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Authors

Evans, Lauran
Moffatt, Clare
Niknejad, Keon
et al.

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Risk Analysis Index Frailty Score as a Predictor of Otolaryngology Surgical Outcomes

Lauran K. Evans, MD, MPH[1], Clare Moffatt, BS[1], Keon Niknejad, BS[2], Hong-Ho Yang, BS[1], Laura Kodaverdian, BA[1], Shady Soliman, MD[1], Francis Reyes Orozco, MD[1], and Dinesh K. Chhetri, MD[1]

Abstract

Objective. The Risk Analysis Index (RAI) score is a screening tool to assess patient frailty. It has been shown to be predictive of postoperative outcomes and mortality in orthopedic, urologic, and neurosurgical patient populations. We sought to evaluate the predictive ability of RAI score for surgical outcomes in an otolaryngology patient population.

Study Design. Retrospective study.

Setting. Academic tertiary medical center.

Methods. A retrospective study was conducted of adult patients undergoing otolaryngology surgery at a tertiary medical care center over 21 months. Patients were sent electronic RAI survey questionnaires via direct messaging, which was completed prior to surgery. Endpoint data were analyzed, including demographics, RAI score, and patient outcome data. Univariate analysis, ROC curves, and predictive modeling were utilized.

Results. A total of 517 patients responded to the RAI questionnaire, resulting in a 59.6% response rate. Mean RAI score was 21.38 ± 11.83. Higher RAI scores were associated with increased 30-day readmissions ($P < .0015$), postoperative complications ($P < .001$), hospital length of stay ($P < .001$), and discharge with home health ($P < .001$). Predictive models for RAI score and postoperative outcomes were created, and a cutoff score of RAI = 30 was established to identify frail patients.

Conclusion. We evaluated if RAI scoring predicted postoperative complications in an otolaryngology patient population. Increased RAI score is significantly associated with poorer surgical outcomes, including increased hospital length of stay, 30-day readmissions, and postoperative complications. We propose a predictive model with suggested RAI cutoff scoring for use in the otolaryngology surgical population.

Keywords

frailty, frailty scoring, postoperative complications, risk analysis index, surgery

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Frailty in a patient encompasses a spectrum of dimensions, that leaves the patient vulnerable to adverse outcomes due to physical, physiological, or psychosocial stressors.[1,2] Frailty has been consistently identified as a clinical risk factor for mortality, postoperative complications, increased length of hospital stay, intensive care unit (ICU) admission, increased risk of readmission, discharge to a rehabilitation/care facility, increase in hospital costs, and overall decline in health-related quality of life.[3] Frailty significantly influences poor outcomes postoperatively in a wide range of surgical specialties. Understanding how frailty predicts short and long-term patient outcomes enables informed risk stratification prior to surgery, which can play an important role in guiding decisions around the approach to surgery itself, as well as postoperative management to minimize morbidity and mortality.

Several instruments have been developed to measure and screen for frailty among surgical patients, including the modified frailty index (mFI), Johns Hopkins Adjusted Clinical Groups frailty-defining diagnosis indicator, Katz score, Timed Up-and-Go, Charlson Index, and Mini-Cog.[4,5] In otolaryngology literature, the most frequently studied is the mFI, which has been shown to predict outcomes across a variety of otolaryngologic surgeries, including complex head and neck surgery,[6] total laryngectomy,[7] skull base surgery,[8] and tracheostomies.[9] However, many frailty tools are

[1]Department of Head and Neck Surgery, David Geffen School of Medicine at UCLA, Los Angeles, California, USA
[2]The Johns Hopkins University School of Medicine, Baltimore, Maryland, USA

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Corresponding Author:
Lauran K. Evans, MD, MPH, Department of Head and Neck Surgery, David Geffen School of Medicine at UCLA, CHS 62-235, 10833 Le Conte Ave. Los Angeles, CA 90095, USA.
Email: LKEvans@mednet.ucla.edu

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optimized for applications in research or administration, including the mFI, which was developed using the National Surgical Quality Improvement Program database,[10] which makes them less practical to streamline into clinical use. The Risk Analysis Index (RAI) is a validated screening tool developed by a multivariate model and introduced in 2017 to assess preoperative frailty in surgical patients.[11] There are 2 versions of the RAI screening tool, the clinical RAI-C, measured prospectively, and the administrative RAI-A, measured retrospectively. In this paper, we focus on RAI-C, the "first frailty index used explicitly for systemwide screening of surgical populations,"[11] which can be calculated using a clinical patient questionnaire. Compared to other frailty indices, the RAI-C offers the unique benefit of being a quick, point-of-care screening tool with a demonstrated median collection time of 33 seconds.[12] With this efficient collection approach, it can be implemented by clinicians across many healthcare settings, without the need for a retroactive search through the electronic medical record (EMR) for patient parameters.

The RAI is a weighted score from 0 to 81 calculated based on age, sex, cancer status, co-morbid medical conditions, living status, nutrition status, cognitive status, and ability to perform activities of daily living (ADLs). The RAI framework has been incorporated in many hospital systems nationwide[12] and continues to be refined.[13] It is equally predictive for both men and women, and amongst a spectrum of surgical specialties including orthopedic surgery, urology, and neurosurgery.[14]

Despite the growing evidence for utilizing RAI to assess frailty, its application specifically within Otolaryngology–Head and Neck Surgery (OHNS) has remained largely unexplored. We aimed to evaluate the utility of the RAI-C in predicting postoperative outcomes. Our hypothesis is that a higher RAI score, quantifying increased patient frailty, will be predictive of negative postoperative outcomes in the OHNS population.

Materials and Methods

Study Design and Data Collection

This single-center retrospective study evaluated all patients who underwent surgery with the Department of Head & Neck Surgery at the University of California, Los Angeles Medical Center between February 2022 and November 2023. We implemented RAI scoring into an easily disseminated Questionnaire through the Epic EMR. RAI questionnaires are prospectively sent to all patients undergoing OHNS at our institution by surgery schedulers through MyChart Messaging. Patients completed the questionnaire, and scores were automatically calculated and placed into the EMR's Flowsheets. Following Institutional Review Board (IRB) approval, retrospective chart review was completed to include demographic, diagnostic, procedural, and postoperative data. Selected outcomes measures were those utilized by the our hospital system for its quality metrics, and included mortality, postoperative complications within 30 days, length of hospital stay, ICU admission, discharge disposition (home, skilled or other nursing facility, home health service), home health skilled nursing or physical therapy, surgical re-operation, 30-day hospital readmission, or 30-day emergency department (ED) visit following discharge (see **Table 2** and Supplemental Appendix S1, available online for list and ICD-10 codes). Subspecialty classification of the surgery was based on the type of surgery and surgeon specialist performing the case. These included facial plastic and reconstructive surgery (FPRS), sleep, head and neck, rhinology, laryngology, and otology.

RAI Questionnaire Scoring

The RAI-C is a multi-parameter tool consisting of 11 items used to screen patients for their risk of frailty, expressed as both total combined point score and category-based points. Scoring consists of parameters including age, sex, cancer diagnoses within the past 5 years, medical comorbidities such as weight loss within the past 3 months, renal failure, congestive heart failure, poor appetite, and shortness of breath at rest. Independence for a patient's ADLs is assigned a score between 0 and 4 (from independent to total dependence) for a patient's mobility, eating ability, toilet usage, and personal hygiene. Deterioration of cognitive skills over the past 3 months is also included in the final calculation. Finalized RAI scores range from 0 to 81. The RAI questionnaire is presented in **Table 1**. Supplemental scoring considerations are in Supplemental Appendix S2, available online.

Statistical Analysis

RAI score was treated as a continuous variable, while other continuous variables, such as length of stay, were treated as both continuous and dichotomized (>1 day vs <1 day length of stay). Categorical and variable data between patient groups was assessed through t-tests and Chi-squared univariable analyses. A 2-tailed $P = .05$ was employed to determine the statistical significance of associations. Qualitative variables were expressed as percentages while quantitative variables were given as means with standard deviations, when appropriate. Violin plots were created for outcome of interest. Univariable analysis for outcomes of interest was also performed using odds ratios with 95% confidence interval (CI). Receiver operating characteristic curve (ROC) curves and probability curves were calculated for outcomes of interest that were found to be associated with RAI via univariable analysis. Sensitivity and specificity were calculated based on best statistical fit. Additionally, sensitivity and specificity were established for a cutoff of 20% risk of an outcome occurring for clinical significance. JMP (Version 17) and Stata (Version 17) were used for statistical analysis and data visualization.

Table 1. An Example of the RAI-C Questionnaire and Scoring Schema Used in This Study for Preoperative Assessment of Surgical Patients in the Department of Head & Neck Surgery

Patient sex	
Female or male?	Female = 0, Male = 3
Residence	
Do you live in a place other than your own home?	No = 0, Yes = 1
Medical conditions	
Any kidney failure or disease, poor kidney function, or seeing a kidney doctor (nephrologist)? If yes, was this for kidney stones or another problem?	No = 0, Yes = 8
Any history of chronic (long-term) congestive heart failure (CHF)?	No = 0, Yes = 5
Any shortness of breath at rest?	No = 0, Yes = 3
In the past 5 years, have you been diagnosed with or treated for cancer?	If no, score without cancer If yes, score with cancer
Nutrition	
Have you lost 10 pounds or more in the past 3 months without trying?	No = 0, Yes = 4
Do you have any loss of appetite?	No = 0, Yes = 4
Cognitive	
During the last 3 months, has it become difficult for you to remember things or organize your thoughts?	If no, score ADL without cognitive decline If yes, score ADL with cognitive decline
Activities of Daily Living (ADL)	
Getting around (mobility)	0. Independent 1. Supervised 2. Limited assistance 3. Extensive assistance 4. Total dependence
Eating	0. Independent 1. Supervised 2. Limited assistance 3. Extensive assistance 4. Total dependence
Toileting	0. Independent 1. Supervised 2. Limited assistance 3. Extensive assistance 4. Total dependence
Personal hygiene (bathing, hand washing, changing clothes)	0. Independent 1. Supervised 2. Limited assistance 3. Extensive assistance 4. Total dependence

Table 2. Clinical Characteristics of the Cohort Undergoing Otolaryngology–Head & Neck Surgery Who Responded to the Risk Analysis Index Frailty Questionnaire

Variable	*n* (%)
RAI Score	Mean = 21.38
Age at surgery	Mean = 54.60 years
Length of stay	Mean = 0.96 days
Sex	
Female	240 (46.4)
Male	276 (53.4)
Unknown	1 (<1%)
All-Cause Mortality (30-day)	1 (0.19)
Length of stay > 1 day	81 (15.66)
Postoperative ICU stay	2 (0.39)
Return to OR (30-day)	13 (2.51)
Return to ED (30 day)	12 (2.32)
Readmission (30-day)	9 (1.74)
Postoperative complications (30-day)	33 (6.38)
Aspiration event	4 (0.77)
Pneumothorax	2 (0.39)
Sepsis	4 (0.77)
Surgical site infection	3 (0.58)
Hematoma	1 (0.19)
Hemorrhage	0 (0.00)
Acute anemia	22 (4.26)
Respiratory distress	0 (0.00)
Tracheostomy complication	2 (0.39)
Flap failure	0 (0.00)
Deep vein thrombosis	0 (0.00)
Pulmonary embolism	0 (0.00)
Postprocedure fever	1 (0.19)
Ileus	1 (0.19)
Discharged with home health skilled nursing	27 (5.22)
Discharged with home health physical therapy	18 (3.48)

Results

The cohort comprised 517 patients who completed RAI scoring. This reflected a 59.6% response rate. Among them, 240 (46.4%) were female, 276 (53.4%) were male, and gender of 1 patient remained unknown. Mean age at surgery was 54.60 years (SD ± 17.70 years). Mean RAI score was 21.38 (SD 11.83, range 0-69), and median RAI score was 20. Mean length of stay was just over 1 day (29.44 ± 53.98 hours). Clinical characteristics of the cohort are listed in **Table 2**.

Mean RAI scores varied across subspecialties, with values of 15.8 for rhinology, 19.1 for otology, 21.8 for sleep, 23.9 for laryngology, 24.8 for head and neck, and 28.2 for FPRS. Response rates by specialty were FPRS (78%), sleep (74%), head and neck (66%), rhinology (57%), laryngology (53%), and otology (49%).

Mean male RAI score was 24.34 ± 11.74, and for female was 18.04 ± 11.04. This represents a 35% increase in the average male RAI as compared to female. Higher RAI scores were significantly associated with increased 30-day readmission rate, discharging with home health nursing or physical therapy, length of stay >1 day, and postoperative complications (all $P < .001$, see **Figure 1** and **Table 3**). Higher RAI score was not associated with 30-day return to the operating room or ED. For the binary variable of cancer diagnosis alone, odds ratio for length of stay >1 day was 4.79 (95% CI = 2.91-7.89). The odds ratio for cancer diagnosis alone for any postoperative complication was 6.64 (95% CI = 3.16-13.94).

The data is presented for the 59.6% of patients who responded to the RAI questionnaire. Among the other 40.4% of nonrespondents, average age was 55.3 years, slightly higher compared to 53.0 years in respondents ($P = .11$), indicating no statistically significant difference. However, further analysis of nonrespondents was limited by data availability.

Utilizing ROC and predictive curves illustrated in **Figure 2**, RAI score was used to predict length of stay >1 day and any postoperative complication. Both outcomes were accurately predicted with utilization of the RAI score ($P < .0001$ and <.001, respectively). Clinically relevant sensitivities (Se) and specificities (Sp) were determined for optimal patient screening. The associated RAI cutoffs and predictive values were RAI = 24 for length of stay >1 day (Se = 69%, Sp = 69%, [95% CI = 58-78, 64-73]) and RAI = 32 for any postoperative complication (Se = 67%, Sp = 77%, [95% CI = 50-80, 73-81]). While the regression model demonstrates RAI = 44 for precisely 20% chance of postoperative complication, the probability of a >20% chance of complication intercepts at RAI = 33.

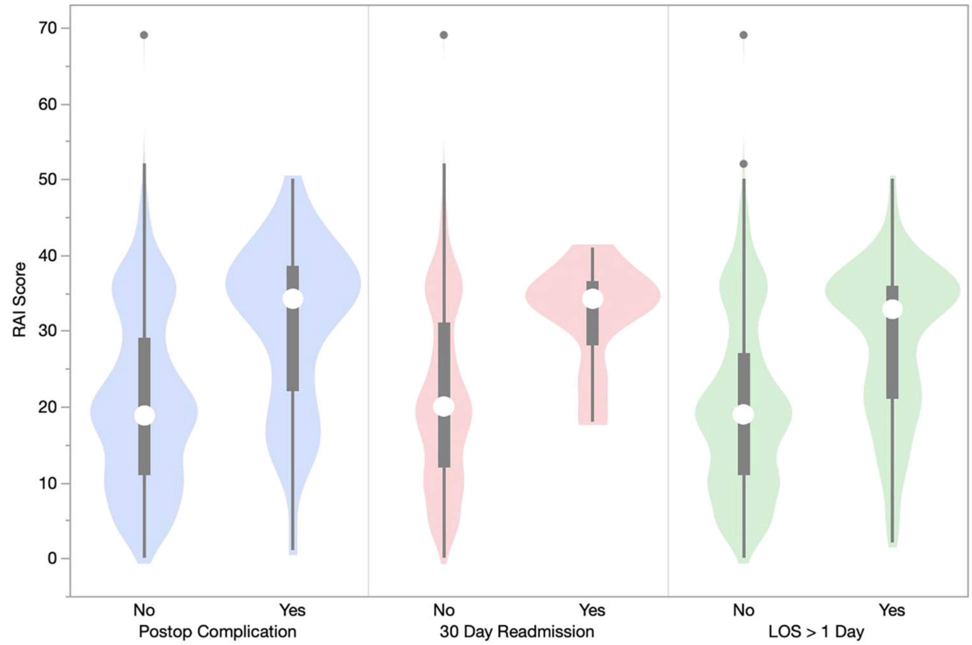

Figure 1. Risk Analysis Index (RAI) score distribution represented via violin plots of 3 outcomes of interest: postoperative complication, 30-day readmission, and length of stay (LOS) >1 day. The ure demonstrates that higher RAI scores are seen among those who experienced a postoperative complication, 30-day readmission, and LOS >1.

Table 3. *T*-Test Univariate Analysis of Mean RAI Scores Compared Between Binary Selected Outcomes, With Associated Significance Value

Variable	Mean RAI Score *with* Outcome (SD)	Mean RAI Score *without* Outcome (SD)	RAI Score Difference	*P* value
Male sex	24.34 (11.74)	18.04 (11.04)	5.30	<.0001*
Length of stay >1 day	27.02 (10.26)	20.03 (11.61)	6.99	<.0001*
Return to OR (30-day)	23.85 (12.58)	21.32 (11.82)	2.53	.498
Return to ED (30 day)	22.50 (13.16)	21.36 (11.81)	1.14	.776
Readmission (30-day)	32.22 (7.03)	21.19 (11.81)	11.03	.0015*
Postoperative Complication (30-day)	30.82 (11.15)	20.74 (11.61)	10.08	<.0001*
Discharged with HH Skilled Nursing	32.93 (9.79)	20.75 (11.61)	12.18	<.0001*
Discharged with HH Physical Therapy	32.83 (10.08)	20.97 (11.69)	11.86	<.001*

Abbreviations: ED, emergency department; HH, home health; OR, operating room; RAI, Risk Analysis Index.
*denotes statistical significance.

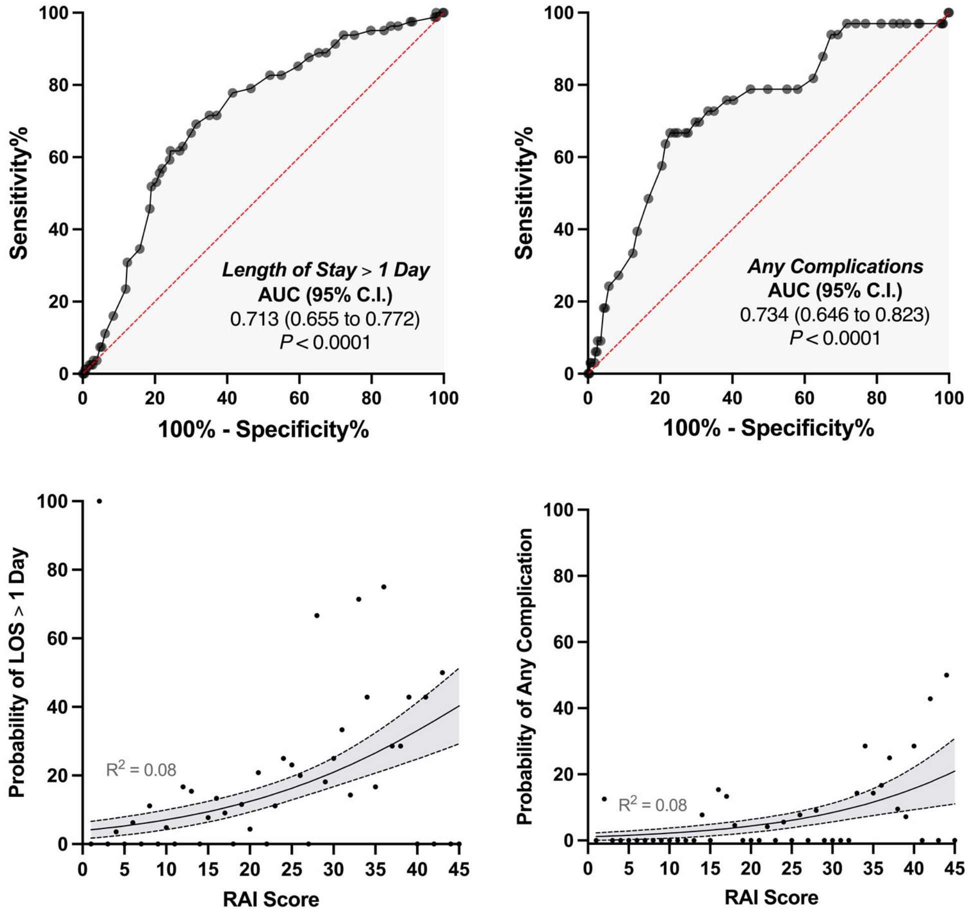

Figure 2. Receiver operating characteristic curve and predictive curves for outcomes of interest predicted by the Risk Analysis Index Score, including length of stay (LOS) >1 day and postoperative complications.

Discussion

Our study aimed to evaluate the efficacy of RAI as a prognostic tool for assessing frailty in patients undergoing OHNS. In our sample of 517 patients, our results suggest that the tool successfully differentiates between frail and nonfrail patients in this surgical setting, with high predictive accuracy of postoperative morbidity. These findings provide valuable insights for the surgical team, empowering them to tailor and optimize patient care based on individual frailty assessments. In our cohort, higher RAI scores were significantly correlated with increased postoperative complications, length of stay, discharge with home health, and readmissions, which aligns with previous studies demonstrating the tool's predictive validity in various surgical populations within multipractice, multihospital healthcare systems.[11,12] Specifically, patients with scores ≥RAI of 33 had >20% chance of postoperative complications. ROC curves demonstrated RAI cutoff scores ranging from 24 to 32, for different postoperative outcomes. As with any selection for cutoff scores, sensitivity must be balanced with specificity. The ideal selection may vary based on healthcare setting.[11] The RAI serves as a screening test to identify frail patients who may necessitate an intervention. With this in mind, utilizing a cutoff score around RAI = 30 is suggested by the predictive models in this study, which aligns with the literature on RAI-C.[11-13,15,16] Cancer diagnosis was also found to increase the odds of length of stay >1 day and postoperative complications but further research is needed to assess if this in an independent risk factor. To the best of our knowledge, this study represents the first outcomes analysis of RAI scores within OHNS patients, cementing the RAI framework as a valuable and relevant tool, and offering a unique perspective on its applicability and significance in otolaryngology.

While elevated RAI scores were associated with most of the negative postoperative outcomes in this study, certain categories did not provide sufficient data for conducting analyses. Namely, mortality only occurred in 1 patient, and postoperative ICU stay only occurred in 2 patients (<1%). Furthermore, outcomes of 30-day readmission, return to OR, and return to ED occurred in a limited number of patients (less than 14 each, <3% of the cohort) thus limiting robust statistical analysis.

When examining differences in average RAI scores between males and females in our cohort, we found that the significantly higher scores in males may run counter to the conventional belief that females tend to exhibit higher frailty scores than males, as demonstrated in prior studies.[17] However, notably this pattern has been shown to vary depending on the specific frailty tool utilized.[18] The RAI-C adds 3 points for male status which is likely meaningfully contributory to the higher score in our cohort. Irrespective of frailty levels, our findings indicate that males exhibit higher overall mortality, sparking discussions around the male-female health-survival paradox, for which biological explanations include genetic, hormonal and autoimmune responses, and psychosocial factors.[19,20]

The RAI score has been validated as a predictor of postoperative morbidity and mortality in several surgical subspecialties, including vascular, gastrointestinal, and orthopedic surgery, neurosurgery, and urology. In addition to predicting outcomes, it can be used to risk stratify patients to identify those at a higher risk for postoperative complications, and as such may not benefit from a high-risk procedure, as was seen in patients undergoing carotid endarterectomy.[21] Not only has it served as a predictor, but its systematic implementation also has in some populations improved postoperative mortality.[22]

The enhanced predictive capacity of RAI for adverse surgical outcomes beckons a transformative shift in clinical paradigms, introducing a readily available, quantifiable measure of frailty. While previous tools such as the mFI have been developed to stratify patients based on their comorbidities[18] none match the efficiency profile of RAI-C in its rapid data collection. With reported data collection times under 1 minute, a frailty score can be promptly generated and made available to the entire surgical team. By furnishing a quantifiable measure of frailty, the RAI empowers clinicians to make more informed decisions regarding surgical recommendations and postoperative care for each patient.

Given the intricate and often invasive nature of OHNS, the RAI's utility lies in its ability to provide numerical guidance to surgeons for tailoring surgical approaches to individual risk profiles. Prehabilitation strategies can be strategically implemented, focusing on patients who stand to benefit the most, with specialized attention aimed at mitigating identified risks based on the scoring parameters. Importantly, a more efficient utilization of resources can be achieved by focusing supplementary care on those patients who are likely to derive the most benefit. For example, in an implementation study of RAI in patients undergoing major, elective noncardiac surgery that led to improved postoperative mortality, interventions included discussions amongst the care team regarding patient frailty score and preoperative palliative planning around surgical goals and postoperative recovery.[22] Accurately predicting which patients are at risk for postoperative complications, 30-day readmissions, and extended length of stays not only improves quality of care but can also reduce hospital-related costs and improve resource allocation.

Several limitations are inherent in this study. First, we were unable to compare the RAI to other frailty indices. Although the RAI has demonstrated predictive abilities in other surgical specialties, confirming our study's findings, a direct comparison with alternate frailty measures such as the mFI, was not undertaken. However, this study remains an important independent assessment of RAI as an effective and efficient frailty tool in otolaryngology. The original creators of the RAI even suggest a 2-stage screening paradigm, where the RAI-C, which has the advantage of speed and sensitivity, can be used to quickly identify frail patients, and a second more labor-intensive stage could further confirm frailty. Thus there is value to further exploring and comparing RAI and alternative frailty indices.[11] The response rate for patients completing the electronic RAI questionnaire was 59.6%, introducing potential selection bias that responders may be more technologically savvy and possibly healthier. However, as there was no significant difference in age between respondents versus nonrespondents, we anticipate this potential to be minimal. Our response rate is also in line with that found in surgical patients based on a recent systematic review, which identified 59.3% ± 18.9% response rate for web-based surveys and 68.0% ± 17.1% for email-based surveys.[23] Future response rates could be bolstered through in-clinic assessment, preoperative day of surgery assessment, and nursing follow-up. Additionally, there is room for improvement in the sensitivity and specificity of the RAI score as a predictor of outcomes. Future studies should examine a larger sample size and delve into modifications of the RAI-C index for improved predictive accuracy. Due to the broad makeup of RAI scores from OHNS subspecialties in this study, it is reasonable to infer that these results would be generalizable to other OHNS academic institutions. Although there is heterogeneity in our patient population, our pilot study demonstrates strong proof of concept of the implementation and merit of RAI-C in an institutional healthcare setting. Ongoing evaluation of RAI scores across various surgical fields remains crucial.

Moving forward, the research trajectory should focus on several key areas. Longitudinal studies are necessary to determine the RAI's efficacy in predicting long-term outcomes, such as the 1 to 2 year horizon post-OHNS. Focus on functional status, quality of life, and long-term survival could offer valuable insight on the patients' longer-term recovery with regard to their frailty. Future research should also explore the potential for RAI score to guide targeted interventions for frailty pre-operatively, enhancing patient resilience to surgical stress and improving the course of their recovery. The utility of RAI in the shared decision-making process warrants further exploration as well. While the standard of patient-centered care already emphasizes informed consent and aligning treatment with each patient's values and preferences, incorporating RAI assessments into preoperative discussions could enhance the quality of shared decision-making. This could provide patients and their families with a clearer understanding of associated expectations and risks, fostering a more comprehensive and informed decision-making process.

Throughout the development of this study, the integration of the RAI into the EMR has consistently remained one of our primary objectives, not only within OHNS but across all surgical subspecialties. Further confirmatory studies of RAI's predictive power within specific surgical subspecialties would be warranted to ensure accurate application and subsequent resource allocation. The significance of having point-of-care scoring available cannot be overstated, benefiting both the patient and their healthcare team. Enabling every member of the patient's care team to share a common understanding of the patient's individual frailty profile enhances communication and coordination. The patient would be able to ensure that the entirety of their relevant markers for frailty are being considered, with overall improved outcomes for the involved patients, providers, and healthcare systems.

Conclusion

In this OHNS cohort, RAI score accurately predicts postoperative complications, 30-day readmissions, and postoperative length of stay. In sum, our study not only confirms the RAI's predictive power within the realm of head and neck surgery but also advocates for its broader application across surgical subspecialties and its integration into the EMR. The RAI-C represents a significant advancement in the quest for personalized surgical care by facilitating a more nuanced understanding of patient frailty through an efficient point-of-care clinical questionnaire. The continued evolution of this tool will undoubtedly hinge on interdisciplinary research efforts with an aim to refine its predictive accuracy and clinical utility even further.

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Author Contributions

Lauran K. Evans, study design, data collection, data analysis, writing, editing; **Clare Moffatt**, study design, data collection, data analysis, writing, editing; **Keon Niknejad**, data collection, writing, editing; **Hong-Ho Yang**, data analysis, editing; **Laura Kodaverdian**, writing, editing; **Shady Soliman**, writing, editing; **Francis Reyes Orozco**, writing, editing; **Dinesh K. Chhetri**, study design, writing, editing.

Disclosure

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Supplemental Material

Additional supporting information is available in the online version of the article.

ORCID iD

Lauran K. Evans https://orcid.org/0000-0002-9860-5248
Clare Moffatt http://orcid.org/0000-0003-2794-9956

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