SUPER-SUPRAGLOTTIC SWALLOW IN IRRADIATED HEAD AND NECK CANCER PATIENTS

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Abstract: *Background.* After radiotherapy to the head and neck, many patients experience swallowing difficulties. Preliminary work indicates that these patients benefit from the super-supraglottic swallow maneuver.

Methods. Lateral videofluoroscopic studies examined oropharyngeal swallowing in 9 patients who suffered from dysphagia after radiation to the head and neck. Each patient completed two swallows each of 1 mL or 3 mL liquid barium without a voluntary swallow maneuver and with the super-supraglottic swallow designed to close the entrance to the airway early. The videotape of each swallow was digitized and the location of pharyngeal structures marked throughout the swallow. Movement over time plots were generated to measure changes in structural movement resulting from the maneuver.

Results. The super-supraglottic swallow resulted in changes in airway entrance closure and hyolaryngeal movement. One patient who aspirated without the maneuver stopped aspirating with the maneuver. Two others had aspiration reduced to a trace with the maneuver. Fewer swallow disorders were observed with the maneuver.

Conclusion. The super-supraglottic swallow results in improved biomechanics of swallow in irradiated head and neck cancer patients. © 1997 John Wiley & Sons, Inc. *Head Neck* **19:** 535–540, 1997.

Keywords: swallowing; videofluoroscopy; swallow maneuvers; head and neck; radiotherapy

Supraglottic laryngectomy involves removal of the top two sphincters in the airway, ie, the epiglottis and the aryepiglottic folds and false vocal folds. When the surgery was introduced into the United States in the 1950s and 1960s, a voluntary swallowing technique was also introduced to improve the patient's ability to protect the airway and eliminate aspiration during swallowing.[1,2] This technique was known as the supraglottic swallow and was designed to close the airway at the true vocal folds before and during the swallow, thus preventing aspiration during the swallow.[3] In this technique, patients are required to take a breath, hold the breath before and during the swallow, and cough at the end of the swallow (before inhaling). The cough after the breath hold is designed to clear any residual material from inside or near the airway entrance, thus prevent-

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ing aspiration of residue in the pharynx after the swallow.

More recently, the super-supraglottic swallowing maneuver has been described, which is designed to close the airway at the entrance, ie, the false vocal folds and the arytenoid to base of epiglottis.[4–6] The super-supraglottic swallow includes the same steps as the supraglottic swallow, but during the voluntary breath-hold period, the patient is asked to bear down, increasing the effort of closure. The increased effort during the breath hold tilts the arytenoids further forward, toward the base of the epiglottis, and pulls in the false vocal folds, generally completely closing the airway entrance above the true vocal folds.[5,6] In normal subjects, the technique not only closes the airway entrance but also elevates the larynx further during the early part of the swallow.[6] The height and timing of maximal laryngeal elevation does not change with the maneuver, however. Though the biomechanical effects of the technique have been described in normal subjects,[6] it has not been examined as to its biomechanical effects on swallowing in a group of dysphagic patients. This investigation presents data on the effects of the super-supraglottic maneuver during swallow in patients who have received high-dose chemotherapy and radiotherapy for tumors of the posterior oral cavity, pharynx, and larynx. These patients were selected because several earlier clinical reports indicated that slowed laryngeal lifting and consequent reduced closure of the airway entrance were frequently observed disorders in irradiated patients and that the Mendelsohn maneuver was generally perceived clinically as not as helpful as the super-supraglottic swallow.[7,8] The Mendelsohn maneuver is designed to increase the extent and duration of laryngeal elevation and anterior movement and thereby increase the duration and extent of opening of the upper esophageal sphincter. Patients are asked to swallow normally and when they feel their "voice box," or "Adam's apple," lift to the top of their throat, to keep it lifted for several seconds.

MATERIALS AND METHODS

Subjects for this study were 9 patients who had undergone high-dose radiotherapy and chemotherapy for tumors of the posterior oral cavity, pharynx, and/or larynx. Radiation dose ranged from 7000 to 7500 cGy. The patients were referred for videofluoroscopy because of severe swallowing problems perceived by their physician during or after treatment. Data on age, sex, tumor site, stage, and timing of treatment for the 9 patients are presented in Table 1. Tumor stage data for three of the patients were not obtainable. Although the tumor sites were heterogeneous, the radiation fields were quite homogeneous, involving the tongue base, pharynx, and larynx in all patients, with only 1–2 mm difference between them. Time between the end of radiotherapy and videofluorographic study ranged from concurrent with treatment to 5 years.

During the videofluorographic study, the patients were seated and viewed in a lateral plane with the oropharyngeal region visualized from the soft palate superiorly to the base of the cervical vertebra inferiorly and from the lips anteriorly to the cervical vertebra posteriorly. Initially, all patients were given 1 mL boluses to swallow. All patients complained of dry mouth, but four patients had difficulty propelling the small (1-mL) bolus because of xerostomia and were given 3-mL boluses. Five patients completed two swallows each of 1 mL liquid with and without the maneuver. One of these patients and the other four patients who had difficulty propelling the 1-mL liq-

Table 1. Tumor site and stage for the nine irradiated patients.

Patient	Sex	Age (yr)	Tumor site	Tumor stage	Time from end of radiation to VFG
1	M	68	R tonsil, tongue base	T4N2BM0	Concurrent
2	M	59	Hypopharynx	T4N2BM0	6 mo
3	M	50	L tonsil, pharyngeal wall, soft palate	T2N3BM0	5 mo
4	F	40	Esophagus	Not known	Concurrent
5	M	69	R oropharynx	T3N1M0	7 mo
6	F	69	R tonsil	T2N2BM0	10 wk
7	M	70	Oropharynx	Not known	5 yr
8	M	55	L tonsil	Not known	10 wk
9	F	60	R tonsil/tongue base	T4N2CMO	3 yr

VFG, videofluorographic study.

uid completed two swallows each of 3 mL liquid using no swallowing maneuver and two swallows each of 3 mL liquid using the super-supraglottic maneuver. They were instructed in this maneuver in the radiographic suite after completing the non-maneuver swallow. Specific instructions were: "Take a breath in and hold your breath, bearing down hard. Keep holding your breath and bearing down until you finish swallowing. Cough immediately when you finish swallowing."

Subjects were given five practice trials with the super-supraglottic maneuver on dry swallows prior to the videofluorographic recording of the super-supraglottic swallows under study. Then, videofluorographic recording was initiated, recording the swallow as the patient used the maneuver.

Videotapes of each patient's swallows were first reviewed in slow motion and frame by frame to identify the swallow disorders present in each swallow. Then the videotapes of each patient's four swallows with and without maneuver were digitized using a Gateway 2000 80486 computer. The digitized video frames were then marked for the location of target structures including: (1) base of tongue and (2) posterior pharyngeal wall, each at 3 levels: inferior corner of C2, mid-C2, and superior corner of C3; (3) anterior and posterior location of cricopharyngeal opening; (4) base of epiglottis; (5) tip of the arytenoid; (6) anterior-superior aspect of the hyoid bone; (7) anterior-superior corner of the tracheal air column as an indicator of the laryngeal position. Movement over time plots were then generated for each structure. From these plots, 26 measures of timing, extent, and coordination of structural movements were made. These included three duration measures (in seconds): (1) base of tongue (bot) contact to posterior pharyngeal wall (ppw); (2) cricopharyngeal opening (cpo); and (3) laryngeal closure (lac). Three onsets of movement in seconds (sec) and four extents of structural movement in millimeters (mm) in relation to first cricopharyngeal (cp) opening were identified, including onsets of: (1) base of tongue movement; (2) posterior pharyngeal wall movement; and (3) laryngeal closure and extents of: (1) laryngeal elevation; (2) anterior laryngeal movement; (3) hyoid elevation; and (4) anterior hyoid movement. The maximal extent (in millimeters) of movement of the base of tongue and posterior pharyngeal wall at the level of the inferior corner of C2, at mid-C2, and at the superior corner of C3 were measured, as was maximal width of cricopharyngeal opening, maximal thickening of the epiglottic base, maximal anterior arytenoid movement, maximal laryngeal and hyoid elevation, and anterior movement and time to maximum cricopharyngeal opening in relation to first cricopharyngeal opening. The time the bolus reached the pyriform sinus in relation to first cricopharyngeal opening (in seconds) was identified. In addition, pharyngeal delay time (in seconds) and approximate percent of oral and pharyngeal residue and presence or absence of aspiration were noted from slow motion and frame-by-frame analysis of each swallow.

Data for the 1-mL and the 3-mL volumes were analyzed separately, each using mixed-model analysis of variance, with subject and maneuver condition as the factors. The PROC MIXED procedure in the SAS statistical software[9] was used to analyze the data. Statistical significance was indicated when $p < .05$.

RESULTS

Review of the swallowing disorders seen on the videofluorographic studies revealed that all nine patients exhibited reduced tongue base retraction, delayed or reduced laryngeal elevation, and reduced or delayed closure of the laryngeal entrance (Table 2). Overall, there were fewer swallowing disorders observed when the patients used the super-superglottic swallow than when they did not.

Three patients aspirated without the maneuver. Two of these patients aspirated during the swallow because of incomplete airway closure, which allowed the liquid to pass through the larynx and directly into the trachea. The third pa-

Table 2. Swallowing motility disorders observed in the nine patients with and without use of the maneuver.

	No maneuver	Maneuver
Reduced lip closure	1	0
Reduced tongue control	1	1
Reduced manipulation of bolus	2	1
Reduced lateral tongue stabilization	2	1
Delayed pharyngeal swallow	5	3
Reduced base of tongue retraction	9	9
Delayed/incomplete airway entrance closure	9	4
Reduced airway closure	1	1
Reduced laryngeal elevation	9	8
Reduced cricopharyngeal opening	2	1
Total	41	29

tient aspirated after the swallow because of reduced laryngeal lifting, which resulted in liquid residue remaining on top of the larynx until the patient breathed after the swallow and the liquid fell through the larynx and into the trachea. With the supraglottic swallow maneuver, one patient's aspiration was eliminated, and the amount of aspiration was reduced to a trace in the other two patients. Results of the analysis of variance for the biomechanical measures of the 1-mL boluses revealed four measures of swallow which were significantly affected by the super-supraglottic maneuver (see Table 3). The onset of posterior base of tongue movement was significantly earlier in relation to first cricopharyngeal opening with the maneuver. Maximal hyoid elevation at the time of first cricopharyngeal opening and overall maximal elevation were increased significantly in the maneuver, whereas maximum width of cricopharyngeal opening was significantly reduced with the maneuver. Earlier onset of airway entrance closure, the goal of the maneuver, was accomplished with the maneuver (occurring .33 seconds after cricopharyngeal opening without the maneuver and .48 seconds before cricopharyngeal opening with the maneuver), but the difference was not statistically significant ($p = .08$). Duration of airway entrance closure increased .72 seconds but not significantly so. Base of tongue movement improved generally at all the levels

Table 3. Measures (mean ± SE) of timing, distance and coordination of oral and pharyngeal swallow events in the five radiated patients with and without the super-supraglottic maneuver (SSG) on 1-mL swallows.

	No maneuver	SSG maneuver	*p*-Value
Duration (sec)			
Bot to ppw contact	.54 (.27)	.59 (.27)	.68
Cp opening	.55 (.08)	.41 (.08)	.14
Laryngeal closure	1.10 (.63)	1.82 (.66)	.31
Onset (sec) or extent (mm) of structural movement in relation to first cp opening			
Bot movement (sec)	.01 (11)	−.16 (.11)	.02*
Ppw movement (sec)	.02 (.06)	−.06 (.06)	.15
Laryn closure (sec)	.33 (.36)	−.48 (.38)	.08†
Laryn elevation (mm)	13.52 (4.13)	20.88 (4.52)	.13
Ant laryn mvmt (mm)	−.21 (1.82)	1.80 (1.94)	.24
Hyoid elevation (mm)	8.03 (2.09)	18.42 (2.42)	.01*
Ant hyoid mvmt (mm)	2.03 (1.88)	1.82 (1.95)	.86
Extent of structural movement (mm)			
Max width cpo	4.93 (1.07)	4.30 (1.08)	.04*
Epi mvmt	5.31 (2.08)	4.24 (2.10)	.41
Aryt mvmt	.48 (1.82)	1.35 (1.85)	.46
Laryn elevation	19.22 (5.52)	20.62 (5.60)	.71
Ant laryn mvmt	3.35 (1.58)	4.56 (1.64)	.49
Hyoid elevation	11.77 (3.22)	18.47 (3.31)	.04*
Ant hyoid mvmt	4.62 (1.57)	4.50 (1.58)	.89
Bot mvmt @ inf-C2	9.12 (1.72)	11.31 (1.78)	.25
Ppw movement @ inf-C2	4.96 (1.12)	5.04 (1.14)	.93
Bot mvmt @ level of mid-C2	7.60 (1.47)	11.25 (1.56)	.10†
Ppw mvmt @ level of mid-C2	7.37 (1.35)	7.20 (1.40)	.91
Bot mvmt @ level of sup-C3	9.29 (1.44)	11.73 (1.53)	.26
Ppw mvmt @ level of sup-C3	4.00 (1.10)	4.81 (1.13)	.48
Time to max cpo rel to 1st cpo	.24 (.05)	.15 (.05)	.20
Time bolus reaches pyriform sinus rel to 1st cpo (sec)	.09 (.08)	.05 (.07)	.70
Pharyngeal delay time (sec)	−.10 (.50)	.36 (.50)	.52
Approximate % residue			
Oral	18.0 (7.9)	7.5 (8.4)	.35
Pharyngeal	25.8 (9.7)	32.4 (10.1)	.57

Abbreviations: bot, base of tongue; ppw, posterior pharyngeal wall; cp, cricopharyngeal; laryn, larynx; epi, epiglottis; ant, anterior; aryt, artyenoid; cpo, cricopharyngeal opening; max, maximum; rel, relative; mvmt, movement; c, cervical vertebra.
*p *Value of .05 or less.*
†p *Value of .10 or less.*

Table 4. Measures (mean ± SE) of timing, distance and coordination of oral and pharyngeal swallow events in the five radiated patients with and without the super-supraglottic maneuver (SSG) on 3-mL swallows.

	No maneuver	SSG maneuver	*p*-Value
Duration (sec)			
Bot to ppw contact	.57 (.15)	.75 (.15)	.29
Cp opening	.47 (.38)	.90 (.37)	.22
Laryngeal closure	.84 (.48)	1.29 (.47)	.30
Onset (sec) or extent (mm) of structural movement in relation to 1st cp opening			
Bot movement (sec)	−.18 (.10)	−.07 (.10)	.11
Ppw movement (sec)	−.12 (.06)	−.02 (.06)	.07*
Laryn closure (sec)	.14 (.11)	.02 (.10)	.09*
Laryn elevation (mm)	14.10 (4.39)	19.19 (4.33)	.08*
Ant laryn mvmt (mm)	.46 (1.19)	2.30 (1.15)	.18
Hyoid elevation (mm)	3.12 (3.49)	11.83 (3.45)	.002†
Ant hyoid mvmt (mm)	1.66 (2.88)	−.36 (2.86)	.19
Extent of structural movement (mm)			
Max width cpo	5.00 (.78)	7.28 (.73)	.06*
Epi movement	8.47 (2.61)	8.85 (2.60)	.72
Aryt movement	2.42 (1.99)	1.83 (1.97)	.59
Laryn elevation	17.91 (3.91)	24.16 (3.86)	.02†
Ant laryn mvmt	2.37 (1.32)	5.51 (1.27)	.06*
Hyoid elevation	6.67 (3.14)	14.89 (3.11)	.0007†
Ant hyoid mvmt	5.46 (1.97)	7.64 (1.90)	.32
Bot mvmt @ inf C2	8.94 (1.62)	10.70 (1.59)	.13
ppw movement @ inf-C2	7.21 (1.55)	5.84 (1.54)	.11
Bot mvmt @ level of mid-C2	13.63 (1.49)	15.44 (1.41)	.38
Ppw mvmt @ level of mid-C2	12.13 (1.32)	8.75 (1.28)	.02†
Bot mvmt @ level of sup-C3	9.24 (1.29)	9.81 (1.22)	.74
Ppw mvmt @ level of sup-C3	5.28 (1.32)	6.12 (1.31)	.25
Time to max cpo rel to 1st cpo	.14 (.23)	.47 (.22)	.15
Time bolus reaches pyriform			
Sinus rel to 1st cpo (sec)	−.05 (.04)	−.05 (.04)	.86
Pharyngeal delay time (sec)	−.02 (.12)	−.15 (.11)	.44
Approximate % residue			
Oral	6.3 (3.1)	9.0 (2.9)	.46
Pharyngeal	12.9 (3.2)	11.3 (3.1)	.63

Abbreviations: bot, base of tongue; ppw, posterior pharyngeal wall; cp, cricopharyngeal; laryn, larynx; epi, epiglottis; ant, anterior; aryt, arytenoid; cpo, cricopharyngeal opening; max, maximum; rel, relative; mvmt, movement; c, cervical vertebra.

*p Value of .10 or less.

†p Value of .05 or less.

but not significantly so, whereas pharyngeal wall movement changed little. Range of movement of other structures tended to be improved slightly or relatively unchanged.

Table 4 presents the biomechanical data on the effects of the super-supraglottic swallows in the 5 subjects who used the maneuver on 3 ml swallows. As in the 1 ml swallows with the maneuver hyoid elevation at the time of first cricopharyngeal opening was significantly greater. Laryngeal elevation was greater at that time but did not quite reach statistical significance. Posterior pharyngeal wall movement occurred later but laryngeal closure occurred earlier with the maneuver and also neared significance as did duration of laryngeal closure. Maximal hyoid elevation increased significantly with the maneuver while the posterior pharyngeal wall movement at mid level of C2 diminished significantly.

Increase in maximal anterior laryngeal movement and in maximal width of cricopharyngeal opening with the maneuver both neared significance. As in the 1-mL swallow measures with the maneuver, there tended to be an increase or relatively little change in range of movements. The goals of the maneuver, to create earlier and more prolonged airway entrance closure, were achieved but not statistically significantly so.

DISCUSSION

The super-supraglottic swallow maneuver is an extension of the supraglottic swallow developed at the time when the supraglottic laryngectomy was introduced to the United States. Earlier studies in normal subjects identified that the super-supraglottic maneuver closes the airway entrance and also results in greater laryngeal elevation at the time of initial cricopharyngeal opening.[6] This current study defined the effects of the super-supraglottic swallow maneuver on swallows of patients who received radiotherapy to the head and neck. In these patients, the maneuver closed the airway entrance earlier but not statistically significantly so. However, despite lack of statistical significance, these differences may be clinically important and quite likely contributed to the elimination or reduction of aspiration in the 3 patients who aspirated without the maneuver but did not aspirate or aspirated less with the maneuver.

The maneuver also resulted in the hyoid and larynx reaching a higher position at the time of cricopharyngeal opening as it did in the study of normal subjects. Maximum hyoid and laryngeal elevation also increased on both 1-mL and 3-mL swallows with the maneuver but only hyoid elevation was statistically significantly changed. Maximum width of cricopharyngeal opening diminished significantly on 1-mL swallows but increased (non-significantly) on 3-mL swallows with the maneuver. The slight increase in width of cricopharyngeal opening on 3-mL swallows probably relates to the improved hyoid and laryngeal movement as well as the improvements in laryngeal anterior and vertical movement since opening of the cricopharyngeal sphincter results from the anterior and superior movement of the hyoid bone pulling the larynx anteriorly.[10–13]

These results suggest that the super-supraglottic maneuver not only improves airway closure at the entrance but improves the speed of hyolaryngeal movement, especially early in the swallow as the cricopharyngeal region opens. It is likely that the reduced hyolaryngeal movement without the maneuver in these radiated patients results from tissue fibrosis, and that the increased effort used to accomplish the super-supraglottic maneuver created the increased hyoid and laryngeal movements. Interestingly, this change in hyolaryngeal movement is an unanticipated benefit of the maneuver in these patients. These results need to be corroborated in a larger number of patients.

The super-supraglottic (SSG) maneuver also created some unanticipated changes in tongue base movement in these patients. The effortful swallow is a maneuver designed to improve tongue base action by asking the patient to "swallow hard" or to "squeeze hard" as they swallow. Studies which compare the effortful swallow maneuver,[4] SSG and the Mendelsohn maneuver in the same subjects are needed to compare the effects of the two maneuvers on hyolaryngeal movement and cricopharyngeal opening. Also, studies examining the SSG maneuver during swallow of larger volumes and various viscosities would further define the effects of this maneuver.

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