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# Longitudinal Examination of Swallowing Safety and Vocal Fold Mobility in Cardiac Surgical Patients

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## Abstract

**BACKGROUND—**Aspiration and vocal fold mobility impairment (VFMI) are frequently reported in adults after cardiac surgery (CS) and impede recovery. Preoperative and postoperative laryngoscopic evaluations have not been undertaken, masking the incidence and evolution of dysphagia and VFMI in CS patients. We therefore sought to determine frequency of unsafe swallowing and VFMI before and after CS.

**METHODS—**Thirty-five adults undergoing elective CS enrolled. Participants underwent fiberoptic endoscopic evaluations of swallowing and VFMI before and after surgical procedure. Trained raters performed duplicate, blinded ratings with the validated Penetration-Aspiration Scale, and a laryngologist performed blinded ratings of VFMI. Descriptive, Wilcoxon signed rank, and McNemar tests were performed.

**RESULTS—**Preoperative swallowing safety profiles were 60% safe, 34% penetration, and 6% aspiration. Postoperative swallowing safety profiles were 14% safe, 63% penetration, and 23% aspiration. Significant differences in preoperative to postoperative swallowing outcomes were noted for Penetration-Aspiration Scale scores ($P < .0001$), unsafe swallowing (40% vs 86%; $\chi^2 =$



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12.8; $P = .0003$), and aspiration (6% vs 23%; $\chi^2 = 6$; $P = .01$). No differences in VFMI were noted preoperatively to postoperatively (partial VFMI, 9% vs 23%; $P > .05$).

**CONCLUSIONS—**A 4-fold increase in aspiration was observed in CS patients. No cases of vocal fold paralysis were observed across time points. These data highlight the utility of instrumental laryngoscopic evaluations during the acute postoperative phase.

Swallowing safety impairment and vocal fold mobility impairment (VFMI) are known complications of cardiac surgery (CS) that are associated with morbidity and death.[1–5] A prospective study of 182 CS patients using fiberoptic endoscopic evaluation of swallowing (FEES) revealed that one-quarter of CS patients exhibited partial (n = 39) or complete (n = 7) VFMI on laryngoscopic examination. CS patients with complete VFMI were noted to have extended length of hospital stay and increased costs of care and demonstrated higher rates of pneumonia, reintubation, and death compared with CS patients without a complete VFMI. FEES also revealed postoperative swallowing safety impairments (penetration, aspiration) in 94% of CS patients.[3] Compared with nonaspirators, CS patients who aspirated had a 43% extended hospital stay, ~$50,000 increase in cost of care, 3-fold increase in pneumonia, 6-fold increase of reintubation, and 3-fold increase in 90-day probability of death.[3]

A retrospective study by Daly and colleagues[1] examining prevalence of postoperative dysphagia in 41 CS patients observed dysphagia in 80% of individuals clinically referred to a speech-language pathologist. Of the 41 CS patients in this study, 24 underwent instrumental swallow evaluations, with silent aspiration observed in 70% of this subcohort (n = 17). Individuals with dysphagia waited 6 days longer to resume oral intake, stayed in the hospital 13 days longer, and had 3.3 higher odds for development of pneumonia.[1] These data reveal that dysphagia and silent aspiration are prevalent after CS and can lead to adverse health outcomes during the acute postoperative recovery phase.

Although prevalence of postoperative dysphagia and VFMI in CS patients has been examined,[1–4] longitudinal instrumental examinations of vocal fold movement and swallowing safety are yet to be undertaken. Consequently, prevalence of preexisting voice and swallowing impairment and relative change in voice and swallowing preoperatively and postoperatively are unclear in this population. We therefore aimed to longitudinally profile preoperative and postoperative pharyngolaryngoscopic anatomy, vocal fold mobility, and swallowing safety in adults undergoing CS.

## MATERIAL AND METHODS

### RESEARCH PARTICIPANTS.

Individuals were recruited from a preoperative clinic. Inclusion criteria were adults aged 18 to 90 years undergoing an elective CS through sternotomy or extended thoracotomy and willing to undergo preoperative and postoperative evaluations of voice and swallowing. Our university's institutional review board approved this study (June 25, 2021; IRB202100993), and enrolled participants provided written informed consent.

### LARYNGOSCOPIC EXAMINATION OF VOCAL FOLD MOBILITY AND SWALLOWING.

Participants underwent standardized preoperative and postoperative evaluations by FEES. An Olympus flexible video high-definition rhinolaryngoscope (ENF-V3) connected to a portable video processor and light source (Olympus CV170) was used. A lubricating jelly and topical lidocaine were applied to the naris, and the laryngoscope was passed transnasally through the velopharyngeal port to the hypopharynx to visualize the pharynx and larynx. Before bolus trial administration, standardized voicing tasks were completed.[5] Standardized bolus trials were then administered.[3] To maintain patient safety, examinations were terminated after 2 episodes of gross aspiration or if >70% of an ingested bolus could not be cleared.

Examinations were conducted within 72 hours of surgical procedure (preoperative) and within 72 hours of extubation (postoperative). For postoperative evaluations, participants needed to have a Richmond Agitation-Sedation Scale[6] score of 0, to sit upright, and to have stable vital signs (oxygen saturation >90%, respiratory rate <30 breaths/min, off of noninvasive ventilation for >30 minutes).

### DATA ANALYSIS.

Trained raters performed duplicate, blinded ratings of swallowing safety using the validated Penetration-Aspiration Scale (PAS).[7] For interrater reliability, 100% exact agreement was required, and consensus meetings were held to resolve discrepancies. Worst PAS score was used for analyses. A board-certified laryngologist completed blinded ratings of VFMI and abnormal laryngeal anatomic and mucosal findings. All data were entered into REDCap.[8,9]

### STATISTICAL ANALYSIS.

Participant demographics and swallowing and VFMI data were exported from REDCap[8,9] into JMP (version 16.1.0; SAS Institute) and GraphPad Prism (GraphPad software version 9.4.1) for statistical analyses. Descriptives were used to summarize demographics, swallowing safety, VFMI, and abnormal laryngeal findings. Wilcoxon signed rank tests were used to examine preoperative to postoperative changes in PAS scores. To examine categorical changes in swallowing safety, PAS scores were recoded as ≤2 (safe) and >2 (unsafe) and as ≤5 (nonaspirator) and >5 (aspirator). Preoperative to postoperative changes in VFMI, abnormal laryngeal findings, and swallowing safety were evaluated by McNemar test.

## RESULTS

Thirty-five adults who met inclusion criteria enrolled. Participant demographics are summarized in the Supplemental Table.

### SWALLOWING SAFETY.

Longitudinal individual PAS and group safety classification data are presented in Figures 1 and 2. Median worst PAS score significantly worsened from preoperative (median, 1; interquartile range, 1–3) to postoperative (median, 3; interquartile range, 3–5) examinations (median PAS difference, 1.9; 95% CI, 1.1–2.7; $P < .0001$). Preoperative swallowing safety

profiles were 60% safe (n = 21), 34% penetration (n = 12), and 6% aspiration (n = 2). After CS, swallowing safety profiles were 14% safe (n = 5), 63% penetration (n = 22), and 23% aspiration (n = 8). Unsafe swallowing (PAS ≥3) increased from 40% (n = 14) to 86% (n = 28) across preoperative to postoperative time points($\chi^2 = 12.8$; $P = .0003$). Similarly, aspiration increased from 6% (n = 2) to 23% (n = 8) across preoperative to postoperative time points ($\chi^2 = 6$; $P = .01$). Supplemental Figure 1 summarizes incident cases of aspiration.

### VOCAL FOLD MOBILITY IMPAIRMENT.

Longitudinal group VFMI data are presented in Figure 3. Preoperatively, 9% (n = 3) demonstrated partial VFMI, and after surgical procedure, 23% (n = 8) demonstrated partial VFMI. No cases (n = 0) of vocal fold paralysis (complete VFMI) were observed. The increase in partial VFMI was not statistically significant ($P > .05$).

### PHARYNGOLARYNGEAL ANATOMY.

Abnormal laryngeal data and representative images are presented in the Table and Supplemental Figures 2 and 3. In rank order, preoperative abnormal laryngeal findings were as follows: posterior commissure hypertrophy, 48.6%; edema, 22.9%; granuloma, 20%; erythema and nodules, 5.7% each; and leukoplakia and vocal fold hemorrhage, 2.9% each. In rank order, postoperative abnormal laryngeal findings were as follows: posterior commissure hypertrophy, 65.7%; edema, 34.3%; ecchymosis, 25.7%; granuloma, 20%; vocal fold hemorrhage, 8.6%; and nodules and leukoplakia, 5.7% each. No statistically significant differences in rates of abnormal laryngeal findings were observed ($P > .05$).

## COMMENT

In this prospective longitudinal instrumental examination of swallowing safety and VFMI, we observed low rates of preexisting dysphagia and VFMI in CS patients awaiting elective surgical procedure. Observed rates of safe swallowing decreased 4-fold and observed rates of aspiration increased 4-fold across preoperative to postoperative time points in this cohort. The current data set revealed that postoperative aspiration was preexisting in only 2 cases (6%) and suggests that previous postoperative reports of dysphagia probably represent incident cases.[1,3] No cases of complete VFMI were noted at either time point, and a nonsignificant increase in partial VFMI was revealed across time points.

Although no study to our knowledge has performed laryngoscopic examinations to longitudinally profile swallowing safety and VFMI in CS patients, a study examined swallowing safety and incidence of postoperative aspiration in 170 individuals who underwent lung transplantation and preoperative and postoperative videofluoroscopic swallow studies.[10] Similar to this study, the study of Dallal-York and colleagues[10] found that most lung transplant patients exhibited safe swallowing preoperatively (83%), with only 7% (n = 12) noted to aspirate preoperatively. Postoperatively, incident cases of unsafe swallowing increased, with aspiration observed in 43% (n = 68) of lung transplant patients. Risk factors for development of postoperative aspiration included reintubation and perioperative venovenous extracorporeal membrane oxygenation.[10] Similarly, in this study,

a variety of postoperative risk factors may have contributed to incident cases of aspiration, including but not limited to prolonged intubation, endotracheal tube size, surgery type, and sedation.[1–3]

Although not statistically significant, the prevalence of VFMI and abnormal laryngeal findings increased postoperatively in this cohort of CS patients. In contrast to previous work, there were no cases of complete VFMI. However, 23% (n = 8) of CS patients exhibited partial VFMI postoperatively, which is similar to our previous data set (21.1%).[5] Notably, this study found a higher incidence of posterior commissure hypertrophy (65.7% vs 37%), edema (34.3% vs 29%), and ecchymosis (25.7% vs 23%) than our previous study. Although not examined in this study because of the small sample, contributing factors for VFMI and abnormal laryngeal findings in CS patients are likely to be multifactorial and include demographic (eg, sex, race), surgical (eg, procedure type, length of surgical procedure), and intubation (eg, endotracheal tube size, length of intubation) variables. Indeed, a prior study of 185 CS patients revealed that risk factors for complete VFMI include aortic arch procedures, body mass index <25 kg/m$^2$, and African American or Hispanic race.[5] Given that 23% of patients in this cohort had aortic arch procedures, it is possible that surgery type contributed to both VFMI and swallowing safety impairments.

In the future, it will be important to conduct larger scale clinical trials in CS patients to further delineate risk factors for VFMI and dysphagia development to mitigate postoperative adverse health outcomes. Future research may consider use of videofluoroscopic swallow evaluations to assess swallowing to improve our understanding of underlying mechanisms that contribute to dysphagia in CS patients so that validated, patient population– specific screening, assessment, and targeted interventions can be developed. Future studies may consider examining VFMI and swallowing safety throughout the postoperative acute recovery phase to evaluate postoperative changes and recovery of vocal fold mobility and swallowing longitudinally in CS patients.

## LIMITATIONS.

This prospective examination of preoperative VFMI and swallowing in CS patients has several limitations. The sample size in this preliminary, prospective study was relatively small (n = 35) and the inclusion criteria were broad, which led to a more heterogeneous sample and limited our ability to perform more complex statistical analyses to determine the impact of demographic and surgical factors on preoperative and postoperative voice and swallow function and health outcomes. In addition, we used FEES to examine swallow function; however, an inherent limitation of FEES is that it provides finite information about swallowing physiology, limiting our ability to determine potential underlying mechanisms that may contribute to swallowing safety impairments in CS patients.

## CONCLUSION.

This longitudinal imaging data set documented low rates of preexisting aspiration and VFMI in CS patients and identified incident cases of dysphagia that develop after surgical interventions. These findings support use of instrumental VFMI and swallowing evaluations in this population to mitigate development of adverse health outcomes. Future larger scale

clinical research trials will be pivotal in identifying preoperative and postoperative risk factors for VFMI and dysphagia development and subsequent adverse health outcomes.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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### DISCLOSURES

Cara Donohue reports financial support was provided by the American Speech-Language-Hearing Foundation, American Heart Association, and National Heart, Lung, and Blood Institute; and a relationship with Vanderbilt University Medical Center that includes: employment. Emily Plowman reports financial support was provided by the American Speech-Language-Hearing Foundation, American Heart Association, and University of Florida Health Aortic Disease Center; and a relationship with the National Institute of Nursing Research, National Institute of Neurological Disorders and Stroke, National Institute on Aging, ALS Association, and University of Florida that includes: employment, and funding grants. Eric Jeng reports a relationship with the National Institute of Nursing Research that includes: employment, and funding grants.

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**IN SHORT**

- Low rates of preexisting aspiration and vocal fold mobility impairments were observed in 35 cardiac surgical patients.
- Aspiration increased 4-fold postoperatively.
- Instrumental laryngoscopic evaluations are necessary to identify vocal fold mobility impairments and swallowing safety impairments in cardiac surgical patients during postoperative recovery.

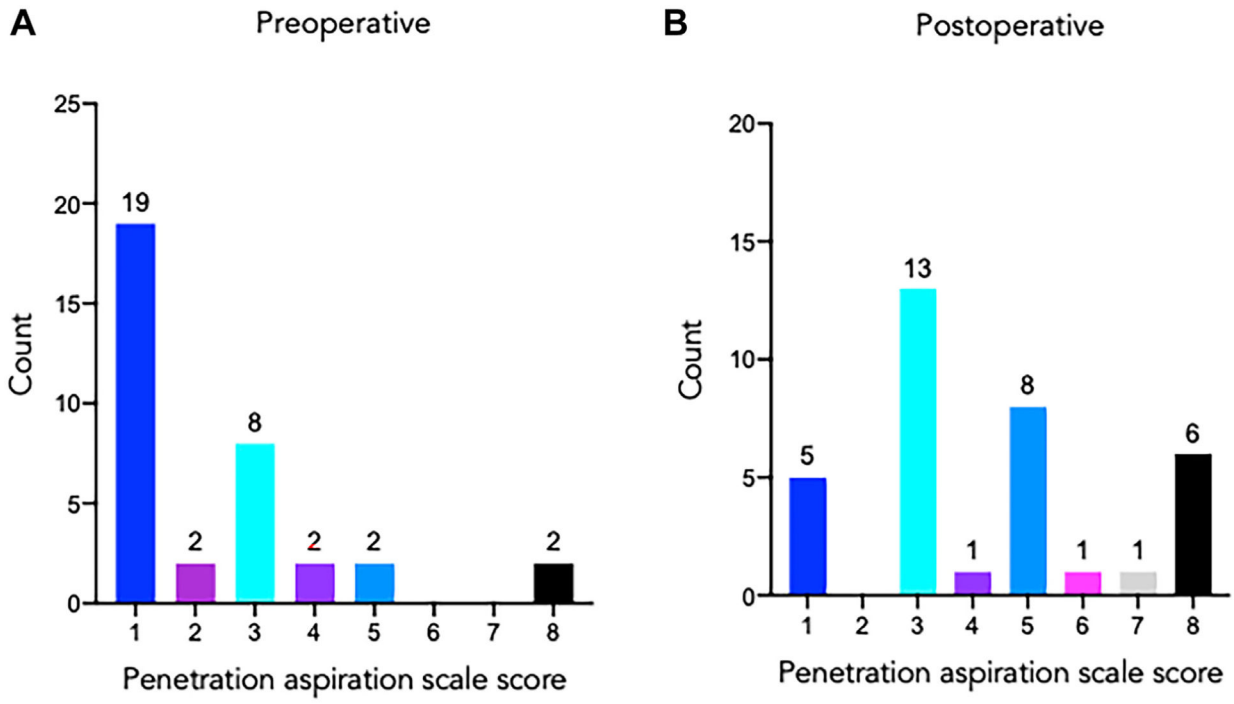


**FIGURE 1.**

Frequency distribution of individual worst Penetration-Aspiration Scale scores (A) preoperatively and (B) postoperatively in cardiac surgical patients.

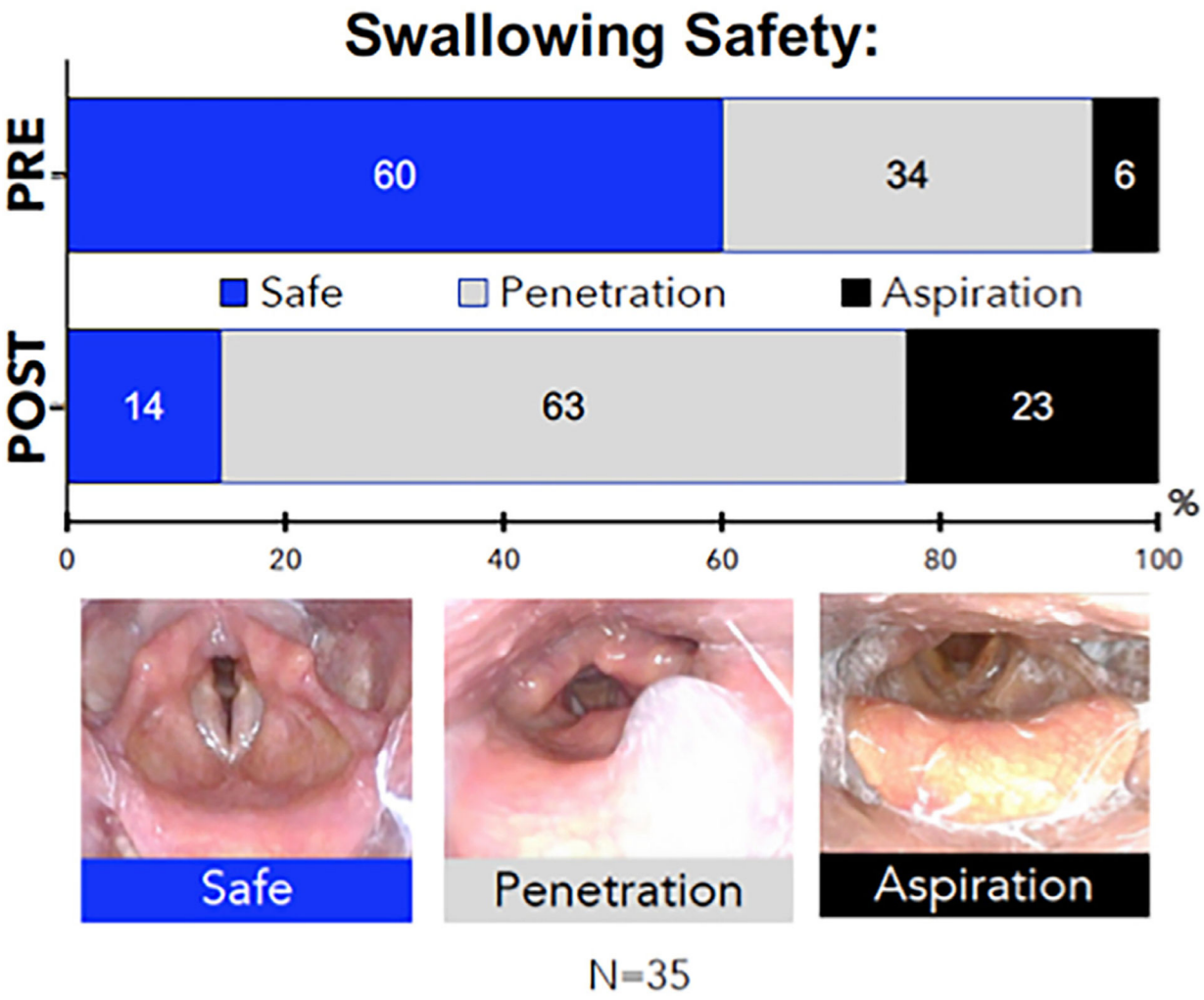


**FIGURE 2.**
Preoperative and postoperative swallowing safety profiles in 35 cardiac surgical patients based on Penetration-Aspiration Scale scores.

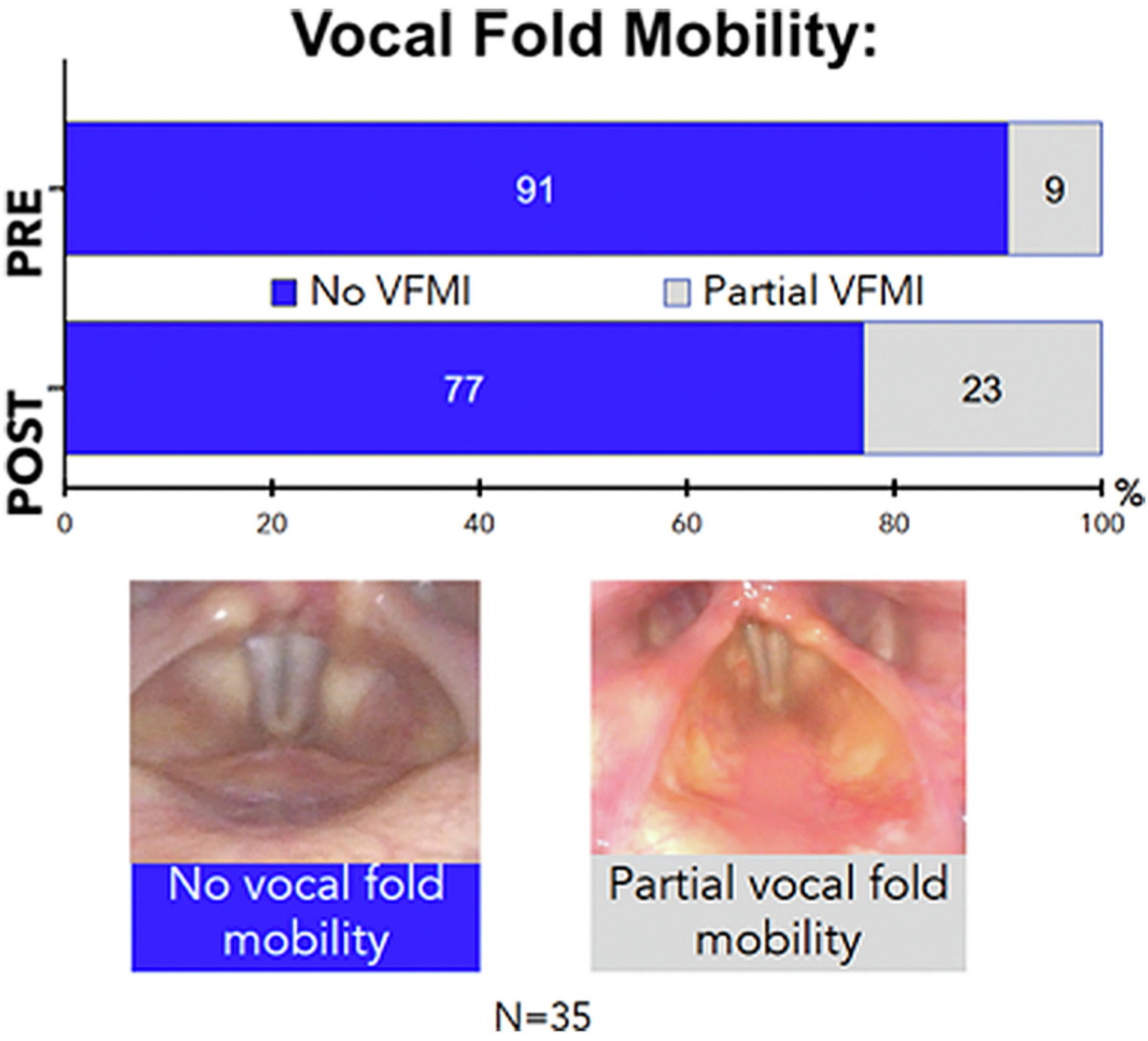


**FIGURE 3.**
Preoperative and postoperative vocal fold mobility impairment (VFMI) profiles in 35 cardiac surgical patients.

## TABLE

Prevalence of Abnormal Laryngeal Findings Preoperatively and Postoperatively in Cardiac Surgical Patients

| Variable | Preoperative Abnormal Laryngeal Findings, % (No.) | Postoperative Abnormal Laryngeal Findings, % (No.) | Change |
|---|---|---|---|
| Posterior commissure hypertrophy | 48.6 (17) | 65.7 (23) | +17.1 (+6) |
| Edema | 22.9 (8) | 34.3 (12) | +11.4 (+4) |
| Ecchymosis | 0 (0) | 25.7 (9) | + 25.7 (+9) |
| Erythema | 5.7 (2) | 17.1 (6) | +11.4 (+4) |
| Granuloma | 20 (7) | 20 (7) | 0 (0) |
| Nodules | 5.7 (2) | 5.7 (2) | 0 (0) |
| Leukoplakia | 2.9 (1) | 5.7 (2) | +2.8 (+1) |
| Vocal fold hemorrhage | 2.9 (1) | 8.6 (3) | +5.7 (+2) |