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ORIGINAL RESEARCH

Preoperative Psoas Muscle Index Predicts Long-Term Survival but Not Postoperative Morbidity After Curative-Intent Gastrectomy for Gastric Cancer

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Background: Sarcopenia is increasingly recognized as a host-related prognostic factor in gastric cancer; however, its relationship with early postoperative outcomes remains inconsistent. The psoas muscle index (PMI) is a practical CT-based surrogate of skeletal muscle reserves.

Methods: This retrospective cohort from two university-based tertiary referral centers included patients who underwent curative-intent upfront gastrectomy for gastric cancer between 2015 and 2020. Patients who received neoadjuvant chemotherapy, or who presented with radiologically bulky lymph nodes or distant metastasis, were excluded. Bilateral psoas muscle areas at L3 were summed and normalized to height squared (mm^2/m^2). Sex-specific Turkish cut-offs defined low PMI (<530 mm^2/m^2 men; <360 mm^2/m^2 women). Early postoperative outcomes and time-specific OS (1-, 3-, 5-year) were compared across PMI-defined categories.

Results: A total of 184 patients were included (106 low-PMI; 57.6% and 78 high-PMI; 42.4%). Low PMI was not associated with higher postoperative morbidity: anastomotic leak 4.72% vs 3.85% (p=1.000), surgical-site infection 11.3% vs 10.3% (p=1.000), transfusion requirement 31.1% vs 30.8% (p=1.000), median hospital stay 13 vs 13 days (p=0.379). In contrast, survival clearly diverged: 1-year OS was not significant (80.19% vs 91.03%; p=0.060), whereas 3-year OS (54.72% vs 79.49%; p<0.001) and 5-year OS (43.40% vs 74.36%; p<0.001) were markedly inferior in low-PMI patients. In multivariable Cox regression, PMI independently predicted mortality (HR 0.996; p<0.001).

Conclusion: Low PMI was not associated with early morbidity, but it independently identified patients at substantially higher long-term mortality risk, supporting the concept that diminished muscle mass reflects impaired long-term biological reserve rather than short-term surgical vulnerability, and may be incorporated into routine preoperative risk stratification.

Keywords: computed tomography, gastrectomy, gastric cancer, psoas muscle index, sarcopenia, overall survival

Introduction

Gastric cancer continues to represent a major global health problem. According to the most recent GLOBOCAN 2022 estimates, stomach cancer accounts for approximately 4.9% of all new cancer diagnoses worldwide and remains among the leading causes of cancer-related mortality, responsible for nearly 6.8% of all cancer deaths.[1] Despite improvements in perioperative care, staging, and systemic therapies over recent decades, the long-term survival of patients with gastric cancer remains suboptimal, particularly in those diagnosed at advanced stages. These observations highlight the persistent need for improved prognostic risk stratification to better identify high-risk subgroups and refine individualized patient management.

Sarcopenia is increasingly recognized as a clinically relevant host-related factor in gastric cancer, reflecting systemic inflammatory and metabolic alterations rather than simple malnutrition.[2] Computed-tomography-based skeletal muscle assessment at the level of the third lumbar vertebra is now widely used to quantify muscle mass and to standardize sarcopenia evaluation in oncologic patients.[3] Lower preoperative skeletal muscle indices have consistently been

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associated with inferior overall survival after gastrectomy. Furthermore, persistent skeletal muscle loss in the post-operative period also appears to negatively influence long-term outcomes.[4]

Although sarcopenia is consistently associated with long-term survival, its impact on early postoperative morbidity in gastric cancer is less clear. Recent studies have reported that patients with low preoperative skeletal muscle mass have higher rates of postoperative complications after gastrectomy, suggesting that reduced muscle reserves may impair physiological resilience to surgical stress.[5,6] In contrast, other cohorts have not identified a significant relationship between sarcopenia and short-term surgical morbidity, indicating that the effect of muscle depletion on early postoperative outcomes remains heterogeneous across studies.[7] The psoas muscle index was chosen because it can be easily and reproducibly derived from routine staging CT scans, is less time-consuming than full-slice L3 skeletal muscle indices, and has demonstrated comparable prognostic value in gastric cancer.

Standardization of cut-off values represents a major methodological limitation in sarcopenia research. Thresholds for CT-derived skeletal muscle indices are not universal and vary across populations depending on ethnicity, sex, age and body-composition characteristics.[8] Multiple analyses have shown that the same cohort can yield markedly different sarcopenia prevalence rates when alternative skeletal-muscle cut-offs are applied.[8–11] Therefore, population-specific reference values are essential for accurate risk stratification — and in this context, using thresholds validated for the Turkish population is particularly relevant for our cohort.[12]

Unlike several previous studies reporting conflicting associations between sarcopenia and postoperative morbidity, the present study addresses this uncertainty by analysing a homogeneous upfront-surgery cohort, applying population-specific PMI cut-off values, and evaluating time-specific survival outcomes.

In this context, despite consistent associations between sarcopenia and overall survival, it remains unclear whether sarcopenia primarily influences early postoperative mortality or manifests as a delayed divergence in long-term survival. In this study, we aimed to investigate whether preoperative psoas muscle index is associated with postoperative complications and 1-, 3- and 5-year overall survival in patients undergoing upfront gastrectomy for gastric cancer, using cut-off values adjusted for the Turkish population.

Methods and Patients

Study Design and Ethical Approval

This retrospective two-center cohort study was conducted at Mersin University Faculty of Medicine and Ege University Faculty of Medicine. Patients who underwent curative-intent gastrectomy between January 2015 and December 2020 were evaluated.

Ethical approval was obtained from the Mersin University Clinical Research Ethics Committee (23 July 2025; Decision No: 2025/838). At the second participating center (Ege University), institutional authorization for the use of anonymized patient data in scientific research was granted by the Office of the Chief Physician (03 July 2025; Authorization No: 2516905), in accordance with national regulations. This study was conducted in accordance with the principles of the Declaration of Helsinki. Given the retrospective design, the requirement for individual informed consent was waived.

Study Population and Inclusion Criteria

Patients with histologically confirmed gastric cancer who underwent primary gastrectomy were included. Patients who received neoadjuvant chemotherapy, or who presented with radiologically bulky lymph nodes or distant metastasis on preoperative staging imaging, were excluded. Only upfront-surgery cases were analyzed.

Sarcopenia was defined using the Psoas Muscle Index (PMI), measured on preoperative axial contrast-enhanced CT sections at the third lumbar vertebral level (L3)—the reference anatomical landmark for skeletal muscle quantification in gastrointestinal oncology. Bilateral psoas cross-sectional areas were manually segmented at L3 and normalized to height squared (mm^2/m^2) (Figure 1). PMI was calculated as: PMI (mm^2/m^2) = (Left psoas CSA + Right psoas CSA) / $height^2$. All measurements were performed by experienced radiologists, with one radiologist from each participating institution, using the same anatomical landmark and segmentation approach. Sex-specific cut-off values previously validated in upper gastrointestinal series and

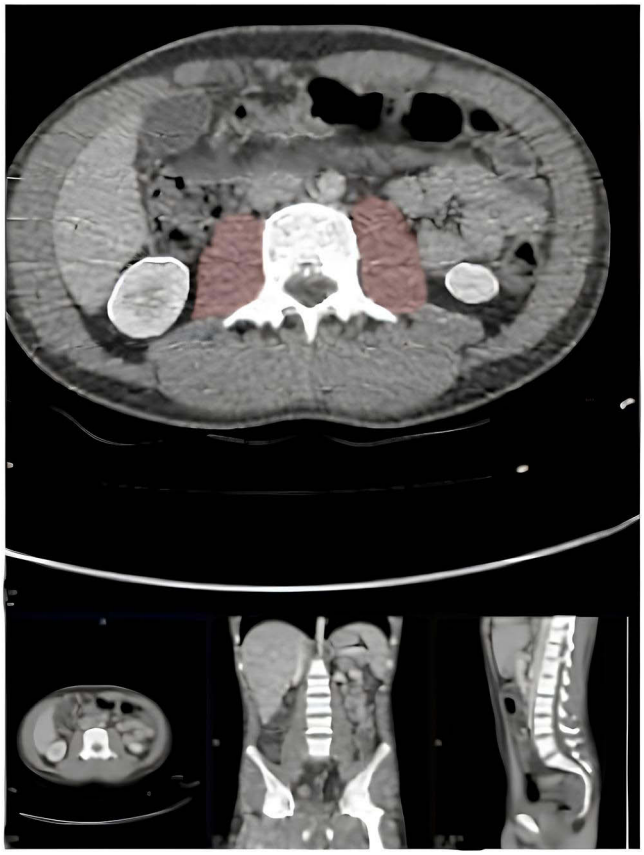

Figure 1 Axial L3 contrast-enhanced CT slice demonstrating manual segmentation of the bilateral psoas muscles at the level of the third lumbar vertebra (L3). The red outlined regions indicate the left and right psoas muscles; the sum of their cross-sectional areas is normalized to patient height squared (mm^2/m^2) to calculate the psoas muscle index (PMI).

Turkish population-based data were applied (<530 mm^2/m^2 for men, <360 mm^2/m^2 for women),[3] and patients were classified into sarcopenic and non-sarcopenic groups accordingly.

Data Collection

Demographic variables (age, sex), pathological stage (I–III), perioperative outcomes (including intra-abdominal abscess, pneumonia, anastomotic leak, duodenal stump leak, postoperative bleeding, prolonged ileus, surgical-site infection), perioperative transfusion requirements, length of hospital stay, and long-term survival status were obtained from electronic hospital information systems. Overall survival (OS) was defined as the time from surgery to death or final follow-up. Patients were routinely followed at 3–6 months after surgery and annually thereafter. When clinically indicated, some patients were monitored at shorter intervals. During follow-up, a proportion of patients were lost to follow-up for various reasons. Only patients with complete follow-up data and confirmed survival status were included in the final survival analyses; patients who were lost to follow-up were excluded from the study. Patients with missing clinical, pathological, or imaging data relevant to the study endpoints were excluded from the final analysis.

Statistical Analysis

Continuous variables were analyzed using the Mann–Whitney *U*-test, while categorical variables were compared using Fisher's exact or χ^2-tests, as appropriate. Kaplan–Meier methods were used to visualize survival. Time-specific overall survival differences (1-, 3- and 5-year OS) between PMI groups were evaluated using Fisher's exact tests at the corresponding time thresholds. Statistical significance was defined as $p < 0.05$. Statistical analyses were performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA).

Results

A total of 184 patients were included (106 sarcopenic; 78 non-sarcopenic). Baseline demographic characteristics and pathological stage distribution were comparable between groups (Table 1). Age (median 66 vs 66 years; p=0.599), sex distribution (74.5% vs 60.3% male; p=0.054) and pathological stage (I/II/III) did not differ significantly between sarcopenic and non-sarcopenic cohorts (overall p=0.224).

Postoperative morbidity did not differ between groups (Table 2). Rates of intra-abdominal abscess, pneumonia, anastomotic leak, duodenal stump leak, postoperative bleeding, prolonged ileus, surgical-site infection and perioperative transfusion requirement were similar between groups, and median length of hospital stay was identical (13 days in both groups, p=0.379). Given the very low number of events within individual complication subtypes, multivariable modelling for postoperative complications was not performed to avoid statistical overfitting.

In contrast, survival outcomes differed clearly between groups (Table 3). While the difference in 1-year OS was borderline (80.19% vs 91.03%; p=0.060), both 3-year and 5-year OS were significantly lower in sarcopenic patients (54.72% vs 79.49% and 43.40% vs 74.36%; both p<0.001). Kaplan–Meier curves demonstrated a sustained and progressive separation in favor of the non-sarcopenic cohort (Figure 2). In multivariable Cox regression analysis adjusted for age, pathological stage (entered as an ordinal variable from stage I → III), perineural invasion and lymphovascular invasion, preoperative PMI remained an independent prognostic factor for overall survival (HR 0.996; p<0.001). Notably,

Table 1 Baseline Clinicopathological Characteristics Stratified by Psoas Muscle Index (PMI)

Variable	Sarcopenic (n=106)	Non-sarcopenic (n=78)	p-value
Age, years (median [IQR])	66 [60–74]	66 [58–73]	0.599
Male sex, n (%)	79 (74.5%)	47 (60%)	0.054
Stage I	16 (15%)	14 (18%)	
Stage II	37 (35%)	17 (22%)	
Stage III	53 (50.0%)	43 (55%)	
Overall stage			0.224
Perineural invasion	66 (62%)	45 (58%)	1.000
Lymphovascular invasion	57 (52%)	45 (58%)	0.365

Table 2 Postoperative Outcomes Stratified by Psoas Muscle Index (PMI)

Outcome	Sarcopenic (n=106)	Non-sarcopenic (n=78)	p-value
Intra-abdominal abscess	3 (2.8%)	2 (2.6%)	1.000
Pneumonia	4 (3.8%)	3 (3.8%)	1.000
Anastomotic leak	5 (4.72%)	3 (3.85%)	1.000
Duodenal stump leak	2 (1.9%)	1 (1.3%)	1.000
Postoperative bleeding	3 (2.8%)	2 (2.6%)	1.000
Prolonged ileus	3 (2.8%)	2 (2.6%)	1.000
Surgical-site infection (wound)	12 (11.3%)	8 (10.3%)	1.000
Perioperative blood transfusion (any)	33 (31.1%)	24 (30.8%)	1.000
Length of hospital stay (days), median [IQR]	13 [10–15]	13 [10–15]	0.379

Table 3 Overall Survival at 1, 3 and 5 years According to PMI Status

Timepoint	Sarcopenic	Non-sarcopenic	p-value
1-year OS (%)	80.19%	91.03%	0.060
3-year OS (%)	54.72%	79.49%	<0.001
5-year OS (%)	43.40%	74.36%	<0.001

pathological stage also retained independent significance, with each incremental increase in stage associated with approximately a three-fold higher mortality risk (HR 3.10; p<0.001) Table 4. Information on nutritional status and body mass index was not consistently available and therefore could not be included in the multivariable models.

Discussion

In this two-center cohort of 184 patients (106 sarcopenic; 57.6% and 78 non-sarcopenic; 42.4%), preoperative psoas muscle index (PMI) clearly discriminated long-term risk. Although the difference in 1-year survival was borderline (80.19% vs 91.03%, p=0.060), both 3-year and 5-year overall survival were substantially worse in the sarcopenic group (3-year OS: 54.72% vs 79.49%, p<0.001; 5-year OS: 43.40% vs 74.36%, p<0.001). Importantly, PMI remained an independent predictor of mortality in multivariable Cox modelling (HR 0.996, p<0.001) despite adjustment for age, pathological stage, perineural invasion and lymphovascular invasion. Given that PMI is a continuous quantitative variable expressed in mm^2/m^2, hazard ratios close to 1.00 are expected, as small incremental PMI changes represent clinically meaningful differences across the full measurement range. In contrast, postoperative complication rates —

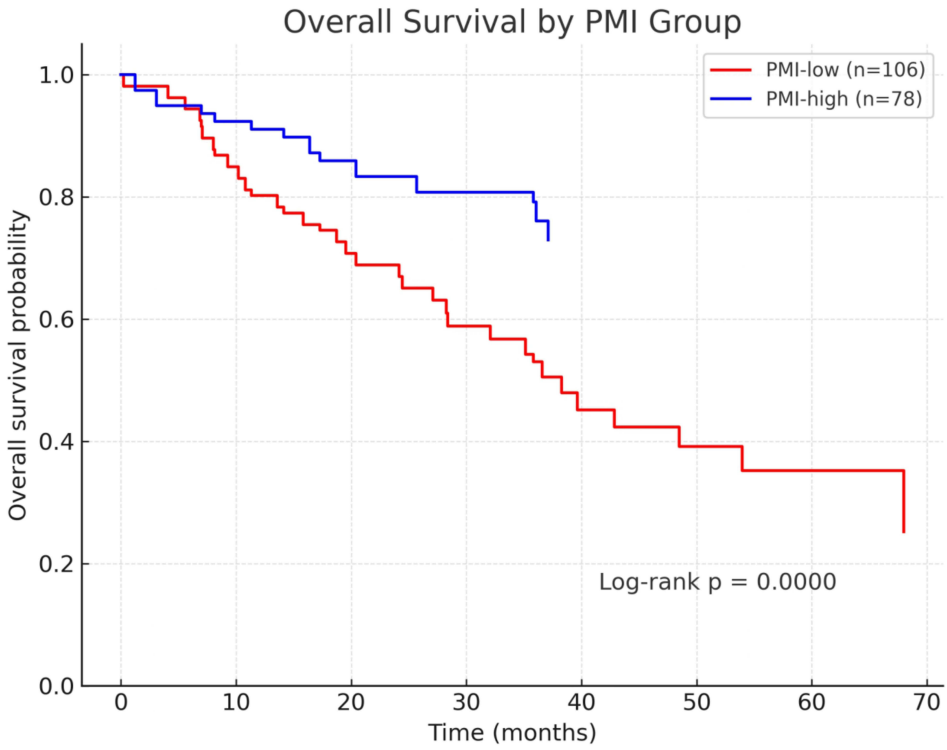

Figure 2 Kaplan–Meier overall survival curves comparing patients with low versus high psoas muscle index (PMI). Patients with low PMI demonstrated significantly lower long-term overall survival compared with those with high PMI (log-rank p < 0.001). The 3-year OS rates were 54.72% and 79.49%, and the 5-year OS rates were PMI, psoas muscle index; OS, overall survival.43.40% and 74.36% in the low and high PMI groups, respectively.
Abbreviations: PMI, psoas muscle index; OS, overall survival.

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Table 4 Multivariable Cox Regression Analysis for Overall Survival

Variable	Hazard Ratio (HR)	p-value
Age	1.003	0.756
Perineural invasion	0.896	0.626
Lymphovascular invasion	1.067	0.812
Psoas Muscle Index (continuous)	0.996	<0.001
Pathological stage (I → III)	3.10	<0.001

Note: Stage entered as an ordinal variable (I → III).

including anastomotic leak, duodenal stump leak, wound infection, bleeding, transfusion requirement and length of stay — were similar between groups (all $p \geq 0.379$), suggesting that skeletal muscle depletion reflects a baseline biological vulnerability that is not captured by early postoperative morbidity but translates into a sustained survival disadvantage.

We selected the psoas muscle index because CT-based psoas muscle quantification at the L3 level is one of the most widely used and reproducible preoperative skeletal-muscle metrics in gastric cancer cohorts,[13] and has repeatedly been shown to reflect clinically relevant host reserves in this specific disease context.[14] Compared with whole-slice skeletal muscle index, PMI is more practical to derive from routine staging CT, requires less segmentation time, and yields similar prognostic discrimination with lower operator-dependent variability—particularly in retrospective surgical datasets.[3,4,7] Thus, the use of bilateral psoas cross-sectional area normalized to height at L3 (mm^2/m^2) represents an efficient, clinically interpretable surrogate of skeletal muscle depletion for gastric cancer risk stratification.[15] Nevertheless, the use of a psoas-based metric instead of whole-slice skeletal muscle index may limit direct comparability with studies employing alternative sarcopenia definitions and should be considered when interpreting cross-study differences.

Evidence on whether preoperative sarcopenia increases early postoperative morbidity after gastrectomy remains heterogeneous. Several studies have suggested that low skeletal muscle mass may predispose to higher rates of postoperative complications, particularly pulmonary events or overall morbidity after radical gastrectomy.[16,17] In contrast, other cohorts have not demonstrated a significant association between skeletal muscle depletion and short-term surgical morbidity, despite confirming a clear negative impact on long-term survival outcomes.[7,13] Our findings are in line with this latter group: although 3-year and 5-year overall survival were markedly lower in sarcopenic patients, postoperative complication rates, transfusion requirement and length of stay were comparable between sarcopenic and non-sarcopenic individuals in our analysis. Notably, the overall incidence of postoperative complications in our cohort was low, which limits statistical power for short-term morbidity analyses and warrants cautious interpretation of these findings. Methodological variation may partly explain the discordance across the literature, including differences in muscle assessment metrics (psoas-based vs whole-slice skeletal muscle index), population-specific cut-off thresholds, tumour stage distributions, and low event counts that can limit the reliability of modelling in postoperative morbidity. Overall, these data support the concept that preoperative muscle depletion in gastric cancer reflects long-term biological reserve rather than short-term physiological resilience, which may explain why its prognostic effect is more pronounced for overall survival than for early postoperative complications. This interpretation is also supported by recent evidence demonstrating that psoas muscle loss is linked to impaired tumour immune microenvironment — including reduced tertiary lymphoid structures (TLS) and diminished $CD3^+/CD20^+$ infiltration — thereby driving long-term survival biology rather than short-term surgical morbidity.[18]

Recent high-quality evidence demonstrates that preoperative skeletal muscle depletion is strongly associated with inferior long-term survival in gastric cancer, with clear divergence of Kaplan–Meier curves emerging during extended follow-up rather than the early postoperative period.[4,5,6] Our findings align with this pattern: although early survival did not differ, long-term mortality was substantially worse in sarcopenic individuals, reinforcing the concept that PMI reflects a chronic biological vulnerability that drives tumour behaviour, immune surveillance inefficiency and long-term oncologic resilience rather than short-term surgical recovery capacity. Importantly, unlike most prior gastric cancer

sarcopenia studies — which typically report OS as a single composite endpoint — we analysed 1-, 3- and 5-year survival separately, allowing us to describe the temporal pattern through which muscle depletion manifests prognostic impact. However, we acknowledge that this observation requires validation in larger external cohorts, and that some studies have indeed demonstrated earlier mortality divergence within the first postoperative year;[19] therefore, our findings should be interpreted as supporting evidence for a predominantly long-term effect rather than a definitive temporal boundary.

This study has several strengths. We analysed a homogeneous upfront-surgery cohort without neoadjuvant therapy, allowing a cleaner evaluation of baseline host reserve. Moreover, the use of sex-specific PMI thresholds derived from Turkish population-based datasets increases real-world applicability in our setting. However, the population-specific nature of these thresholds may limit their external generalizability beyond Turkish cohorts and warrants validation in other ethnic and geographic populations. Although the cohort originated from two high-volume tertiary referral centres and thus reflects practice in specialist environments, the absolute sample size remains modest; therefore, some subgroup comparisons – particularly for early postoperative events – lacked sufficient power for multivariable modelling. In addition, as adjuvant therapy is a well-recognized determinant of long-term survival in gastric cancer, the absence of detailed data on adjuvant treatment regimens, completion rates, and relative dose intensity represents an important limitation. Consequently, we were unable to determine the extent to which the observed survival differences were mediated by treatment-related factors rather than baseline muscle reserve alone, and the survival findings should be interpreted with appropriate caution. Furthermore, standardized comorbidity indices such as the Charlson Comorbidity Index or ASA score were not consistently available in this retrospective dataset and therefore could not be incorporated into the analyses, which should be considered when interpreting the results. Finally, muscle quality indices such as myosteatosis were not assessed; future prospective studies integrating both muscle quantity and quality metrics may further refine prognostic stratification.

Conclusions

In conclusion, preoperative psoas muscle depletion was not associated with increased postoperative morbidity in our cohort; however, it was clearly linked to inferior long-term overall survival. The absence of an observed association with early postoperative morbidity should be interpreted with caution, as the low incidence of postoperative events may have limited the ability to detect such an effect. These findings suggest that low PMI reflects a long-term biological vulnerability rather than short-term physiological fragility. From a clinical perspective, PMI represents a simple and readily available CT-based metric that may be incorporated into routine preoperative assessment to identify patients at higher long-term oncologic risk and to guide targeted nutritional and physical optimization strategies before surgery.

Institutional Review Board Statement

Ethical approval was obtained from the Mersin University Clinical Research Ethics Committee (23 July 2025; Decision No: 2025/838). At the second participating center (Ege University), institutional authorization for the use of anonymized patient data in scientific research was granted by the Office of the Chief Physician (03 July 2025; Authorization No: 2516905), in accordance with national regulations.

Data Sharing Statement

Data are available from the corresponding author upon reasonable request.

Informed Consent Statement

Given the retrospective design, the requirement for individual informed consent was waived by the ethics committee in accordance with national regulations.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no conflicts of interest in this work.

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