Therapeutic Singing as a Swallowing Intervention in Head and Neck Cancer Patients With Dysphagia

Seongmoon Jo, BS\textsuperscript{1,2†}, Myung Sun Yeo, PhD\textsuperscript{3,4†}, Yoon-Kyum Shin, PhD\textsuperscript{1,2}, Ki Hun Shin, BS\textsuperscript{5}, Se-Heon Kim, MD, PhD\textsuperscript{6}, Hye Ryun Kim, MD, PhD\textsuperscript{7}, Soo Ji Kim, PhD\textsuperscript{3,4*}, and Sung-Rae Cho, MD, PhD\textsuperscript{1,2,8*}

Abstract

Background: Head and neck cancer patients often suffer from dysphagia after surgery and radiotherapy. A singing-enhanced swallowing protocol was established to improve their swallowing function. This study aimed to evaluate the beneficial effects of therapeutic singing on dysphagia in head and neck cancer (HNC) patients. Methods: Patients who participated in this study were allocated to the intervention group (15 patients) and the control group (13 patients). Patients assigned to the intervention group received therapeutic singing 3 times per week for 4 weeks. Each group was divided into 2 subgroups, including the oral cavity cancer group and the pharyngeal cancer group. The patients’ vocal functions were evaluated in maximum phonation time, pitch, intensity, jitter, shimmer, harmonics to noise ratio, and laryngeal diadochokinesis (L-DDK). To evaluate swallowing function, videofluoroscopic swallowing study was done, and the results were analyzed by videofluoroscopic dysphagia scale (VDS) and dynamic imaging grade of swallowing toxicity (DIGEST). Results: Among the voice parameters, L-DDK of the intervention group significantly increased compared to that of the control group. Swallowing functions of the intervention group were significantly improved in VDS and DIGEST after the intervention. Detailed items of VDS and DIGEST showed improvements especially in the pharyngeal phase score of VDS, such as laryngeal elevation, pharyngeal transit time, and aspiration. In addition, the pharyngeal cancer group showed significant improvements in VDS and DIGEST scores after the intervention. Conclusions: Our outcomes highlight the beneficial effects of singing for HNC patients with dysphagia. The notable improvements in the pharyngeal phase suggest that therapeutic singing would be more appropriate for HNC patients who need to improve their intrinsic muscle movements of vocal fold and laryngeal elevation.

Keywords
head and neck cancer, deglutition disorders, laryngeal elevation, aspiration, singing

Submitted April 30, 2021; revised November 7, 2021; accepted November 19, 2021
Given the extensive impact of dysphagia on the morbidity of HNC patients, therapies to prevent, reduce, and alleviate swallowing difficulties are urgently needed. Most of them are related to respiratory-swallowing training based on a hierarchy of motor skill acquisition to encourage autonomous and optimal respiratory-swallowing coordination. Although meta-analysis has presented the evidence that swallowing exercises are effective in the management of complications from the HNC treatment, there are still many reports that HNC patients suffer from swallowing difficulties.

To delay and reverse some of the devastating effects of cancer treatments, it is essential to ensure continued use of swallowing musculature by adherence to targeted vocal, respiration, and swallowing exercises for HNC patients. Based on the coordinative relation between respiration, vocalization, and oropharyngeal swallowing, singing can be an efficient therapeutic approach after cancer treatments. Both speech and singing rely on the tension on vocal cords resulting in modulations of the fundamental vocal frequency. Singing a set of tones induces larynx elevations that contract several muscles, including an upper esophageal sphincter, to protect the airway against aspiration. Within this context, singing can play a role in functional movement of swallowing, respiration, and vocalization.

Recently, singing has been introduced as a viable treatment in swallowing rehabilitation. Singing can improve oral motor functions related to articulation and breathing control. In other words, singing enhances the mobility and breathing functions of the facial and oral cavity muscles by inducing the coordination of vocalization organs and patterned breathing in the singing process. In addition, musical elements, such as rhythm, can support timed and controlled muscle movements with oral motor control, laryngeal elevation, and breathing during singing. Moreover, singing also offers additional benefits, including emotional arousal, reduced stress, and ease of self-administration for cancer survivors.

In this context, singing may be considered a beneficial intervention to improve the swallowing function of HNC patients, who need multi-faceted exercises to stimulate impaired anatomical structures accompanied by dysphagia. Therefore, this study aimed to evaluate the effectiveness of therapeutic singing in HNC patients with dysphagia after surgery, radiation therapy, and chemotherapy.

**Materials and Methods**

**Participants**

Patients who met the following inclusion criteria were recruited. The inclusion criteria of this study were patients who (1) were diagnosed with HNC, including tongue cancer, oral cavity cancer, nasopharyngeal cancer, oropharyngeal cancer, or mandibular gland cancer; (2) underwent surgical procedures, such as tracheostomy, glossectomy, mandibullectomy, partial laryngectomy, and/or reconstruction of the palate and pharynx; and (3) underwent several sessions of radiotherapy for their tumors. The exclusion criteria were as follows: (1) under 7 years of age; (2) hearing-impaired and unable to hear music stimuli; and (3) unable to speak due to poor vocalization.

This study was approved by the Institutional Review Board of Yonsei University Health System (Approval No. 4-2012-0483). Twenty-eight patients were asked to participate in this study and written informed consent was obtained from 21 patients before the initiation of intervention (Figure 1). The characteristics of patients are presented in Table 2, including gender, age, onset duration, and tumor types. There were no differences in the characteristics of groups. Most of the subjects were outpatients, except for 1 patient. All patients had the capacity for oral intake and showed no other significant cognitive or communication impairment. Premorbid musical ability was not required for participation in the study. All participants received conventional therapy for dysphagia such as oromotor exercise, sensory stimulation, and compensatory maneuver, while participants in the intervention group additionally underwent therapeutic singing.

Participants were randomly allocated to either intervention or control groups by an independent research coordinator who generated random numbers using simple randomization. When
each participant was recruited, the independent coordinator informed therapists of the group allocation via random numbers in digital documents. Among participants allocated to the intervention group, a wait-list control design was applied to 7 participants. After the wait-list period, they participated in the intervention with pre- and post-assessments of vocal and swallowing functions. Finally, outcomes from 15 patients in the intervention group and 13 patients in the control group were analyzed in this study (Figure 1). In addition, outcomes were analyzed into 2 subgroups based on the HNC patients’ cancer characteristics; oral cavity cancer and pharyngeal cancer. Patients with tongue cancer, oral cavity cancer, and mandibular gland cancer were classified as the oral cavity cancer group. Patients with nasopharyngeal cancer and oropharyngeal cancer were classified as the pharyngeal cancer group.

Intervention

Each patient received 3 individual sessions per week for 4 weeks (total of 12 sessions). A singing-enhanced swallowing protocol consisted of physical preparation, vocalization for warm-up, singing exercises for laryngeal elevation, and modified singing of approximately 20 minutes in duration. The interventions using therapeutic singing were designed to develop control and strength in the muscles and mechanisms used for singing. When the patients sang, therapeutic techniques such as feedback, encouragement, prompting, and modeling were also employed to assist the patients in achieving maximum intelligibility, naturalness in speech, and optimizing patient compliance. The study protocol consisted of 4 steps (Table 1).

The first step involved breathing for relaxation of respiratory and oral muscles as physical preparation. During this activity, the music therapist provided instruction to the patient during inhalation and exhalation to gain awareness of diaphragm movements. The patient breathed in and out as cued by live musical accompaniment. The duration and tempo of the music-cued breathing exercises were determined by observing the regular breathing pattern at the beginning of the session. After the breathing exercise, the patients underwent muscle relaxation by stretching their arms, neck, and shoulders. This was achieved through upper
body movements: turning the neck right and left, lifting and lowering the shoulders, and stretching by fully extending the arms forward.\textsuperscript{30}

The second step was respiratory muscle training, including humming and pitch glides as preparation for step 3. Patients were asked to breathe in and out while following the therapist’s accompaniment by a keyboard. They inhaled with an ascending melody and exhaled with a descending melody line. The accompaniment provided cues for the duration of breathing and facilitated flow and competency in breathing. Then, the patients were asked to sing a glissando from their comfortable highest pitch to lowest pitch on the single vowel sound, including /a/, /i/, /o/, and /u/. This activity was designed to stimulate the patient’s laryngeal musculature and to prepare for singing exercise for laryngeal elevation.

In the third step, 2 different notes were used in singing for laryngeal elevation. The notes were selected within the range based on the patient’s ability to produce vocal sounds while singing. The use of 2 different pitches was more critical than making accurate pitches. The patient vocalized 2 vowel sounds from lower to higher pitches in a sequence. The therapist asked the patient to produce the /u/ sound with a lower pitch and /i/ sound with a higher pitch. When the patient made the /i/ sound, suggestions were made to be conscious of the lip movement and maintain the lip and mouth shape. Changes in pitches are associated with the direction of vocal folds. Stretched vocal folds produce a higher pitch, and relaxed vocal folds make a lower pitch. Therefore, this activity was designed to facilitate laryngeal elevation as well as the intrinsic muscle movement of the vocal fold.

In the final step, step 4, the patients sang a song that was modified by a music therapist. The patients were asked to sing a song in a comfortable tempo and pitch range about 2 times. In this step, the patients were introduced to structured, sequential vocal patterns that employ gradual dynamics and expanded ranges with intervals to strengthen vocal capacity. Some conversations and verbal feedback regarding the patients’ experiences during therapy were also shared. The patients were able to verbally share their feelings related to their voices or the songs.

**Voice Data Collection**

Voice data were collected as secondary outcomes of this study. All voice data were collected and measured by music therapists. Sound data were recorded in a quiet room with ambient noise of less than 50 dB. A 10-cm distance was

---

**Table 1. The Process of Singing-Enhanced Swallowing Protocol.**

| Steps | Procedures (minute) | Descriptions |
|-------|---------------------|--------------|
| 1     | Physical preparation (2) | Breathing for relaxation of respiratory and oral muscles and stretching arms, neck, and shoulders to relax the muscles |
| 2     | Vocal warm-up (3) | Humming and pitch glides as preparation for the next step |
| 3     | Singing exercise for laryngeal elevation (10) | Singing two-interval notes from lower to higher pitches in a sequence with /u/ sound (lower pitch) and /i/sound (higher pitch) |
| 4     | Modified singing (5) | Singing a modified song (by a music therapist) and taking the intervention as a home-task |
maintained between the mouth and condenser microphone (SONY ECM-MS907, SONY Corp., Tokyo, Japan). The program was digitized at a sampling rate of 44.1 Hz and 16-bit quantization. The recording level was fixed at -12 dB. Data were analyzed using Praat, a motor speech software program that is a module of the Computerized Speech Lab model 5105. Maximum phonation time (MPT) and vocal intensity were collected. For MPT measurement, the patients were asked to produce the long vowel /a/ sound. This vocalization was measured 3 times, and the longest MPT was recorded.31,32 To measure changes in the patient’s voice quality, the patient was instructed to speak the vowel /a/ as comfortably as possible. Among the measured intervals, a relatively stable 3-second period of time was analyzed to measure pitch, intensity, jitter, shimmer, and harmonics to noise ratio (HNR). To evaluate the range and the speed of vocal fold movement, each patient was asked to repeat the glottal syllable /a/ as quickly, consistently, and accurately as possible for 5 seconds. The rate of laryngeal diadochokinesis (L-DDK) was measured by calculating the number of syllables spoken.33-36 Two independent raters with more than 2 years of clinical experience randomly selected a sample of 5 participants from the data and calculated the reliability. The intra-rater reliability of the results was obtained twice by randomly selecting a sample of 5 participants at different times.

Swallowing Study
Swallowing data were collected as the primary outcomes of this study. Experienced physiatrists performed a video-fluoroscopic swallowing study (VFSS) in a radiography room. The patient and examiner sat across from each other. The patient was positioned appropriately for observation of the anatomical structure and swallowing function. The patient swallowed the bolus, which was mixed with a barium sulfate solution (yogurt powder 4.5 g, Baritop HD power 4.5 g, water 150 mL), while radiographic recordings were acquired fluoroscopically. The tapes of the dynamic radiographic procedures provided useful information for analyzing the patients’ anatomical and physiological abnormalities. Two independent raters with more than 2 years of clinical experience evaluated the recordings based on swallowing scales and calculated the reliability. The raters were completely blinded when they were scaling VFSS. The intra-rater reliability was obtained twice from the results of all patients.

Assessment of Swallowing Function
Videofluoroscopic dysphagia scale (VDS) and dynamic imaging grade of swallowing toxicity (DIGEST) were used to evaluate the swallowing function. VDS is a numerical scale that quantifies the degree of oropharyngeal function

Table 2. Clinical Characteristics of Participants.

| Characteristics          | Intervention group          | Control group          |
|-------------------------|-----------------------------|------------------------|
|                         | Oral cavity cancer (N = 11) | Oral cavity cancer (N = 8) |
|                         | Pharyngeal cancer (N = 4)   | Pharyngeal cancer (N = 5) |
|                         | Total (N = 15)              | Total (N = 13)         |
| Gender (%)              |                             |                        |
| Male                    | 6 (54.5)                    | 6 (75.0)               |
| Female                  | 5 (45.5)                    | 2 (25.0)               |
| Age, year               | 46.82 ± 3.78                | 56.60 ± 5.23           |
| Onset duration, month   | 24.82 ± 10.24               | 23.40 ± 11.59          |
| T classification (%)    |                             |                        |
| 1                       | 1 (9.1)                     | 3 (37.5)               |
| 2                       | 0 (0)                       | 1 (12.5)               |
| 3                       | 1 (9.1)                     | 1 (12.5)               |
| 4a                      | 8 (72.7)                    | 3 (37.5)               |
| 4b                      | 1 (9.1)                     | 0 (0)                  |
| N classification (%)    |                             |                        |
| 0                       | 5 (45.5)                    | 6 (75.0)               |
| 1                       | 2 (18.2)                    | 1 (12.5)               |
| 2                       | 4 (36.3)                    | 1 (12.5)               |
| Tumor stage (%)         |                             |                        |
| 1                       | 1 (9.1)                     | 3 (37.5)               |
| 2                       | 0 (0)                       | 1 (12.5)               |
| 3                       | 1 (9.1)                     | 1 (12.5)               |
| 4a                      | 8 (72.7)                    | 3 (37.5)               |
| 4b                      | 1 (9.1)                     | 0 (0)                  |

Data are presented as n (%), frequencies or mean ± SEM.
Table 3. Vocal Function in Head and Neck Patients With Dysphagia After the Intervention.

| Variables | Intervention group | Control group | Time | Group | Time × group |
|-----------|--------------------|---------------|------|-------|-------------|
|           | Pre                | Post          | Pre  | Post  | F    | P value | F    | P value | F    | P value |
| MPT       | 12.12 ± 1.91       | 13.91 ± 2.50  | 10.17 ± 2.58 | 10.54 ± 3.04 | 1.857 | .186   | .585 | .452   | 0.799 | .381   |
| Pitch     | 145.60 ± 11.07     | 148.81 ± 12.56| 147.13 ± 16.52| 130.57 ± 16.66| 0.944 | .341   | 0.202 | .057   | 2.071 | .164   |
| Intensity | 66.03 ± 2.60       | 67.87 ± 2.81  | 69.47 ± 2.13  | 70.45 ± 1.99  | 0.930 | .345   | 0.768 | .390   | 0.088 | .770   |
| Jitter    | 0.86 ± 0.27        | 0.54 ± 0.15   | 1.20 ± 0.53   | 0.58 ± 0.18   | 1.857 | .089   | 0.680 | .419   | 0.680 | .419   |
| Shimmer   | 10.98 ± 2.30       | 8.55 ± 1.81   | 9.94 ± 2.78   | 9.48 ± 2.03   | 1.563 | .224   | 0.000 | .986   | 0.726 | .403   |
| HNR       | 0.10 ± 0.03        | 0.06 ± 0.03   | 0.19 ± 0.08   | 0.18 ± 0.07   | 1.430 | .244   | 0.335 | .568   | 0.335 | .568   |
| L-DDK     | 13.60 ± 1.33       | 16.47 ± 1.38† | 13.73 ± 1.34  | 14.00 ± 1.35  | 13.715 | .001**| 0.275 | .605   | 5.559 | .027**|

Data are presented as frequencies, mean ± SEM. Abbreviations: MPT, maximum phonation time; HNR, noise-to-harmonics ratio; L-DDK, laryngeal diadochokinesis.
†P < .05. **P < .01 significant effect by two-way repeated measures ANOVA.
††P < .01 significant difference by Wilcoxon signed-ranked test.

observed during VFSS. VDS scale consists of the following 14 items: lip closure, bolus formation, mastication, apraxia, tongue-to-palate contact, premature bolus loss, oral transit time, pharyngeal swallow triggering, vallecular residue, laryngeal elevation, pyriform sinus residue, coating of pharyngeal wall, pharyngeal transit time, and aspiration. The first 7 items (lip closure, bolus formation, mastication, apraxia, tongue-to-palate contact, premature bolus loss, oral transit time) are used for functional assessment of the oral phase, and the other 7 items (pharyngeal swallow triggering, vallecular residue, laryngeal elevation, pyriform sinus residue, coating of pharyngeal wall, pharyngeal transit time, and aspiration) are used to assess the pharyngeal phase. VDS scale has a maximum score of 100. A higher score of VDS indicates a greater impairment of swallowing function.37,39 DIGEST utilizes safety and efficiency components to quantify pharyngeal bolus transit. A patient’s safety profile is scored while accounting for the frequency and quantity of high-grade penetration/aspiration events. The efficiency profile is assigned through the estimation of the maximum high-grade penetration/aspiration events. The efficiency score is determined while accounting for the frequency and quantity of pharyngeal bolus transit. A patient’s safety profile is DIGEST utilizes safety and efficiency components to quantify pharyngeal bolus transit. A patient’s safety profile is DIGEST utilizes safety and efficiency components to quantify pharyngeal bolus transit. A patient’s safety profile is DIGEST utilizes safety and efficiency components to quantify pharyngeal bolus transit. A patient’s safety profile is DIGEST utilizes safety and efficiency components to quantify pharyngeal bolus transit. A patient’s safety profile is DIGEST utilizes safety and efficiency components to quantify pharyngeal bolus transit. A patient’s safety profile is DIGEST utilizes safety and efficiency components to quantify pharyngeal bolus transit. A patient’s safety profile is DIGEST utilizes safety and efficiency components to quantify pharyngeal bolus transit. A patient’s safety profile is

**Results**

**Clinical Characteristics of Patients**

The present study consisted of the intervention group (N = 15) and the control group (N = 13). Based on the characteristics of HNC treatment, each group was divided into 2 subgroups. The intervention group was divided into 2 subgroups, including the oral cavity cancer group (N = 11) and the pharyngeal cancer group (N = 4). The control group was also divided into the oral cavity cancer group (N = 8) and the pharyngeal cancer group (N = 5) (Table 2). Clinical characteristics including gender, age, onset duration, and tumor characteristics were not statistically different between the groups.

**Vocal Function**

Vocal functions of patients with HNC were evaluated using MPT, pitch, intensity, jitter, shimmer of voice, HNR, and L-DDK. The inter-rater reliability of MPT, HNR, and L-DDK showed intra-class correlation coefficients (ICC) of .713, .954, and .813, respectively. The intra-rater reliability of the results was obtained twice by randomly selecting a sample of 5 participants at different times by each rater. As a result, each rater showed ICC = .936, .924 for MPT, ICC = .971, .975 for HNR, and ICC = .903, .912 for L-DDK.

In this study, there were no significant differences in scores of MPT, pitch, intensity, jitter, shimmer of voice, and HNR after the intervention. However, L-DDK showed an interaction effect between time and group (F(1,25) = 5.559, P = .027) and time effect (F(1,25) = 13.715, P = .001) (Table 3). This indicated that the intervention group showed an improvement in laryngeal elevation with enhanced L-DDK score at post-test compared to the baseline (P = .003 by Wilcoxon signed-rank test). However, the control group did not show the time-dependent change in laryngeal elevation.
Swallowing Function

VDS and DIGEST were scored during the VFSS. The inter-rater reliability of DIGEST and VDS showed ICCs of .920 and .901, respectively, in patients scored by 2 independent scorers. The intra-rater reliability of DIGEST and VDS was obtained from the results conducted to all participants by one rater, with ICCs of .898 and .902, respectively.

VDS showed an interaction effect between time and group in pharyngeal phase score and total score (F1,25 = 14.683, P = .001; F1,25 = 17.454, P < .001) (Table 4). The results indicated an improvement in swallowing function of the intervention group, especially in the pharyngeal phase, with significant reverse patterns of the control group (P = .042 in the control group; P = .008 in the intervention group by Wilcoxon signed-rank test) (Table 4, Figure 2).

In DIGEST, the safety and efficiency profiles give an overall score which indicates the severity of dysphagia. The safety, efficiency, and total grades showed an interaction effect between time and group (F1,25 = 1.823, P = .045; F1,25 = 17.847, P < .001; F1,25 = 11.537, P = .002). Group effects were shown in safety and total grades (F1,25 = 6.262, P = .019; F1,25 = 21.097, P < .001). Time effect was also found in safety grades (F1,25 = 6.700, P = .016) (Table 4). For safety grade, the intervention group only showed definite improvement in swallowing function (P = .016 by Wilcoxon signed-rank test). The result indicated an improvement in efficiency grade of the intervention group with significant reverse patterns of the control group (P = .025 in the control group; P = .006 in the intervention group by Wilcoxon signed-rank test). For total grade, significant improvement was only found in the intervention group (P = .008 by Wilcoxon signed-rank test) (Table 4, Figure 2).

Each parameter of VDS was also analyzed to identify which parameter in a specific phase was influenced by the intervention in this study. In the oral phase, only oral transit time showed group effect (F1,25 = 6.380, P = .018) with a reverse pattern between groups. However, this should be carefully interpreted due to the lack of statistical significance of time-dependent change in the intervention group. In the pharyngeal phase, 3 parameters, including laryngeal elevation, pharyngeal transit time, and aspiration, showed significant interaction effect between time and group, individually (F1,25 = 11.607, P = .002; F1,25 = 5.058, P = .033; F1,25 = 10.335, P = .003). The results indicated that the swallowing function of the intervention group was significantly improved (P = .014; P = .046; P = .011 by Wilcoxon signed-rank test), especially in the pharyngeal phase with reverse patterns of the control group (Table 5).

When VDS and DIGEST were analyzed in 2 subgroups of oral cavity cancer and pharyngeal cancer, pharyngeal phase and total VDS scores showed the time effect (F1,25 = 14.986, P = .002; F1,25 = 17.257, P = .001). In addition, safety grade, efficiency grade, and total grade of DIGEST showed that there were the time effects (F1,25 = 7.875, P = .015; F1,25 = 9.683, P = .003; F1,25 = 9.683, P = .008). The results indicated that swallowing function of the pharyngeal cancer group was improved, showing significant time-dependent changes in pharyngeal phase VDS score, safety grade, efficiency grade, and total grade of DIGEST (P = .037; P = .041; P = .034; P = .039 by Wilcoxon signed-rank test) (Table 6).

Furthermore, we analyzed each parameter of VDS to identify which parameter was affected by the intervention in each subgroup. Parameters of the pharyngeal phase, including laryngeal elevation, pharyngeal transit time, pyriform sinus residue and aspiration, showed time effects
**Figure 2.** Videofluoroscopic Dysphagia Scale (VDS) and Dynamic Imaging Grade of Swallowing Toxicity (DIGEST) in Head and Neck Patients With Dysphagia After the Intervention. (A) VDS Total Score. (B) VDS Oral Phase Score. (C) VDS Pharyngeal Phase Score. (D) DIGEST Total Grade. (E) DIGEST Safety Grade. (F) DIGEST Efficiency Grade. 

*P < .05. **P < .01. ***P < .001 by Wilcoxon signed-ranked test.

**Table 5.** Videofluoroscopic Dysphagia Scale in Head and Neck Patients With Dysphagia After the Intervention.

|                         | VDS                           | Time          | Group          | Time × group |
|-------------------------|-------------------------------|---------------|---------------|--------------|
|                         | Intervention                  | Control       | F  P value    | F  P value   | F  P value   |
| Lip closure             | 0.00 ± 0.00                   | 0.00 ± 0.00   | –             | –             | –             |
| Bolus formation         | 2.20 ± 0.68                   | 1.80 ± 0.57   | 3.00 ± 0.74   | 3.50 ± 0.72  | 0.033 .858   | 2.469 .128   | 1.611 .216   |
| Mastication             | 2.67 ± 0.84                   | 2.13 ± 0.77   | 4.00 ± 0.98   | 4.33 ± 0.92  | 0.029 .866   | 2.995 .095   | 0.725 .402   |
| Apraxia                 | 0.00 ± 0.00                   | 0.00 ± 0.00   | 0.00 ± 0.00   | 0.00 ± 0.00  | –             | –             | –             |
| Tongues to palate contact | 2.67 ± 0.96                   | 2.00 ± 0.82   | 2.50 ± 0.75   | 3.33 ± 0.94  | 0.042 .840   | 0.428 .519   | 2.045 .165   |
| Premature bolus loss    | 2.50 ± 0.32                   | 2.00 ± 0.32   | 2.38 ± 0.47   | 2.38 ± 0.39  | 3.202 .085   | 0.025 .875   | 3.202 .085   |
| Oral transit time       | 1.00 ± 0.38                   | 0.40 ± 0.27   | 1.75 ± 0.45   | 2.25 ± 0.39  | 0.013 .911   | 6.380 .018*  | 3.664 .067   |
| Triggering of pharyngeal swallow | 1.20 ± 0.53                   | 0.60 ± 0.41   | 1.13 ± 0.59   | 1.13 ± 0.59  | 1.592 .218   | 0.166 .687   | 1.592 .218   |
| Vallecular residue      | 3.33 ± 0.50                   | 3.20 ± 0.47   | 3.67 ± 0.48   | 3.67 ± 0.48  | 0.141 .710   | 0.294 .592   | 0.141 .710   |
| Laryngeal elevation     | 7.80 ± 0.82                   | 4.20 ± 1.20†  | 6.00 ± 1.28   | 8.25 ± 0.75  | 0.464 .502   | 0.611 .442   | 11.607 .002** |
| Pyriform sinus residue  | 6.00 ± 1.05                   | 4.80 ± 1.03†  | 6.38 ± 1.17   | 7.13 ± 1.03  | 0.143 .709   | 0.284 .598   | 3.571 .070   |
| Coating on the pharyngeal wall | 6.60 ± 1.06                   | 4.80 ± 1.20†  | 6.38 ± 1.17   | 7.15 ± 1.18  | 1.034 .319   | 1.896 .180   | 2.554 .122   |
| Pharyngeal transit time | 2.40 ± 0.79                   | 0.80 ± 0.55†  | 3.50 ± 0.89   | 3.50 ± 0.89  | 1.264 .271   | 1.812 .190   | 5.058 .033*  |
| Aspiration              | 5.60 ± 0.92                   | 2.40 ± 0.79†  | 3.50 ± 0.89   | 4.00 ± 0.85  | 2.584 .120   | 0.464 .502   | 10.335 .003** |

Data are presented as frequencies, mean ± SEM.

Abbreviations: VDS, videofluoroscopic dysphagia scale.

*P < .05. **P < .01. ***P < .001 significant effect by two-way repeated measures ANOVA.

†P < .05 significant difference by Wilcoxon signed-ranked test.
Table 6. Swallowing Functions in Subgroups of Participants.

| Intervention group | Variables | Oral cavity cancer | Pharyngeal cancer | Time | Group | Time × group |
|--------------------|-----------|--------------------|-------------------|------|-------|-------------|
|                    |           | Pre                | Post              | Pre  | Post  | F  | P value | F  | P value | F  | P value |
| VDS                | Oral phase| 12.00 ± 2.92       | 9.45 ± 2.55       | 8.38 ± 2.86 | 5.25 ± 2.84 | 2.794 | .119    | 0.718 | .412    | 0.029 | .867    |
|                    | Pharyngeal phase| 30.45 ± 5.76      | 21.05 ± 5.95      | 39.75 ± 1.88 | 20.13 ± 7.13 | 14.986 | .002** | 0.188 | .672    | 1.855 | .196    |
|                    | Total score| 42.45 ± 7.27       | 30.50 ± 7.15      | 43.13 ± 4.00 | 25.38 ± 9.02 | 17.257 | .001** | 0.001 | .982    | 1.670 | .219    |
| DIGEST             | Safety grade| 0.91 ± 0.39       | 0.18 ± 0.12       | 1.25 ± 0.48 | 0.00 ± 0.00 | 7.875 | .015*   | 0.041 | .843    | 0.550 | .471    |
|                    | Efficiency grade| 1.82 ± 0.40      | 1.00 ± 0.36       | 2.25 ± 0.25 | 1.00 ± 0.41 | 9.683 | .003** | 0.126 | .728    | 0.574 | .462    |
|                    | Total grade  | 1.36 ± 0.31        | 0.73 ± 0.24       | 1.75 ± 0.25 | 0.75 ± 0.25 | 9.683 | .008**  | 0.246 | .628    | 0.478 | .501    |
| Control group      | VDS        | 14.19 ± 3.46       | 17.81 ± 2.95      | 12.50 ± 2.76 | 11.75 ± 2.95 | 0.496 | .497    | 0.708 | .420    | 1.149 | .309    |
|                    | Oral phase  | 27.56 ± 6.85       | 32.81 ± 6.08      | 37.63 ± 2.18 | 41.75 ± 1.79 | 3.819 | .079    | 1.072 | .325    | 0.055 | .819    |
|                    | Pharyngeal phase | 41.75 ± 7.44      | 50.63 ± 5.72      | 50.13 ± 3.92 | 53.50 ± 3.80 | 3.357 | .097    | 0.360 | .562    | 0.677 | .430    |
|                    | Total score  | 41.75 ± 7.44       | 50.63 ± 5.72      | 50.13 ± 3.92 | 53.50 ± 3.80 | 3.357 | .097    | 0.360 | .562    | 0.677 | .430    |
| DIGEST             | Safety grade| 1.00 ± 0.38       | 0.88 ± 0.35       | 1.60 ± 0.40 | 1.60 ± 0.40 | 1.426 | .258    | 4.170 | .604    | 0.453 | .506    |
|                    | Efficiency grade| 2.00 ± 0.38      | 2.38 ± 0.26       | 2.00 ± 0.45 | 2.40 ± 0.24 | 6.611 | .026*   | 0.145 | .007**  | 0.935 | .721    |
|                    | Total grade  | 2.00 ± 0.27        | 2.25 ± 0.16       | 2.20 ± 0.20 | 2.60 ± 0.24 | 3.043 | .109    | 0.994 | .340    | 0.695 | .556    |

Data are presented as frequencies, mean ± SEM.
Abbreviations: VDS, videofluoroscopic dysphagia scale; DIGEST, dynamic imaging grade of swallowing toxicity.
†P < .05 significant difference by Wilcoxon signed-ranked test.
‡P < .01 significant effect by two-way repeated measures ANOVA.

The inter- and intra-rater reliability of our voice and swallowing data showed high ICCs and demonstrated our data were reliable. The vocal functions of HNC patients were first evaluated in various vocal scales to elucidate the effect of therapeutic singing. Among the vocal measurements, L-DDK score, specifically related to the intrinsic muscle movement of vocal fold and laryngeal muscle movement, showed a significant improvement. Since the singing-enhanced swallowing protocol was designed to make patients sing with different pitches, the therapy facilitated the upper esophageal sphincter’s width, opening and increasing the extent and duration of laryngeal elevation. It indicates that therapeutic singing mainly focuses on improving the vocal fold and laryngeal movement.

Functional improvements based on statistical significance in VDS and DIGEST scores showed the beneficial effects of music application for HNC patients with dysphagia. Music application, such as singing in different pitches and breathing control with rhythmic cues, can stimulate muscles involved in swallowing from the activation of central and peripheral neural network. During the intervention, singing with different pitches targets the intrinsic muscle movement of the vocal fold and the proper coordination of the muscle for laryngeal elevation when a patient makes a higher pitch sound. When vocalizing in different pitches, intensities generally change while showing different vibrations and strength through acoustic sound.

Discussion

A singing-based intervention can facilitate appropriate laryngeal and pharyngeal muscle movements to produce significant therapeutic effects for patients with swallowing difficulties. Anatomical relationships between breathing, singing, and swallowing imply the integration of laryngeal and pharyngeal muscle movements, and these integrated functions are essential mechanisms for swallowing intervention in the concept of this study. The present study evaluated the effectiveness of therapeutic singing on swallowing function of HNC patients. Our protocol involved muscle exercises targeting the laryngeal elevation and the intrinsic muscle movement of swallowing. All HNC patients received the intervention after the primary cancer treatment. Overall, a rehabilitative approach using singing was effective in patients with HNC who had difficulties in voice and swallowing, as evidenced by the outcomes of L-DDK, VDS, and DIGEST changes in this study.
In this study, HNC patients with dysphagia performed singing with different pitches, which requires vocal fold vibration, including the intrinsic muscle movement of the vocal fold and laryngeal movement in a structured musical behavior. When considering the swallowing difficulties and poor vocal functions in HNC patients with dysphagia,\textsuperscript{15} patients with HNC need to enhance laryngeal elevation non-invasively and prevent aspiration by improving the intrinsic muscle movement of vocal folds.

In addition, we also analyzed the swallowing function of the oral cancer group and the pharyngeal cancer group in VDS and DIGEST to identify which parameters of swallowing function were more sensitive according to cancer sites. Especially, the pharyngeal cancer group showed time-dependent changes in pharyngeal phase scores. This suggests that the pharyngeal cancer group showed recovery in swallowing function of the pharyngeal phase, including aspiration after the intervention, even though the group had poor condition in the pharyngeal phase at baseline. These results indicate that patients with pharyngeal cancer had a sensitive response to therapeutic singing since our protocol mainly involved exercises related to laryngeal elevation and intrinsic muscle movement of the vocal folds.

The limitation of the study is that the investigation of patient-reported experiences was not performed to evaluate the effect of therapeutic singing on patients’ psychometrical properties. In addition, speech-language pathologists were not involved to measure vocal and swallowing data in the study, even though music therapists trained by experienced physiatrists were involved. Moreover, a further clinical trial with larger sample size is essential to make a definite conclusion. However, our results may suggest potential benefits of therapeutic singing by improving swallowing functions in HNC patients. Therefore, the present study may shed some light on the rehabilitative approach with a novel intervention for HNC patients with swallowing difficulties after indispensable surgical procedures and radiotherapies.

**Conclusion**

The present study showed the potential benefit of therapeutic singing on swallowing function in HNC patients with dysphagia. A significant effect was observed in the pharyngeal phase during the swallowing process. The therapeutic singing was more responsive for pharyngeal cancer group with swallowing problems during the pharyngeal phase. Our protocol involved improving the patients’ pharyngeal functions, such as laryngeal elevation movement and intrinsic muscle movement of the vocal fold. Therefore, HNC patients who suffered from dysphagia are recommended to take therapeutic singing to improve their swallowing function.

**Acknowledgments**

We are grateful to these patients for their participation in this study. The study was approved by the Institutional Review Board of Yonsei University Health System (Approval No. 4-2012-0483), and complied with the 1964 Helsinki Declaration and its later amendments. Patients were well informed about the purpose and contents of our study by the investigators. Written consent was obtained from all patients prior to initiation of intervention.

### Table 7. Videofluoroscopic Dysphagia Scale in Subgroups of the Intervention Group.

| VDS                        | Oral cavity cancer | Pharyngeal cancer | Time | Group | Time × group |
|---------------------------|--------------------|-------------------|------|-------|--------------|
| Lip closure               | 0.00 ± 0.00        | 0.00 ± 0.00       | –    | –     | –            |
| Bolus formation           | 2.18 ± 0.82        | 1.91 ± 0.73       | 2.15 | 0.44  | 1.50 ± 0.87  |
| Mastication               | 2.55 ± 0.98        | 2.55 ± 0.98       | 3.00 | 1.91  | 1.00 ± 1.00  |
| Apraxia                   | 0.00 ± 0.00        | 0.00 ± 0.00       | 0.00 | 0.00  | 0.00 ± 0.00  |
| Tongues to palate contact | 3.18 ± 1.22        | 2.27 ± 1.04       | 1.25 | 1.25  | 1.25 ± 1.25  |
| Premature bolus loss      | 2.73 ± 0.40        | 2.18 ± 0.42       | 1.88 | 0.38  | 1.50 ± 0.00  |
| Oral transit time         | 1.36 ± 0.47        | 0.55 ± 0.37       | 0.00 | 0.00  | 0.00 ± 0.00  |
| Triggering of pharyngeal swallow | 1.64 ± 0.68  | 0.82 ± 0.55       | 0.00 | 0.00  | 0.00 ± 0.00  |
| Vallecular residue        | 3.45 ± 0.67        | 3.45 ± 0.61       | 3.00 | 0.58  | 2.50 ± 0.50  |
| Laryngeal elevation       | 7.36 ± 1.10        | 4.09 ± 1.42       | 9.00 | 0.00  | 4.50 ± 2.60  |
| Pyriform sinus residue    | 5.73 ± 1.37        | 5.32 ± 1.33       | 6.75 | 1.30  | 3.38 ± 1.13  |
| Coating on the pharyngeal wall | 5.73 ± 1.37  | 4.09 ± 1.42       | 9.00 | 0.00  | 6.75 ± 2.25  |
| Pharyngeal transit time   | 2.18 ± 0.91        | 1.09 ± 0.73       | 3.00 | 1.73  | 0.00 ± 0.00  |
| Aspiration                | 4.36 ± 0.85        | 2.18 ± 0.91       | 9.00 | 1.73  | 3.00 ± 1.73  |

Data are presented as frequencies, mean ± SEM.

Abbreviation: VDS, videofluoroscopic dysphagia scale.

*P < .05, **P < .01 significant effect by two-way repeated measures ANOVA.

\textsuperscript{†}P < .05 significant difference by Wilcoxon signed-ranked test.
Author contributions
All authors made substantial contributions to this study. Seongmoon Jo, Myung Sun Yeo, Yoon-Kyum Shin, and Ki Hun Shin contributed to the acquisition and interpretation of data and writing of the manuscript. Soo Ji Kim and Sung-Rae Cho designed the study and reviewed and approved the manuscript. They were also responsible for the integrity of the data as co-corresponding authors.

Declaration of Conflicting Interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding
The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article. This study was supported by the grant from Hyundai Motor Chung Mong-Koo Foundation.

ORCID iD
Sung-Rae Cho https://orcid.org/0000-0003-1429-2684

References
1. Cognetti DM, Weber RS, Lai SY. Head and neck cancer: an evolving treatment paradigm. Cancer. 2008;113:1911-1932. doi:10.1002/cncr.23654
2. Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2018;68:394-424. doi:10.3322/caac.21492
3. Forastiere A, Koch W, Trotti A, Sidransky D. Head and neck cancer. Oral Oncol. 2011.10.017
4. Beadle BM, Liao KP, Elting LS, et al. Improved survival using intensity-modulated radiation therapy in head and neck cancers: a SEER-Medicare analysis. Cancer. 2014;120:702-710. doi:10.1002/cncr.238372
5. Wall LR, Ward EC, Cartmill B, Hill AJ. Physiological changes to the swallowing mechanism following (chemo)radiotherapy for head and neck cancer: a systematic review. Dysphagia. 2013;28:481-493. doi:10.1007/s00455-013-9491-8
6. Dort JC, Farwell DG, Findlay M, et al. Optimal perioperative care in major head and neck cancer surgery with free flap reconstruction: a consensus review and recommendations from the enhanced recovery after surgery society. Otolaryngol Head Neck Surg. 2017;143:292-303. doi:10.1010/jamaoto.2016.2981
7. Haddad RI, Shin DM. Recent advances in head and neck cancer. N Engl J Med. 2008;359:1143-1154. doi:10.1056/NEJMr0707975
8. Liao CT, Hsueh C, Lee LY, et al. Neck dissection field and lymph node density predict prognosis in patients with oral cavity cancer and pathological node metastases treated with adjuvant therapy. Oral Oncol. 2012;48:329-336. doi:10.1016/j.oraloncology.2011.10.017
9. Ang KK, Trotti A, Brown BW, et al. Randomized trial addressing risk features and time factors of surgery plus radiotherapy in advanced head-and-neck cancer. Int J Radiat Oncol Biol Phys. 2001;51:571-578. doi:10.1016/s0360-3016(01)01690-x
10. Chen AY, Frankowski R, Bishop-Leone J, et al. The development and validation of a dysphagia-specific quality-of-life questionnaire for patients with head and neck cancer: the M. D. Anderson dysphagia inventory. Arch Otolaryngol Head Neck Surg. 2001;127:870-876.
11. Rinkel RN, Verdonck-de Leeuw IM, Doornaert P, et al. Prevalence of swallowing and speech problems in daily life after chemoradiation for head and neck cancer based on cut-off scores of the patient-reported outcome measures SWAL-QOL and Shi. Eur Arch Otorhinolaryngol. 2016;273:1849-1855. doi:10.1007/s00405-015-3680-z
12. Kar A, MR A, Bhaumik U, Rao VUS. Psychological issues in head and neck cancer survivors: need for addressal in rehabilitation. Oral Oncol. 2020;110:104859. doi:10.1016/j.oraloncology.2020.104859
13. Martin-Harris B, McFarland D, Hill EG, et al. Respiratory-swallow training in patients with head and neck cancer. Arch Phys Med Rehabil. 2015;96:885-893. doi:10.1016/j.apmr.2014.11.022
14. Banda KJ, Chu H, Kao CC, et al. Swallowing exercises for head and neck cancer patients: a systematic review and meta-analysis of randomized control trials. Int J Nurs Stud. 2021;114:103827. doi:10.1016/j.ijnurstu.2020.103827
15. Manikantan K, Khode S, Sayed SI, et al. Dysphagia in head and neck cancer. Cancer Treat Rev. 2009;35:724-732. doi:10.1016/j.ctrv.2009.08.008
16. Ku PKM, Holsinger FC, Chan JYK, et al. Management of dysphagia in the patient with head and neck cancer during COVID-19 pandemic: practical strategy. Head Neck. 2020;42:1491-1496. doi:10.1002/hed.26224
17. Park T, Kim Y. Effects of tongue pressing effortful swallowing in older healthy individuals. Arch Gerontol Geriatr. 2016;66:127-133. doi:10.1016/j.archger.2016.05.009
18. Zatorre RJ, Baum SR. Musical melody and speech intonation: singing a different tune. PLoS Biol. 2012;10:e1001372. doi:10.1371/journal.pbio.1001372
19. Yagi N, Nagami S, Lin MK, et al. A noninvasive swallowing measurement system using a combination of respiratory flow, swallowing sound, and laryngeal motion. Med Biol Eng Comput. 2017;55:1001-1017. doi:10.1007/s11517-016-1561-2
20. Malandraki GA, Hind JA, Gangnon R, Logemann JA, Robbins J. The utility of pitch elevation in the evaluation of oropharyngeal dysphagia: preliminary findings. Am J Speech Lang Pathol. 2011;20:262-268. doi:10.1044/1058-0360(2011/10-0097)
21. Miloro KV, Pearson WG Jr, Langmore SE. Effortful pitch glide: a potential new exercise evaluated by dynamic MRI. J Speech Lang Hear Res. 2014;57:1243-1250. doi:10.1044/2014_JSLHR-S-13-0168
22. Kim SJ. Music therapy protocol development to enhance swallowing training for stroke patients with dysphagia. J Music Ther. 2010;47:102-119. doi:10.1093/jmt/47.2.102
23. Yeos MS, Yoo GE, Cho SR, Kim SJ. Does etiology matter? Comparative analysis of a singing-enhanced swallowing protocol for patients with neurological impairment versus head
and neck cancer. *Brain Sci.* 2021;11:997. doi:10.3390/brain-sci11080997

24. Stegemöller EL, Hibbing P, Radig H, Wingate J. Therapeutic singing as an early intervention for swallowing in persons with Parkinson's disease. *Complement Ther Med.* 2017;31:127-133. doi:10.1016/j.ctim.2017.03.002

25. Cohen AJ. Singing. In: Rentfrow PJ, Levitin, DJ, eds. *Foundations in Music Psychology: Theory and Research.* The MIT Press; 2019;685-750.

26. Kang J, Scholp A, Jiang JJ. A review of the physiological effects and mechanisms of singing. *J Voice.* 2018;32:390-395. doi:10.1016/j.jvoice.2017.07.008

27. Fancourt D, Perkins R, Ascenso S, Carvalho LA, Steptoe A, Williamson A. Effects of group drumming interventions on anxiety, depression, social resilience and inflammatory immune response among mental health service users. *PLoS One.* 2016;11:e0151136. doi:10.1371/journal.pone.0151136

28. Pauloski BR. Rehabilitation of dysphagia following head and neck cancer. *Phys Med Rehabil Clin N Am.* 2008;19:889-928. x. doi:10.1016/j.pmr.2008.05.010

29. Takes RP, Rinaldo A, Silver CE, et al. Future of the TNM classification and staging system in head and neck cancer. *Head Neck.* 2010;32:1693-1711. doi:10.1002/hed.21361

30. Park P, Hashmi M. Occupational therapy for the head and neck cancer patient. *Cancer Treat Res.* 2018;174:225-235. doi:10.1007/978-3-319-65421-8_13

31. Dromey C, Ramig LO, Johnson AB. Phonatory and articulatory changes associated with increased vocal intensity in Parkinson disease: a case study. *J Speech Hear Res.* 1995;38:751-764. doi:10.1044/jsshr.3804.751

32. Maslan J, Leng X, Rees C, Blalock D, Butler SG. Maximum phonation time in healthy older adults. *J Voice.* 2011;25:709-713. doi:10.1016/j.jvoice.2010.10.002

33. Lombard L, Solomon NP. Laryngeal diadochokinesis across the adult lifespan. *J Voice.* 2020;34:651-656. doi:10.1016/j.jvoice.2019.04.004

34. Louzada T, Beraldinelle R, Berretin-Felix G, Brasoletto AG. Oral and vocal fold diadochokinesis in dysphonic women. *J Appl Oral Sci.* 2011;19:567-572. doi:10.1590/s1678-77572011000600005

35. Ollivere B, Duce K, Rowlands G, Harrison P, O'Reilly BJ. Swallowing dysfunction in patients with unilateral vocal fold paralysis: aetiology and outcomes. *J Laryngol Otol.* 2006;120:38-41. doi:10.1017/S0022215105003567

36. Wilson JA, Pryde A, White A, Maher L, Maran AG. Swallowing performance in patients with vocal fold motion impairment. *Dysphagia.* 1995;10:149-154. doi:10.1007/BF00260968

37. Han TR, Paik NJ, Park JW, Kwon BS. The prediction of persistent dysphagia beyond six months after stroke. *Dysphagia.* 2008;23:59-64. doi:10.1007/s00455-007-9097-0

38. Kim DH, Choi KH, Kim HM, et al. Inter-rater reliability of videofluoroscopic dysphagia scale. *Ann Rehabil Med.* 2012;36:791-796. doi:10.5535/arm.2012.36.6.791

39. Kim J, Oh BM, Kim JY, Lee GJ, Lee SA, Han TR. Validation of the videofluoroscopic dysphagia scale in various etiologies. *Dysphagia.* 2014;29:438-443. doi:10.1007/s00455-014-9524-y

40. Hutcheson KA, Barrow MP, Barringer DA, et al. Dynamic imaging grade of swallowing toxicity (DIGEST): scale development and validation. *Cancer.* 2017;123:62-70. doi:10.1002/cncr.30283

41. Leeper HA, Jones E. Frequency and intensity effects upon temporal and aerodynamic aspects of vocal fold diadochokinesis. *Percept Mot Skills.* 1991;73:880-882. doi:10.2466/pms.1991.73.3.880