Velar Motility, Velopharyngeal Closure, and Speech Proficiency in Cartilage Pharyngoplasty: An Eight Year Study

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It is generally accepted that velopharyngeal closure is critically important for the development and maintenance of acceptable speech patterns. In the normal manifestation of this neuromuscular complex, the soft palate tenses, lifts, and retracts in effecting a meshed contact between its superior surface and the posterior pharyngeal wall. Mesial movement of the lateral pharyngeal walls is also probably an important characteristic of this total action.

For persons with cleft palate and for others with problems of velopharyngeal incompetence, the primary difficulty in achieving normal velopharyngeal closure generally results more from a failure of the velar component rather than from the pharyngeal component of the mechanism. For example, in an assessment of velopharyngeal function of 80 normal subjects and 50 cleft palate patients, Hagerty and Hill (*3*) found that, although there was more forward movement of the posterior pharyngeal wall in the cleft palate group than in the normal group, the magnitude of this movement and its contribution to speech proficiency could be considered to be relatively insignificant. Moreover, in a comparison of the relative extent of velopharyngeal closure on /ɑ/ and /s/, these same authors found systematic differences in favor of a normal group of subjects over the postoperative cleft palate subjects with whom they were compared. Since these differential measures could not be attributable to movements in the posterior pharyngeal wall, there is reason to infer that the postoperative soft palate, by reason of inadequate length or limited mobility, is the principal contributor to the relative failure of velopharyngeal closure.

From these findings, it seems logical to investigate methods by which the posterior wall might be extended anteriorly to enhance velopharyngeal closure in patients with cleft palate or with other manifestations or velopharyngeal incompetency. In a review of such methods to improve velo-

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pharyngeal closure, the efforts of Passavant (*13*), Gersuny (*2*), Hollweg and Perthes (*10*), Von Gaza (*15*), Wardill (*16*), Bentley (*1*), Hynes (*11*), and Lando (*12*) were studied.

The use of autogenous cartilage was first reported by Hollweg and Perthes (*11*) who described a transplantation of cartilage between the mucous membrane and the musculature of the posterior pharyngeal wall by means of a cervical approach immediately posterior to the sternocleidomastoid muscle. They reported some improvement in speech associated with reduction of the oral-nasal aperture. Wardill (*16*) introduced a transoral approach that involved a horizontal incision over the anterior arch of the atlas bone and vertical closure of the wound margins after wide undermining. Bentley (*1*) reported inadequate improvement four to eight years following this procedure. The advantages of the transoral operative approach were restated by Lando (*12*), who also employed a homogenous cartilage graft into the posterior pharyngeal wall of a postoperative cleft palate patient. Speech improvement in the absence of speech therapy was perceptible ten months postoperatively.

Thus a transoral route with a cartilage implant appeared to be satisfactory for the improvement of velopharyngeal closure. Moreover, experimentation with the relative merits of autogenous and viable homogenous cartilage led us to conclude that homogenous cartilage is superior to autogenous cartilage in that it is readily available in adequate size in addition to being simply prepared and easily cut into the desired shape (*7*). Comparison of storage methods (*4–6*) revealed that homogenous cartilage stored in air in sterile containers at 3 to 5 degrees centigrade maintains viability much longer and is associated with less fibrous tissue invasion than is the case in merthiolate-saline and plasma storage methods.

The procedure for cartilage pharyngoplasty employs a transoral approach under general anesthesia. A transverse incision approximately 2 cm in length is made superior to the anterior tubercle of the atlas after injection with saline solution. A pocket is developed superiorly with special scissors. One or two pieces of shaped cartilage are introduced into the pocket, and the incision is closed with chromic catgut sutures. Care is taken to place the cartilage in a position that will permit optimal velar contact with the posterior pharyngeal wall.

Previous evaluations of results of this procedure have utilized preoperative and postoperative speech recordings, auditor judgments, roentgenograms, and audiometric data (*7–9*). Improvement in speech proficiency and in velopharyngeal closure was reported up to four years postoperatively. However, the design of these studies was only grossly longitudinal, and the method of analysis would not permit assessment of significance of difference of several variables for each evaluation period. Reliability of auditor judgments as criterion measures was not reported.

This report is the first of several on the longitudinal assessment of the results of cartilage pharyngoplasty for patients who had this operative

procedure during an eight-year period. Reported here is information about changes in velar motility, velopharyngeal closure, and speech proficiency that occurred following the operation.

Procedures

One hundred and eighty-one upright cephalometric laminographic skullfilms of 31 patients were studied to obtain the data for assessing changes in velar motility and velopharyngeal closure for each of three evaluations: pre-pharyngoplasty, immediate post-pharyngoplasty, and most recent post-pharyngoplasty (made from one to eight years postoperatively). For each evaluation, x-ray films for /ɑ/ and /s/ were superimposed by using bony cranial landmarks, and tracings were then oriented in the nasal plane. In this manner, tracings of the soft palate, the pharyngeal wall, and the tubercle of the atlas were obtained. Tracings of the superior surface of the tongue also were made, but they were not employed in the present analysis.

Velar motility was measured as a vertical linear distance, in millimeters, above and below the nasal plane from a given reference point on the superior surface of the soft palate. Positive linear measures of velar motility were obtained as the distance between the point of highest elevation of the medial third of the superior velar surface and the nasal plane. Negative linear measures were operationally derived as the distance from the nasal plane to a point dividing the anterior one-third and the middle one-third of the superior velar surface.

Degree of velopharyngeal closure was determined in two ways: extent of velopharyngeal gap, expressed as the shortest linear distance, in millimeters, between any point on the superior velar surface and the posterior pharyngeal wall; and extent of linear contact between the soft palate and posterior pharyngeal wall, as determined, in millimeters, by a vernier spanner.

From 157 speech recordings, the speech proficiency of the 31 subjects was assessed at seven evaluation periods: pre-pharyngoplasty, immediately post-, one year post-, two year post-, three years post-, four years post-, and five or more years post-pharyngoplasty. From these speech recordings, and for each of the evaluation periods, listener judgments were obtained for three speech parameters: degree of nasal resonance, degree of articulatory proficiency, and degree of intelligibility. The speech samples consisted of 30–60 seconds of recorded material that included any or all of the following types of speaking: automatic speech responses (counting, reciting the days of the week, reciting the months of the year), oral reading, and conversation. The recordings for the subjects were arranged in a random order, so that there was no consecutive presentation of any subject's speech.

Before playback for auditor judgments, the judges were trained to recognize normal dialectal variations, particularly with regard to articulation. The judges were three experienced speech clinicians, all of whom were clinically certificated in speech pathology by the American Speech and

Hearing Association. The tapes were played back at a level of approximately 82 dB SPL for most frequent peaks. Three separate listening sessions were held, one for each of the three speech attributes. The listening task was repeated with thirty samples of speech, during a period up to two weeks after the original listening was performed, to obtain estimates of reliability. All speech recordings and playback employed Ampex equipment and the judgments were performed in a sound-treated audiometric suite.

Since preliminary evaluation of the tapes had revealed that some of the patients sounded hyponasal, particularly after cartilage pharyngoplasty, the seven point scale to be used for degree of nasal resonance ranged from −3 (severe denasality) to +3 (severe hypernasality), with 0 representing normal degree of nasal resonance. To judge intelligibility and articulatory proficiency, seven point scales that ranged from 1 to 7, from least defective to most defective, were employed.

Age of the 31 subjects at the time of operation ranged from five years, ten months, to 37 years, seven months, with an average age of 13.6 years. Seventeen of the subjects were male. Twenty-six subjects had received viable homogenous cartilage grafts, and five had received autogenous cartilage. Twenty-six of the subjects had postoperative cleft palate, and five subjects had been judged as demonstrating congenital velopharyngeal incompetency.

For the greater part, the design of this study provided for nonparametric analysis. For all roentgenographic and speech judgment measures that could be matched from one evaluation period to another, the Wilcoxon signed-ranks test (*14*, p. 373–375) was employed to assess significance of difference. This type of nonparametric analysis was selected for the most realistic appraisal of differences among the various evaluation periods, since all subjects were not represented at all evaluation periods. The test yields a T statistic for all matchable subjects at any two evaluation periods under consideration. The magnitude of the T is then assessed in terms of the number of available comparisons used in arriving at evaluations of possible significance of difference.

Reliability of judgments were determined by the Pearson product-moment formula and by t-test. Other types of analysis will be specified in subsequent reports.

It must be acknowledged that for this type of longitudinal research the number of subjects is rather limited. This shortcoming is accentuated in subsequent reports, where certain comparisons are rendered relatively meaningless by reason of the smallness of the N. However, the authors hope that the mode of analysis and report may spur greater general interest in longitudinal study. This particular design can be applied in most research centers where standard data are collected from patients at routine intervals.

Results and Discussion

Figure 1 shows the superimposed x-ray tracings of /ɑ/ and /s/ production for three of the 31 subjects (subjects 22, 23, and 33). It is not intended that

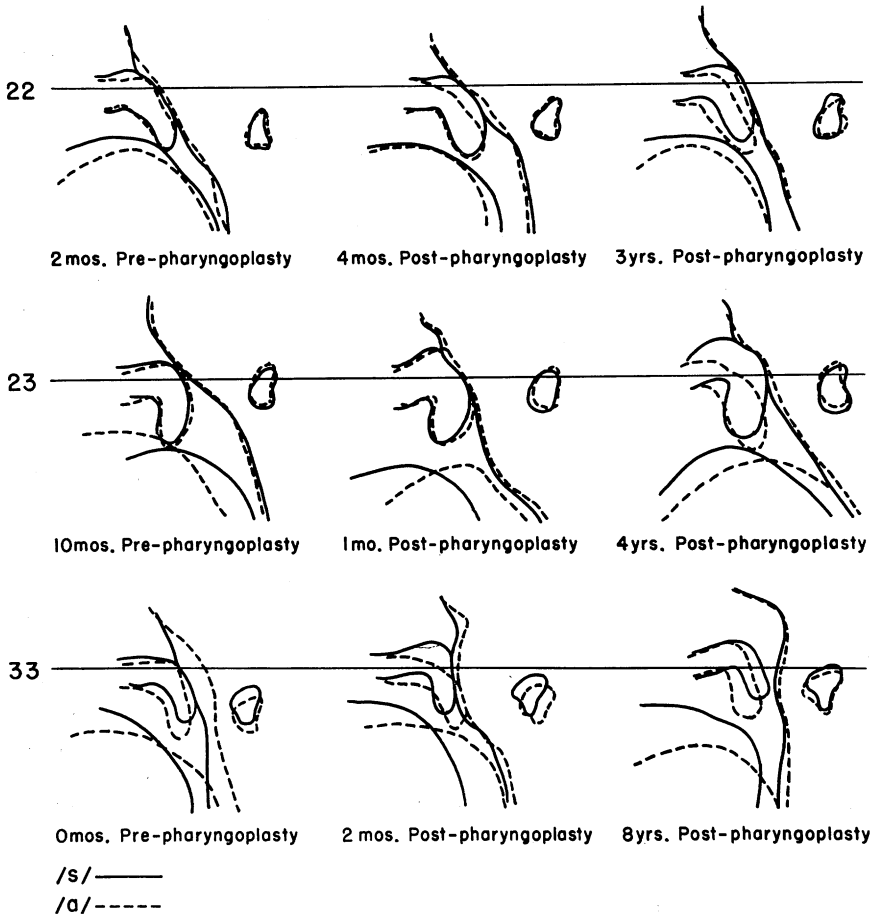

FIGURE 1. Superimposed x-rays of /a/ and /s/ production for three subjects at three evaluation periods: pre-pharyngoplasty, post-pharyngoplasty, and most recent post-pharyngoplasty evaluation (one to eight years).

these particular x-ray tracings are necessarily representative of the entire group of subjects. Rather, they may aid the reader to visualize how measures of velar motility and velopharyngeal closure were obtained for each of three evaluation periods: pre-pharyngoplasty, post-pharyngoplasty, and the most recent evaluation (one to eight years).

Auditor judgments of the speech recordings proved to be sufficiently reliable and stable for use in the statistical analysis, at least regarding possible differences between judges. The obtained *r*s were: degree of nasal resonance, .74 (after a delay of two weeks); degree of intelligibility, .90 (after a one-week delay); and degree of articulatory proficiency, .90 (after a three-hour delay). None of the *t*s indicated significant differences from judgment to rejudgment.

Table 1 shows the measures of velar motility, velopharyngeal gap, and extent of linear velopharyngeal contact that were obtained for each of the

TABLE 1. Measures of velar motility, velopharyngeal gap, and linear velopharyngeal closure during /ɑ/ and /s/, all in millimeters, at three evaluations: I, presurgery; II, immediately post-surgery; and III, the most recent evaluation.

x-ray measures	*evaluation number*					
	I		*II*		*III*	
	/ɑ/	/s/	/ɑ/	/s/	/ɑ/	/s/
velar motility						
Mean	1.76	1.12	1.68	3.02	2.66	4.57
N	31	30	31	31	29	28
velopharyngeal gap						
Mean	5.52	6.76	2.58	4.83	3.45	5.00
N	31	19	19	9	21	8
extent of closure						
Mean	—	7.48	7.73	10.45	8.41	10.36
N	—	11	12	22	8	20

three evaluations. The pre-surgical evaluation (Evaluation I) was conducted, on the average, 4.79 months before surgery. Evaluation II was conducted, on the average, 3.13 months after surgery, and Evaluation III was conducted, on the average, 4.86 years after surgery. It should be noted that, although 31 subjects were employed in the present investigation, measures were obtained for only 29 subjects, at the most, at the most recent evaluation period. Recency of operation precluded use of this evaluation (the third one) in two cases. In one case an X-ray film was not available for the evaluation period under consideration. In another case, use of the x-ray film for /s/ production was deemed inadvisable because there appeared to be tongue-assisted velopharyngeal closure.

Velar Motility. Inspection of Table 1 reveals that cartilage pharyngoplasty appears to have a facilitating effect on velar motility for /s/ but not for /ɑ/. Within three months following the operation the average patient showed approximately two millimeters of greater elevation in the soft palate during /s/ than he had shown prior to the operation. On the other hand, there was no change in velar motility for /ɑ/ production immediately following the operation. Approximately five years after the operation, velar motility for /s/ production continued to increase by one and one-half more millimeters over that shown pre-surgically, and velar motility for /ɑ/ production had increased by approximately one millimeter.

Results of statistical analysis (Wilcoxon signed-ranks test) substantiate the impression that cartilage pharyngoplasty does not effect significant changes in velar motility for /ɑ/ production up to an average of about five years following the operation but that cartilage pharyngoplasty exerts an immediate postoperative excitatory effect on velar motility for /s/ production, and that this effect on vertical lifting movement continues to be sig-

nificantly improved up to approximately five postoperative years, on the average.

This suggests that the operative procedure tends to encourage greater lifting action in the soft palate when it is most needed, that is, on the production of a sustained /s/. The less dramatic effect on lifting action for /ɑ/ production may be related to the possibility that the production of a low vowel like /ɑ/ involves relatively little demand for complete velopharyngeal closure in the achievement of essentially normal oronasal resonance. By the same token, the use of an /ɑ/ vowel for preoperative and postoperative assessment of velar motility does not put palatal lifting potential to its most robust test.

Velopharyngeal Gap. As shown in Table 1, prior to operation, all of the 31 subjects exhibited velopharyngeal gap, averaging 5.52 mm, on /ɑ/ production. Following the operation, 19 subjects showed velopharyngeal gap on /ɑ/ production and the mean gap measurement averaged about three millimeters less than that shown prior to surgery. Very slight regression was noted in the period of the most recent evaluation, when 21 subjects exhibited velopharyngeal gap of about three and one-half millimeters, on the average. For /s/ production, 19 subjects showed preoperative velopharyngeal gap, averaging 6.76 mm. Following cartilage pharyngoplasty, only nine subjects exhibited velopharyngeal gap, averaging 4.83 mm. At the time of most recent evaluation, eight of these subjects continued to show velopharyngeal gap that averaged 5.00 mm. These figures suggest that, for either /ɑ/ or /s/, the results of surgery show relatively immediate improvement in reducing velopharyngeal gap, and that this level of improvement is roughly maintained up to an average of five postoperative years, even though some slight regression may occur.

Differences between preoperative and immediate postoperative velopharyngeal gap and between prepharyngoplasty and the most recent evaluation were statistically significant for /ɑ/ and for /s/. Differences between the immediately post-pharyngoplasty period and the most recent evaluation were not significant, suggesting that the level of improvement shown immediately following the operation was generally maintained for an average of five postoperative years.

Extent of Velopharyngeal Contact. Table 1 further suggests that, for either /ɑ/ or /s/, there was substantial increase in extent of linear velopharyngeal contact following the operation. This degree of improvement appeared to be maintained for the most part for the subsequent five year period. The differences between preoperative and immediate postoperative comparisons and between preoperative and the most recent comparisons were statistically significant by the Wilcoxon test. Lack of significance of the difference between the immediate postoperative period and the period of most recent evaluation suggests again that the level of improvement was generally maintained and did not show significant reduction in degree.

Speech Evaluation. Presented in Table 2 are mean judgments of degree

TABLE 2. Mean and median judgments of degree of nasal resonance, degree of articulatory proficiency, and degree of intelligibility at pre-pharyngoplasty and at six subsequent evaluations.

	evaluations						
	pre-surgery	*immediately post-*	*1 yr. post-*	*2 yrs. post-*	*3 yrs. post-*	*4 yrs. post-*	*5+ yrs. post-*
number of subjects	30	27	23	25	18	15	19
degree of nasal resonance							
mean judgment	+1.8	+1.0	+1.0	+0.6	+0.5	+0.3	+0.8
median judgment	+2	+1	+1	+1	0	0	+1
degree of artic. prof.							
mean judgment	3.6	2.9	2.6	2.6	2.2	2.5	2.9
median judgment	3.5	3	2	2	2	2	2
degree of intelligibility							
mean judgment	3.4	2.7	2.4	2.2	2.1	1.8	2.7
median judgment	3	2	2	2	2	2	2

of nasal resonance, degree of articulatory proficiency, and degree of intelligibility for each of the seven evaluation periods. Before pharyngoplasty, the average subject exhibited moderate hypernasality (mean judgment of +1.8), had moderately defective articulation (mean judgment of 3.6), and was moderately impaired in intelligibility, to the extent that occasional words and phrases were not understood devoid of context (mean judgment of 3.4).

In each speech parameter, there was greatest improvement among the subjects immediately following cartilage pharyngoplasty. There was further improvement in degree of nasal resonance from one year post-pharyngoplasty through the fourth year after the operation, at which time the average subject had practically normal nasal resonance. Comparable improvement in intelligibility occurred during this period and, at four years after the operation, the average subject was only mildly impaired in intelligibility. Improvement in articulatory proficiency was gradual through the period from one to three years; there was slight regression at four years.

Mean judgments for the five-or-more-year evaluation indicate what could be interpreted as a sizeable overall regression in all speech parameters. In fact, however, data for this evaluation period include the results for two subjects who had not been evaluated previously on an annual basis. One subject was mentally retarded and the other was probably of no higher than borderline intelligence. Both were severely nasal, practically unintelligible, and severely impaired in articulatory proficiency at the time of latest evaluation. Had they been excluded from consideration, the data for the five-

or-more-year evaluation would have been much more comparable with the data for four years post-pharynogoplasty. By the same token, their exclusion as data in the pre-pharyngoplasty and post-pharyngoplasty periods would have altered the mean judgments for these periods somewhat. To rule out such extreme influences, the data can be viewed in another way, by appraisal of medians (shown in Table 2). These data reflect less change with time than did the means for all three parameters.

The significance of the differences among all evaluations for the three parameters of speech was evaluated by the Wilcoxon *T* statistic. The differences in degree of nasal resonance between the pre-pharyngoplasty period and all subsequent evaluation periods and between the one year post-pharyngoplasty period and the third and the fourth yearly evaluation periods were significant. Similar significant differences were obtained for degree of articulatory proficiency and for degree of intelligibility.

Ten of the 31 subjects had received speech therapy following pharyngoplasty. All 10 of these subjects were among the youngest in operative age, based on the mean figure for operative age for the entire group, 13.6 years. Eight of the 10 subjects receiving speech therapy were below 10 years of age at the time of their operation. An interesting finding, to be explored more deeply in a subsequent report, was that subjects of younger operative age excelled subjects of older operative age in velopharyngeal function at all evaluation periods, including the pre-surgical evaluation. The younger subjects also tended to show greater speech improvement following surgery than the older subjects, although not significantly so. Results suggest that cartilage pharyngoplasty exerts its most beneficial influence on velopharyngeal function if carried out before the more dramatic downward and forward movement of the maxillofacial complex has occurred. It is also probable that subsequent speech therapy enhances continued velopharyngeal closure. These are impressions that will be dealt with in greater detail in a subsequent report.

Summary

For 31 patients who had undergone cartilage pharyngoplasty over the past eight years, radiographic films and listener judgments were analyzed to assess changes in degree of velar motility, degree of velopharyngeal closure, degree of nasal resonance, degree of articulatory proficiency, and degree of intelligibility. Results of this investigation suggest the following conclusions. a) Cartilage pharyngoplasty results in increased velar motility for /s/ production that is manifested immediately after the operation, and that continues up to five or more years following the operation. Similar effects were observed for /ɑ/ but to a lesser extent. b) The procedure results in improved velopharyngeal closure, in terms either of velopharyngeal gap reduction or an increase in extent of velopharyngeal contact. This improvement in velopharyngeal closure tends to be maintained for as long as five years, on the average. c) Significant reduction in degree of nasal

resonance and significant improvement in intelligibility and in articulatory proficiency are exhibited both immediately and after several years following cartilage pharyngoplasty.

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