21 (2.9)	.02
Length of stay (mean, SD)	3.8 (5.8)	2.6 (3.8)	5.7 (7.6)	<.00001
>10 days	135 (7.1)	29 (2.5)	106 (14.4)	<.0001

NLR = neutrophil-to-lymphocyte ratio; SD = standard deviation.

Low NLR < 9.7024; high NLR ≥ 9.7024.

*Number and percentage unless otherwise indicated.

nonruptured, infrarenal AAA (diagnosis codes: 441.02, 441.4, 447.72). The ICD-9 procedure codes for open and EVAR refer to discrete numeric codes that identify the procedure performed for a particular patient (eg, 38.44 refers to resection of vessel with replacement, aortic, abdominal). They were developed to identify procedures for billing but are frequently used for research purposes.

To ensure we captured only infrarenal AAA procedures, we excluded ICD-9 codes that were related to thoracic aneurysm, thoracoabdominal aneurysm, and other repairs of the suprarenal aorta. We also excluded patients who were younger than 21 years at admission, had an admission during which both EVAR and open procedures were performed, had admissions flagged as emergent or urgent, were discharged to hospice, had an adjacent encounter within 3 hours of admission or discharge of the encounter in which AAA repair occurred, were diagnosed with a ruptured aneurysm (diagnosis code, 441.3), or had no laboratory data or diagnoses in the encounter record.

Analysis

All analyses were performed in SAS version 9.4 (SAS Institute, Cary, NC). We calculated NLR by dividing the absolute neutrophil count by the absolute lymphocyte count. Postoperative NLR was divided into low (<9.7024) and high (≥9.7024) values based on

TABLE 2

MULTIVARIABLE LOGISTIC REGRESSION MODELS

	OR (95% CI)	P-*value*
Renal failure (n = 131)		
NLR (high vs. low)	2.19 (1.45–3.31)	.0002
Age	1.02 (0.99–1.04)	.16
Gender (female vs. male)	1.82 (1.19–2.77)	.005
Race (Caucasian vs. other race)	0.78 (0.44–1.39)	.39
Procedure type (open vs. endovascular)	4.30 (2.80–6.60)	<.0001
Chronic heart disease	1.13 (0.76–1.68)	.54
Chronic kidney disease	7.88 (5.18–12.0)	<.0001
Diabetes	1.50 (0.96–2.35)	.07
In-hospital mortality (n = 37)		
NLR (high vs. low)	0.96 (0.46–1.98)	.90
Age	1.06 (1.02–1.11)	.008
Gender (female vs. male)	3.11 (1.54–6.27)	.001
Race (Caucasian vs. other race)	1.80 (0.42–7.73)	.43
Procedure type (open vs. endovascular)	11.84 (5.26–26.6)	<.0001
Chronic heart disease	1.27 (0.62–2.59)	.51
Chronic kidney disease	2.74 (1.25–6.00)	.01
Diabetes	2.46 (1.16–5.24)	.01
Cardiac complication/MI (n = 42)		
NLR (high vs. low)	2.41 (1.21–4.77)	.01
Age	1.03 (0.99–1.08)	.09
Gender (female vs. male)	1.80 (0.93–3.48)	.07
Race (Caucasian vs. other race)	0.91 (0.35–2.39)	.84
Procedure type (open vs. endovascular)	2.49 (1.24–5.00)	.01
Chronic heart disease	1.39 (0.73–2.66)	.31
Chronic kidney disease	2.58 (1.27–5.25)	.009
Diabetes	1.39 (0.68–2.87)	.37
Respiratory problems (n = 166)		
NLR (high vs. low)	1.73 (1.22–2.45)	.003
Age	1.01 (0.99–1.03)	.63
Gender (female vs. male)	2.11 (1.48–3.00)	<.0001
Race (Caucasian vs. other race)	1.07 (0.63–1.81)	.80
Procedure type (open vs. endovascular)	4.03 (2.79–5.83)	<.0001
Chronic heart disease	0.99 (0.70–1.40)	.96
Chronic kidney disease	1.75 (1.13–2.71)	.0128
Diabetes	1.90 (1.30–2.79)	.001
Infection (n = 100)		
NLR (high vs. low)	2.59 (1.65–4.07)	<.0001

(*Continued*)

TABLE 2

CONTINUED

	OR (95% CI)	P-*value*
Age	1.01 (0.99–1.04)	.37
Gender (female vs. male)	3.26 (2.13–5.00)	<.0001
Race (Caucasian vs. other race)	0.90 (0.48–1.68)	.73
Procedure type (open vs. endovascular)	2.64 (1.66–4.19)	<.0001
Chronic heart disease	0.90 (0.59–1.39)	.63
Chronic kidney disease	1.13 (0.62–2.06)	.70
Diabetes	2.11 (1.32–3.38)	.001

CI = confidence interval; MI = myocardial infarction; NLR = neutrophil-to-lymphocyte ratio; OR = odds ratio.

the results of a receiver operating characteristic analysis that used a combined outcome of in-hospital mortality, cardiac problem, or myocardial infarction (MI) (see Figure 1).

Chi-square analysis compared the characteristics of patients who had high versus low postoperative NLR. Multivariable logistic regressions were examined to determine patient characteristics associated with postoperative outcomes. We used odds ratios (ORs) and 95% confidence intervals (CIs) to test for associations of covariates with outcomes. Because we excluded encounters with no laboratory data or diagnoses, we assumed that laboratory tests were not administered and diagnoses were not present when they were not found within the patient's encounter record.

We developed separate multivariable logistic regression models for renal failure, in-hospital mortality, cardiac problems/MI, respiratory problems, infection, and length of stay >10 days, using diagnoses, procedure type, patient demographic characteristics, and NLR group as independent variables. We calculated the Charlson Index[31] for each patient, based on the diagnoses (primary, secondary, discharge, or billing) present during the encounter. We initially created a base model that included the procedure type (EVAR vs open) and patient characteristics (age, sex, race/ethnicity, and Charlson Index). Comorbid diagnoses and encounter characteristics were allowed entry into each base model using stepwise selection, using $P = .10$ as the significance level for variable entry and retention. Backward elimination models were also run to determine whether the same variables were retained in the final models. ORs and 95% CIs were calculated. We assessed model discrimination with the c-statistic, where 1 indicates perfect fit and 0.5 is no better than a coin toss. Model calibration was assessed with the Hosmer-Lemeshow goodness-of-fit test, where $P > .05$ indicates adequate fit over the range of predicted outcome.

RESULTS

Patient characteristics

There were 1,908 elective AAA procedures performed where postoperative NLR was able to be calculated. Endovascular repair was undertaken in 80% of patients (N = 1,529; Table 1). Mean postoperative NLR was 9.0 with a range from 0.32 to 20. Postoperative NLR was split into groups low (<9.7024) and high (≥9.7024) based on the receiver operating characteristic analysis. Men comprised 76.4% of the sample, mean patient age was 72.2 years, and most (88.2%) were Caucasian. The mean Charlson Index was 2.1.

Chronic heart disease was present in 46% of patients, with chronic kidney disease present in 12% and diabetes in 20%. Regarding overall outcomes; in-hospital mortality was low (2%), with renal failure occurring in 7% of patients, cardiac complications/MI in 2.2%, respiratory problems in 8.7%, infection in 5%, and a prolonged hospital stay greater than 10 days in 7% of all patients. Compared with patients with low postoperative NLR, patients with high postoperative NLR experienced (Table 1) longer hospital stays (5.7 vs 2.6 days, $P < .0001$); higher rates of in-hospital death (2.9% vs 1.4%, $P = .002$); and higher rates of renal failure (11.6% vs 3.9%, $P < .0001$), cardiac problems/MI (3.8% vs 1.2%, $P = .0002$), respiratory problems (13.3% vs 5.8%, $P < .0001$), or infection (8.9% vs 2.9%, $P < .0001$).

Multivariable analysis

Analyses were performed for six postoperative outcomes (Table 2): renal failure, in-hospital mortality, cardiac complications/MI, respiratory problems, infection, and length of stay >10 days. The Hosmer-Lemeshow statistic demonstrated adequate fit for all models except the model for length of stay >10 days ($P = .001$). Because model fit for this outcome was so poor, results for extended length of stay are not presented or discussed.

High postoperative NLR was associated with a 2.6 times increased odds of infection compared with low NLR (OR, 2.59; 95% CI, 1.65–4.07), a 2.4 times increased odds of cardiac complications/MIs compared with low NLR (OR, 2.41; 95% CI, 1.21–4.77), a 2.2 times increased odds of renal failure compared with low NLR (OR, 2.19; 95% CI, 1.45–3.31), and a 1.7 times increased odds of respiratory failure compared with low NLR (OR, 1.73; CI, 1.22–2.45).

Renal failure after aneurysm repair was associated with chronic kidney disease (OR, 7.88; 95% CI, 5.18–12.00), having an open procedure performed (OR, 4.30; 95% CI, 2.80–6.60), and female sex (OR, 1.82; 95% CI, 1.19–2.77). Model fit was

adequate (P = .49) and discrimination was moderate (c-statistic = 0.83).

In-hospital mortality was associated with open AAA repair (OR, 11.8; 95% CI, 5.26–26.6), female sex (OR, 3.11; 1.54–6.27), chronic kidney disease (OR, 2.74; 1.25–6.00), diabetes (OR, 2.46; 95% CI, 1.16–5.24), and increased age (OR, 1.06; 95% CI, 1.02–1.11). No association was found, however, between in-hospital mortality and postoperative NLR. Model discrimination was moderate (c-statistic = 0.86) and fit was adequate (P = .76).

Two covariates were associated with developing cardiac complications/MIs after AAA repair: chronic kidney disease (OR, 2.58; 95% CI, 1.27–5.25) and having an open procedure performed (OR, 2.49; 95% CI, 1.24–5.00). Model fit was adequate (P = .12), and discrimination was modest (c-statistic = 0.77).

Respiratory problems were associated with open AAA repair (OR, 4.03; 95% CI, 2.79–5.83), female sex (OR, 2.11; 95% CI, 1.48–3.00), diabetes (OR, 1.90; 95% CI, 1.30–2.79), and chronic kidney disease (OR, 1.75; 95% CI, 1.13–2.71). Similarly, infection in the postoperative period was associated with female sex (OR, 3.26; 95% CI, 2.13–5.00), diabetes (OR, 2.11; 95% CI, 1.32–3.38), and open AAA repair (OR, 2.64; 95% CI, 1.66–4.19). Model discrimination was modest and fit was adequate for both of these models as well.

DISCUSSION

This retrospective large cohort study of outcomes after elective AAA repair identified common themes in terms of comorbidities and risk factors for complications. Broadly, open AAA repair, female gender, diabetes, and chronic kidney disease were all associated with poor outcomes after aneurysm repair. These risk factors were significantly associated for all six postoperative outcomes evaluated in this study; renal failure, in-hospital mortality, cardiac problems/MI, respiratory problems, infection, and length of stay >10 days, which were chosen as these represented clinically the most impactful complications after major vascular surgery.

The analysis was also focused on the strong association of elevated postoperative NLR with these six postoperative complications. An elevated NLR was independently associated with renal failure, cardiac problems/MI, respiratory problems, infection, and length of stay >10 days. This analysis highlights an important association between elevated NLR and poor outcome after AAA repair that has not been well-described previously.

The NLR has been studied in more detail in the cancer literature, with very little work described in the cardiovascular field; however, the association of inflammation and an elevated NLR has been recognized in the development of cardiovascular disorders and specifically atherosclerosis. Given the status as a biomarker for inflammation, as seen in the cancer literature, the role of NLR in atherosclerotic disorders has been more intensely studied recently. Recent studies have described the predictive effect of NLR on death, MI, and high-risk for coronary artery disease,[32–34] as well as an association with classic atherosclerotic risk factors such as diabetes mellitus, hypertension, metabolic syndrome, obesity, hyperlipidemia, and endothelial dysfunction.[21] Animal models of atherosclerosis additionally demonstrate neutrophil invasion of atherosclerotic plaque, and release of proteolytic enzymes by neutrophils may be responsible for plaque vulnerability—a known risk factor for MI[35] and postulated to be also involved in carotid thromboembolic processes.[36]

Moving from animal models and experimental evidence of the role of NLR in inflammation and atherosclerosis to the clinical realm; Bhutta et al published their findings in a multi-institutional review of elective major vascular surgery, evaluating the role of the NLR in predicting medium-term survival. The authors describe the two-year mortality associated with carotid endarterectomy, AAA repair, and lower limb revascularization and used a preoperative NLR cutoff of > 5 to categorize patients into low- and high-NLR groups. Multivariate analysis was used to evaluate all significant factors on univariate analysis and revealed that patients with a preoperative NLR of > 5 were more likely to die within two years after elective major vascular surgery. The clinical value of this information, despite the heterogeneity of the surgery and risk factors evaluated, should not be underestimated. The ability to predict poor outcomes after elective surgery, including death, is of paramount importance in a field such as vascular surgery, where many operations are performed "prophylactically" to reduce the risk of a catastrophic event occurring. AAA surgery and carotid artery procedures exemplify vascular surgery procedures with a significant risk of complications that are performed on patients who are already at high risk to prevent a catastrophe such as aneurysm rupture or stroke.

Predicting outcome in vascular surgery has remained a fundamental principle when discussing operative or interventional treatment for any disorder due to the risks involved. Predictive tools and calculators of risks are sparse for vascular procedures, although these tools have been published and are used in clinical practice for specific cancer-related mortality decisions such as in prostate cancer[37] or breast cancer.[38] Vascular surgery risk calculators have focused primarily on adverse cardiac risk after common vascular surgery operations with the most commonly used and well-validated online risk calculators being the National Surgical Quality Improvement Program, which is a nationally validated, risk-adjusted, outcomes based program to measure and improve the quality of surgical care,[39] the Revised Cardiac Risk Index, which is a validated tool for estimating a patient's risk of perioperative cardiac complications using patient-specific comorbidities[40] and the Vascular Study Group of New England Cardiac Risk Index, which is a similar risk prediction tool based on specific comorbidities in the vascular population.[41] Although major adverse cardiac events are seen commonly in vascular patients and are clinically important, there are presently no robust risk prediction tools for noncardiac complications, such as stroke after carotid intervention, bypass thrombosis, or restenosis after lower extremity revascularization. Furthermore, there is scant information regarding the risk of catastrophic events such as stroke or aneurysm rupture in patients who are being serially followed with these disorders although interest in the clinical value of NLR in vascular disorders is increasing.

A recent publication by Massiot et al describes a moderate single-institution series of consecutive patients who underwent carotid endarterectomy for internal carotid artery (ICA) stenosis in the context of the NLR. The authors captured 270 patients and divided them into four groups based on NLR quartiles. The proportion of patients with symptomatic ICA stenosis was significantly higher in the highest NLR quartile group than in the other groups.

The authors conclude that a high preoperative NLR was significantly associated with symptomatic ICA stenosis and warrants further study as predictors of postoperative outcomes for carotid patients.[42]

Lareyre et al similarly examine the association of high NLR with symptomatic and ruptured thoracic aortic aneurysm (TAA) in a small single-institution series. The authors describe a significantly greater proportion of patients with pain or with ruptured TAA in the group with NLR > 3.5 compared with those < 3.5. Interestingly, a higher preoperative NLR was not associated with 30-day overall mortality and morbidity. The authors conclude that circulating neutrophils and lymphocytes may be markers of aortic rupture and further studies are required to evaluate the potential predictive value of NLR on outcome and in the pathogenesis of TAA.[43]

In this present study, we demonstrated that a high postoperative NLR value was associated with significant complications after elective aneurysm repair. This was independent of the treatment modality and other comorbidities and risk factors of the patients. We did not find a significant correlation with preoperative NLR and postoperative outcome and this may have been due to the much lower numbers of patients with available preoperative data (470 patients) as opposed to those with postoperative values (1,536 patients).

This study has limitations secondary to using ICD-9 codes, as coding may vary between institutions. Because the procedure type was not randomly assigned, selection bias could explain the differences between groups; we addressed this with a propensity score analysis. Residual confounding is still possible despite controlling for multiple covariates.[44] Cerner Corporations' Health Facts is a proprietary database comprising electronic clinical records from hospitals and hospital systems that use Cerner's EHR, and the ethnicity and patient mix may not be representative of the wider U.S. population. Proportions by ethnicity, however, are comparable to our previously published evaluation of carotid intervention using Medicare data, which is considered representative of the elderly U.S. population.[45]

CONCLUSIONS

An elevated NLR < 1 week after surgery was strongly associated with postoperative complications after elective endovascular and open AAA repair. NLR has been identified to be associated with poor prognosis for cardiovascular and oncologic disorders and holds promise as a novel biomarker of outcome. Future study is planned to evaluate the role of preoperative NLR, in conjunction with other traditional predictors of outcome, as part of a multimodal risk prediction tool to stratify patients at risk for significant complications after vascular procedures.

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