Sulcus vocalis

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2007/08/08

Definition

- Luchsinger and Arnold
  - a long thin groove running lengthwise along the free edge of the vocal fold
  - involve all or any segment of the edge of the fold

Classifications

- Bouchayer and Cornut
  - a stage in the natural course of epidermoid cyst of the vocal fold
  - Presence of a cyst or of keratin fragments embedded deep within the sulcus
  - ***True sulcus***
    - open epidermoid cyst with thickened epithelium
    - The bottom of the cystic pouch is adherent to the vocal ligament
  - ***Sulcus vergeture***
    - atrophy of the mucosa covering the vocal ligament

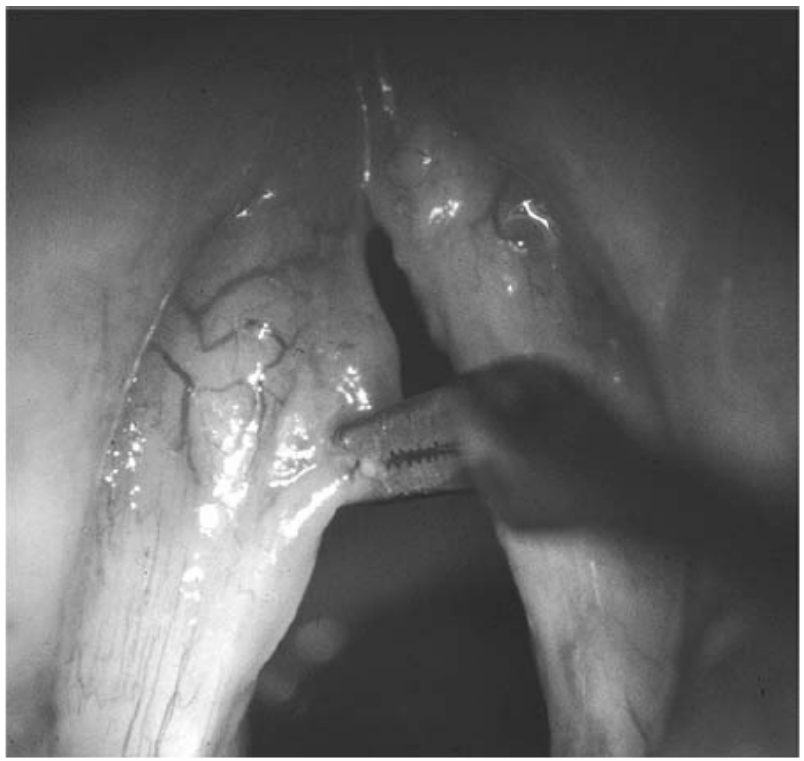


Fig. 1 True sulcus (open cyst)

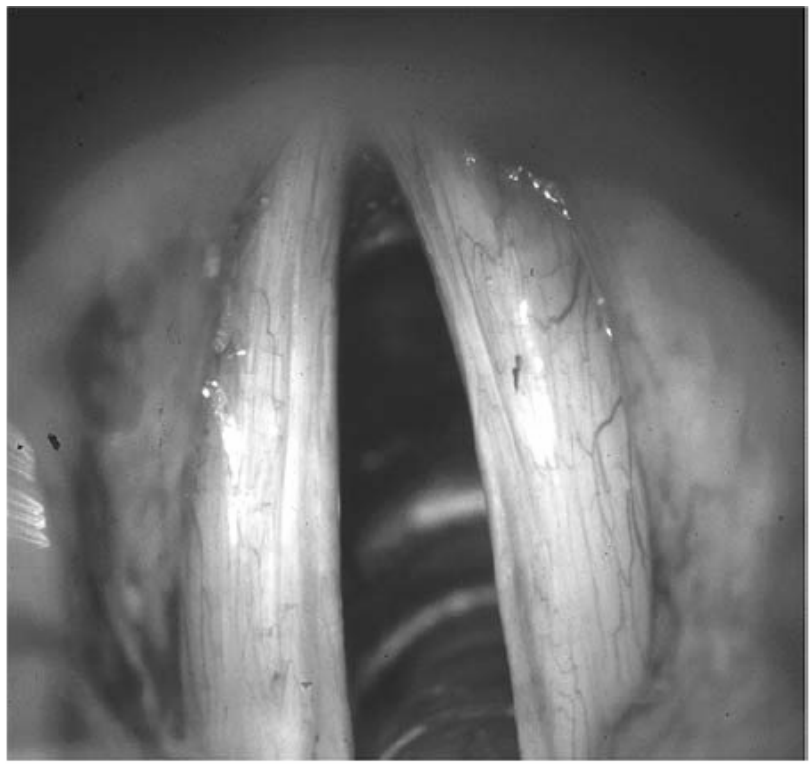
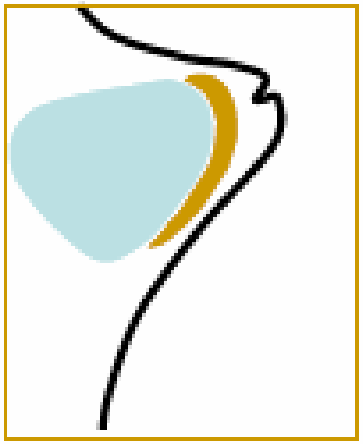
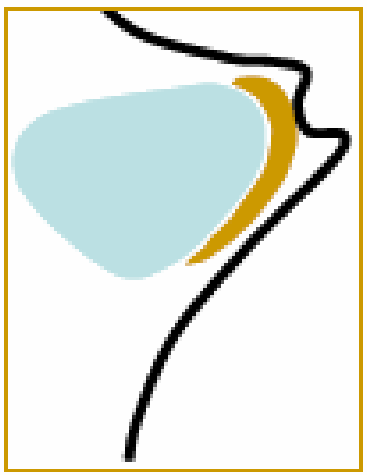


Fig. 2 Sulcus vergeture

- Ford
  - ***Type I sulcus or superficial type***
    - superficial portion of the lamina propria
    - Physiologic
  - ***Type IIa*(II) *sulcus or deep type* (sulcus vergeture)**
    - disappearance of a functional superficial lamina propria with extension to the vocal ligament
    - linear indentation with atrophic mucosa (vergeture)
    - moderate dysphonia
  - ***Type IIb*(III) *or "pouch" type* (true sulcus)**
    - Bottom of the pouch extends to the vocal ligament and may even penetrate the thyro-arytenoid muscle
    - severe dysphonia

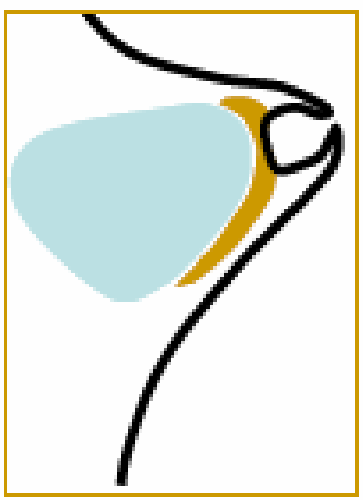


Type I
Physiological



Type IIa
Sulcus vergeture
Atrophic epithelium

Moderate dysphonia
Superf lamina propria involved/lost
Vocal ligament normal/involved
Vocalis muscle normal

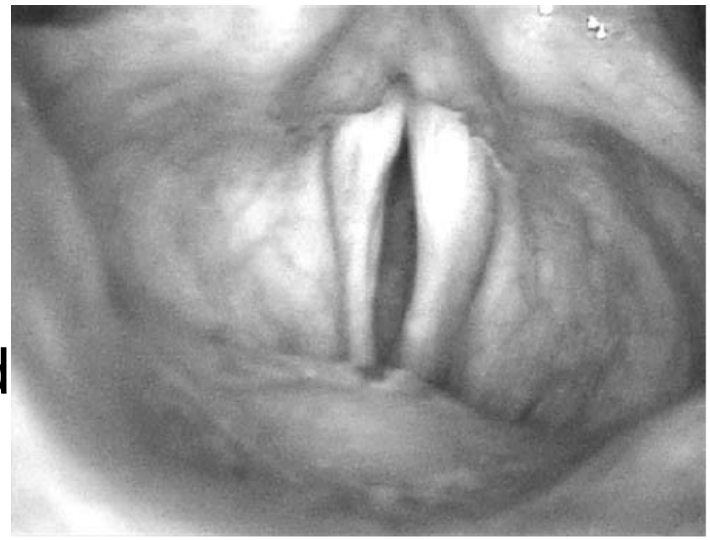


Type IIb
Sulcus vocalis
(open cyst)
Thickened epithelium

Severe dysphonia
Superf lamina propria involved/lost
Vocal ligament attached/lost
Vocalis muscle involved +/-

Pathophysiology

- alters the relationship between the body of the fold and its cover
- inhibits normal propagation of the mucosal wave
- An increase in the density of collagen fibers is observed around the sulcus



- the main features
  - ***"bowed" or "curved"*** vocal fold
  - ***enhanced stiffness***
  - ***glottic incompetence***
    - air leakage through the midline of the anterior two-thirds
  - *hypertonia of the ventricular folds* in some cases
- strained quality with vocal fatigue and laryngeal dysesthesia

- high pitch disturbances, little voice adaptability, low intensity with difficulty speaking loudly, typical tone change (husky, breathy, strained), increased tension in the laryngeal muscles
- Hsiung
  - 72 cases of autopsied larynx
  - Increased vascular proliferation and increased fibrosis in the laryngeal specimens with a sulcus when compared to larynges without a sulcus

Table 1 Summary of findings of sulci in the autopsied larynges ($n = 72$) (*I* physiological sulcus, *II* sulcus vergenture, *III* sulcus vocalis, *Ant* anterior third of vocal fold, *Mid* middle third of vocal fold, *Post* posterior third of vocal fold)

Type	No. of patients	No. of bilateral sulci	No. of folds	Location of sulcus			
				Ant	Mid	Post	Mean length (mm)
I	16 (22%)	4	20 (14%)	11 (55%)	16 (80%)	8 (40%)	7.0 ± 2.4
II	10 (14%)	3	13 (9%)	8 (61%)	9 (69%)	5 (38%)	7.3 ± 2.8
III	0	0	0	0	0	0	0
n	56 (64%)	0	112 (77%)	0	0	0	0
Total	72 (100%)	7	144 (100%)	19 (58%)	25 (76%)	13	7.2 ± 2.5

Table 2 Summary of subepithelial changes in the autopsied larynges ($n = 72$)

	No. of vocal folds	Increased vascular proliferation	Increased fibrosis
Physiological sulcus	20	8 (40%)	11 (55%)
Sulcus vergenture	13	10 (77%)	10 (77%)
Nonsulcus	111	21 (19%)	32 (29%)
Total	144	39 (27%)	53 (37%)

- Hirano
  - used GRBAS (grade, rough, breathy, asthenic, strained) scale to grade the voices of 126 patients presenting unilateral or bilateral sulcus
  - two-thirds of the patients studied presented grade I sulcus
  - ↓ : maximum phonation time, fundamental frequency range, and sound pressure level of phonation
  - ↑ : Airfow during phonation
  - voice quality was correlated more with glottic incompetence than with stiffness

- Yu et al.
  - analysis of dysphonia in 14 women with grade 1 sulcus (*n* = 3) and grade IIa and IIb sulcus (*n* = 11)
  - glottic incompetence induced a decrease in phonation time and an increase in airflow during phonation
  - Stiffness of the lamina propria led to slightly irregular and asymmetric vibration

Table 1 Objective analysis of dysphonia in sulcus vocalis

	Fo	Range	MPT	OAF	SNR	ESGP	Jitter
Controls (n:34)	215	418	13.5	136	24	66	0.5
Sulcus G1:3G2:9G3:2	229	225	9.3	216	14.7	10.6	0.8
P	NS	*	*	*	*	*	NS

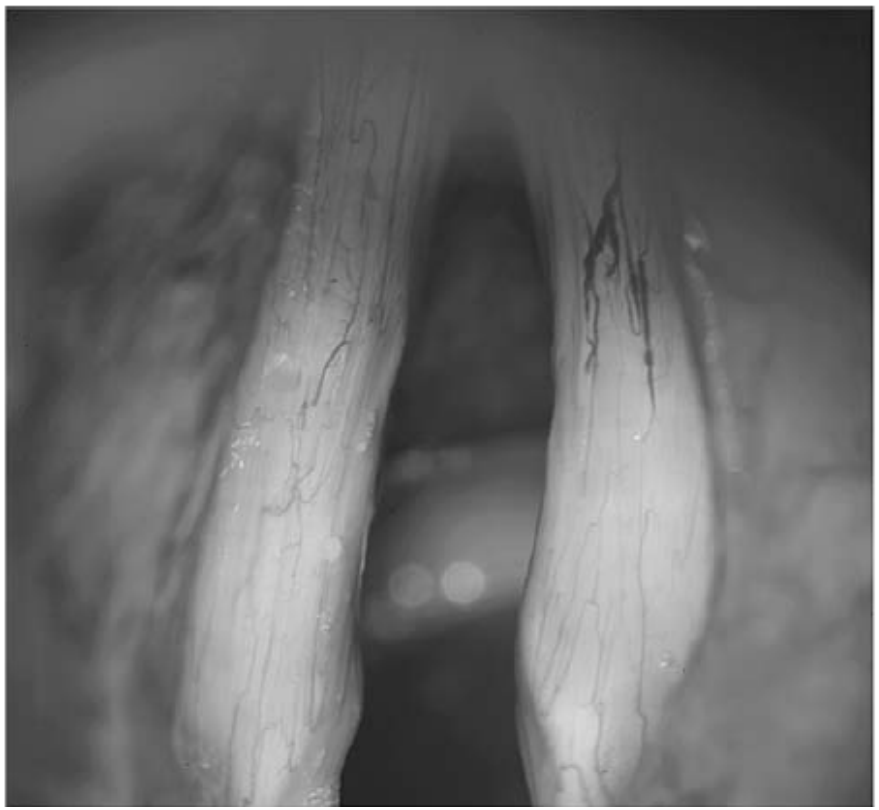
*P (t test) <0.05

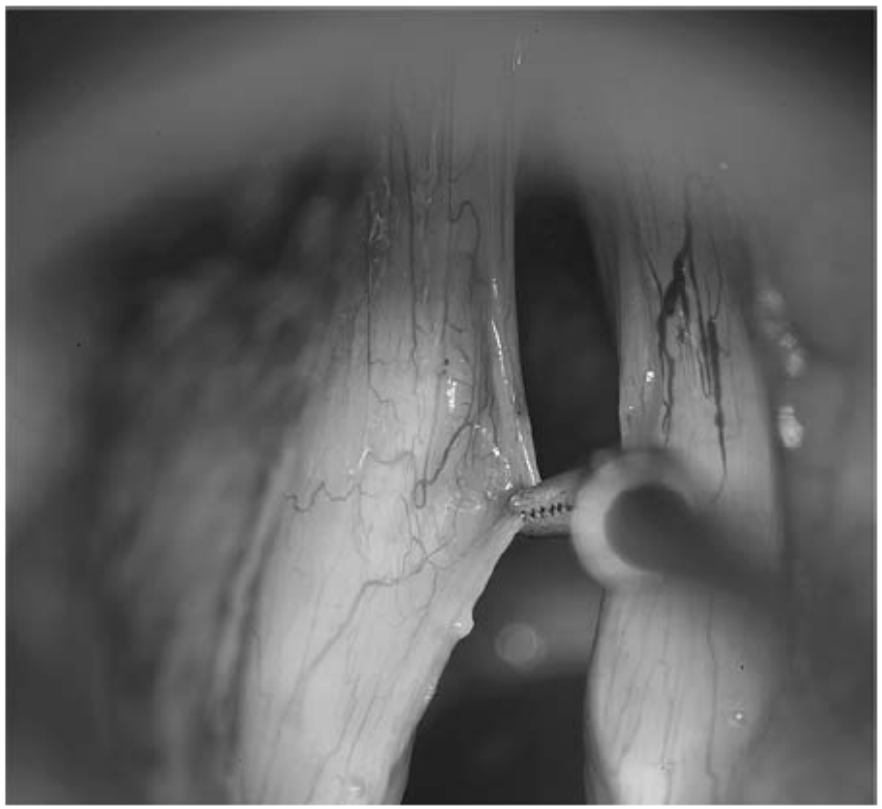
Fo Fundamental frequency, *Range* difference between the lower to the higher pitch possible, *MPT* Maximum phonatory *Time* *OAF* oral airflow during phonation, *SNR* Signal to noise ratio induced by high frequency, *ESGP* estimated subglottic pressure, *Jitter* index of vocal signal stability, *NS* non significant difference

Diagnosis

- Difficult
- suspected based on fold-bowing resulting in a spindle-shaped glottis during phonation
- median line air leakage in the anterior two-thirds of the vocal folds
- Vessels on the surface of the fold are often dilated
- Video-stroboscopy is a highly effective diagnostic tool for sulcus
  - distinction between true sulcus and sulcus vergeture is difficult
  - sulcus vergeture: stiffness is localized and the mucosal wave is usually preserved
  - true sulcus: mucosal wave generally disappears

- Suspension laryngoscopy allows visualization and classiffication of the lesion
  - use a forceps to expose the free edge of the vocal fold and to palpate the edge using micro-instruments
  - Type IIa: Palpation demonstrates no sliding plane between the mucosa and ligament.
  - Type IIb
    - A deeper thickened aspect
    - low-grade inflammation and edema of the rest of the vocal fold
    - lower lip sometimes presents a thickened hyperkeratosic or even nodular aspect





Differential diagnosis

- “fold bowing”
  - Myositis of the vocal muscle following an inflammatory process such as laryngitis or upper airways infection
  - weakness of the vocalis muscle after any severe general disease
  - misuse of the voice
  - neurological lesions involving the vocal muscle
  - Senile larynx (presbylarynx)
- D.Dx between long-standing sulcus and atrophy of vocal fold mucosa due to laryngitis or aging of the larynx can be difficult

- pseudosulcus vocalis
  - described in 1995
  - Infraglottic edema extending from the anterior commissure to the posterior larynx
  - Belafsky
    - Patients with pseudosulcus were 2.3 times more likely to have pH-documented LPR
    - The sensitivity and specificity of pseudosulcus in the diagnosis of LPR are 70% and 77%, respectively

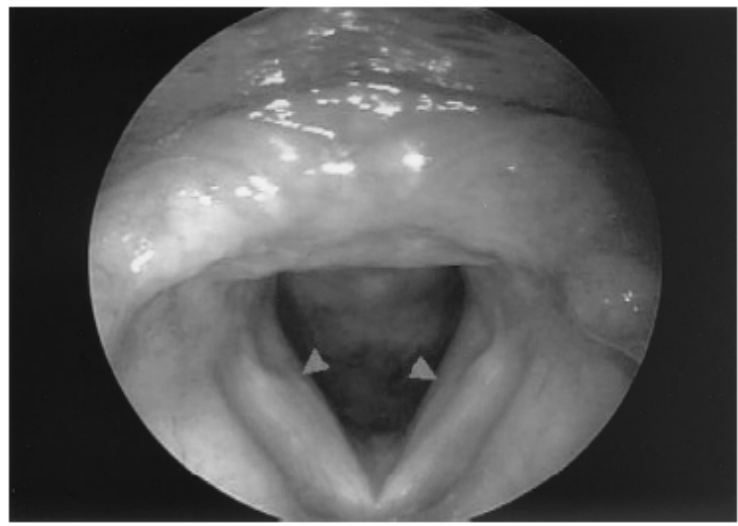


Fig 1. Bilateral laryngeal pseudosulcus *(arrowheads)*, showing the subglottic edema extendings from the anterior commissure past the vocal process to the posterior larynx.

Etiology

- controversial: congenital or acquired
- *congenital*
  - Darwin
    - it was the reappearance of an additional vocal fold that had disappeared during evolution
  - Bouchayer and Cornut
    - defect in the development of the 4th and 6th brachial arches
    - may be the consequence of a rupture of an epidermoid cyst
    - onset of dysphonia during childhood in 55% of patients
    - associated with a frequent familiar occurrence, cyst formation, and failure of lesions to return after adequate excision

- *acquired*
  - Itoh
    - two-thirds of cases: onset of dysphonia occurred after 40 years
  - Nakayama
    - 48% incidence of sulcus vocalis in surgical specimens of patients with laryngeal cancer
    - suggesting that irritation and inflammation play a significant role
- Sato and Hirano
  - associated with degeneration of fibroblasts in the maculae flavae, with a decrease in their synthesis
  - an increase in collagenase activity
  - Collagen cycle cannot subsist

Treatment--Resection

- Removing fibrous tissue and abnormal mucosa
- Increase mucosa flexibility and allows normal vibration
- Procedure
  - Concomitant lesions should be treated
  - hydrocortisone may be injected to unfold the sulcus
  - type IIb
    - mucosa is incised on the topside of the vocal fold parallel to the free edge

- the pouch is gradually detached from the ligament
- whole sulcus is undermined from the outside in and top to bottom
- A few millimeters of the glottic mucosa is then undermined to obtain a small sliding flap to cover the bare zone

- Remacle
  - CO_2 laser microdissection
  - 45 patients with type II sulcus vocalis
  - Steroids injection when redraping
  - Fibrin glue application to approximate the epithelial edges

Fig. 7 First time of the removal is to incise mucosa at the level of the upper lip of the groove

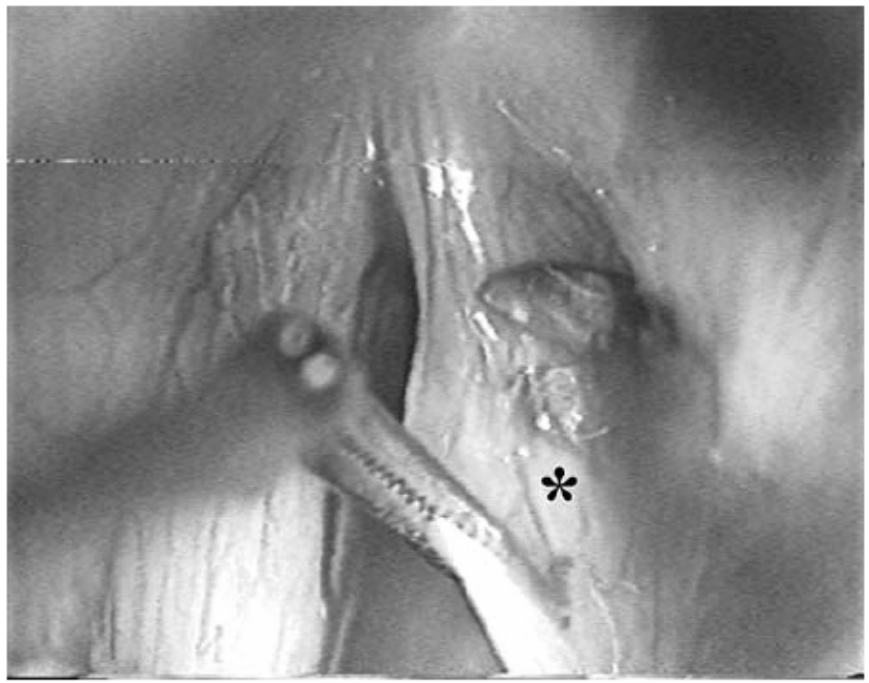


Fig. 8 Undermining the mucosa without entering the vocal ligament (asterisks)

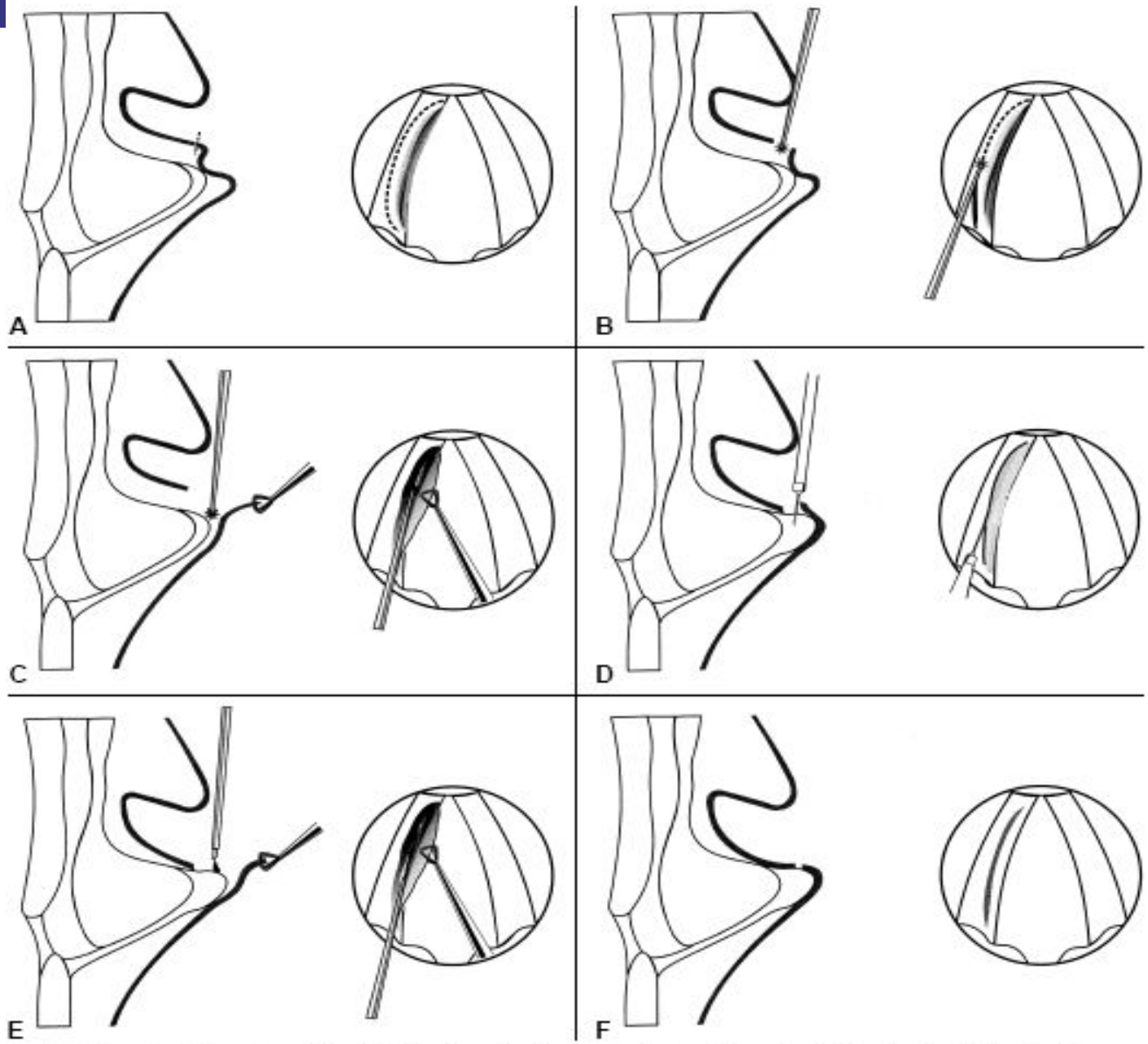
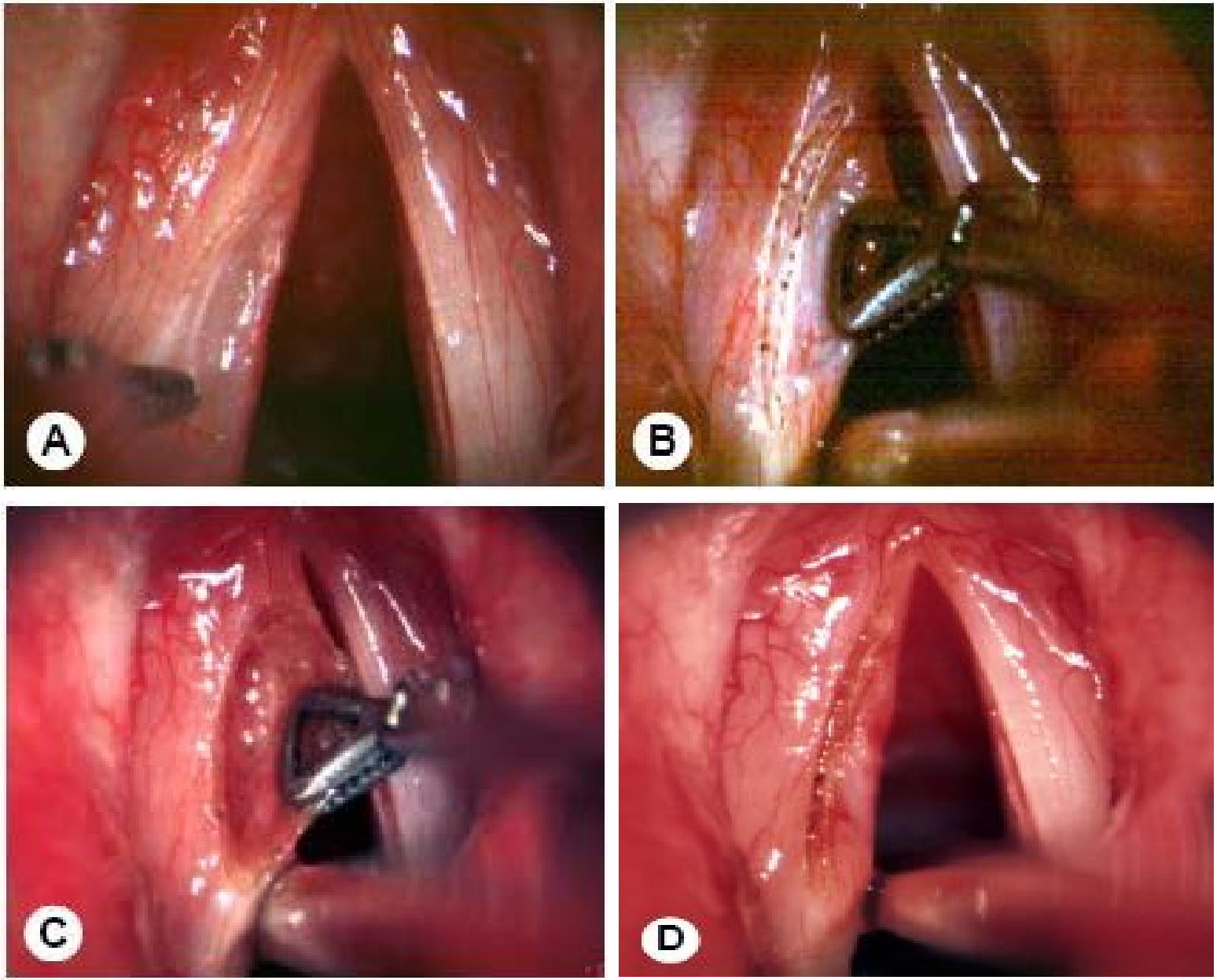


Fig 2. Drawings of procedure. A) Incision line along lateral and superior edge of vergeture. B) Carbon dioxide laser incision, 250-µm beam, Super-pulse, single pulse, 0.1 second, 3 W. C) Carbon dioxide laser dissection between epithelium and vocal ligament, with same parameters, and traction of epithelium to midline. D) Collagen injection into vocal ligament. E) Redraping of epithelium with fibrin glue. F) Final view.


A
B
C
D

Treatment--Reconstruction

- augmentation of the vocal fold volume and/or restoration of its layer structure
- goal
  - improve vocal fold vibration in terms of symmetry, amplitude and mucosal wave

- Endoscopic augmentation techniques
  - collagen, fat and fascia
  - Remacle
    - the technique to obtain *autologous collagen*
    - mucous flap is draped over the injection zone and attached using fibrin glue
    - No immune reaction and stable over time
  - Hsiung and Woo
    - autologous fat injection
    - Spontaneous postoperative resorption
  - Tsunoda
    - Autologous transplantation of fascia in the vocal fold (ATFV)
    - Satisfactory glottal closure and excellent mucosal wave 1 year after the ATFV
  - Hsiung
    - Combination of fascia transplantation and fat injection (FTFI)
    - Better prognosis than fat injection alone
    - Type 3 responded better than type 2
    - Can repeated multiple times

TABLE I.

Summary of Patients Who could be followed More than 3 Years after Undergoing Autologous Transplantation of Fascia into the Vocal Fold (ATFV) Type 1 for Sulcus Vocalis.

Case No.	Age (y), Sex	ATFV bil. or u.	PreATFV (seconds)	6 Months (seconds)	1 Year (seconds)	2 Years (seconds)	3 Years (seconds)	After 3 Years (seconds)
1	58M	bil.	4*†	14†	23	19	22	(8 years) 22
2	15M	bil.	15*	22	22	32	25	(5 years) 34
3	62M	bil.	8*†	18	20	20	21	
4	23M	bil.	7*†	39	32	35	36	
5	51F	bil.	16*	25	36	39	36	(5 years) 36
6	39M	bil.	11*†	29	29	30	35	
7	42M	bil.	11*†	37	40	40	41	
8	51F	u.	11*†	17†	28	27	28	
9	53M	u.	5*†	43	44	65	63	(4 years) 60
10	71M	u.	5*†	14*†	22	22	22	(5 years) 22

Stroboscopic observation: *unsatisfactory glottal closure without mucosal wave. †Hyperadduction of false vocal folds. Bil. = bilateral; u. = unilateral; M = male; F = female.

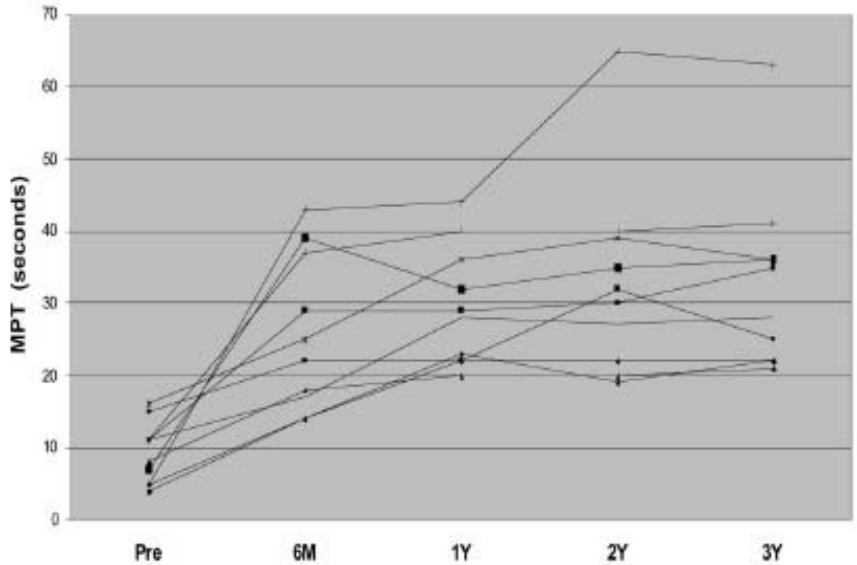


Fig. 6. Maximum phonation time before and after ATFV (type 1). Results are shown before surgery and at the indicated intervals after surgery.

Tsunoda

Hsiung

TABLE 1. SUMMARY OF SULCUS VOCALIS PATIENTS WHO UNDERWENT FASCIA TRANSPLANTATION AND FAT AUGMENTATION

Patient	*Age (y)*	*Sex*	*Follow-Up (mo)*	*Result*	*Sulcus Type*
1	33	M	21	Excellent	3
2	21	F	20	Excellent	3
3	23	M	19	Excellent	3
4	32	M	19	Excellent	3
5	38	M	19	Improved	3
6	48	M	18	Excellent	3
7	38	F	18	Excellent	3
8	42	F	18	Excellent	2
9	58	F	18	Excellent	3
10	50	M	18	No change	3
11	46	M	17	No change	2
12	19	F	17	Improved	2
13	22	M	17	Excellent	2
14	30	F	16	Excellent	3
15	31	F	16	No change	2
16	24	M	16	Excellent	2
17	31	F	15	Excellent	2
18	36	F	15	Improved	3
19	35	F	15	Excellent	2
20	22	F	15	Excellent	3
21	24	F	12	Excellent	3
22	25	M	12	Excellent	2

TABLE 2. STATISTICAL RESULTS OF PHONATORY FUNCTION AND STROBOSCOPIC ANALYSIS MEASURES

	No. of Patients	*Median Preop*	*Median Postop*	*p*
F0 in women (Hz)	12	252	259	.253
F0 in men (Hz)	6	145	133	.128
Jitter (%)	18	0.28	0.20	.213
Shimmer (%)	18	1.63	1.27	.125
Harmonics-to-noise ratio (dB)	18	27.28	26.73	.452
Phonation time (s)	18	11.4	14.0	.046*
Grade	22	3	2	.041*
Roughness	22	3	2	.035*
Breathiness	22	3	1	<.001*
Amplitude	20	3	2	.035*
Mucosal wave	20	3	2	.035*

F0 — fundamental frequency.

*Statistically significant by Wilcoxon (matched pairs) signed rank test.

- external medialization techniques
  - Isshiki (Isshiki type I): described in 1989
  - Zeitels
    - *Gore-Tex medialization laryngoplasty*
    - Medialized seletively the healthy cover of the infraglottic edge
  - Su
    - strap muscle transposition
    - Bipedicled flap including the whole sternohyoid muscle with the upper and lower attachments which is transposed into the space between the lamina and the paraglottic soft tissue

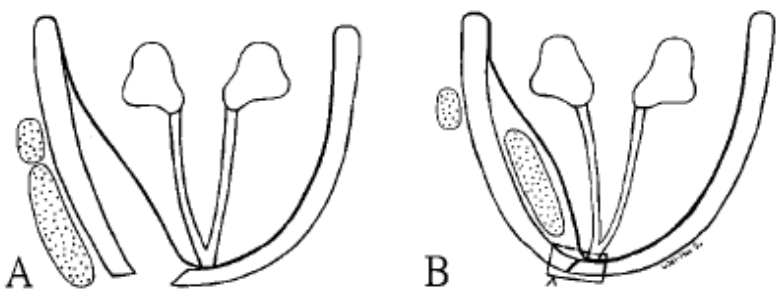


Fig. 1. Medialization laryngoplasty with sternohyoid muscle transposition for vocal fold atrophy.

TABLE I.
Summary of 27 Cases of Vocal Fold Atrophy Treated With Strap Muscle Transposition.

Case No.	Sex/Age (y)	Laryngeal Findings	Maximum Phonation Time*		Glottal Gap*		Voice Grading*		Follow-up (mo)
			Preop (sec)	Postop (sec)	Preop (E1/E2)	Postop (E1/E2)	Preop (E1/E2)	Postop (E1/E2)	
1	M/23	r't atrophy	10.0	20.4	2/2	1/1	1/2	0/1	24
2	F/25	bil atrophy	9.0	10.0	4/4	1/1	2/2	0/0	22
3	F/47	bil atrophy	8.3	16.0	2/2	0/1	2/2	0/0	16
4	M/27	bil atrophy	13.4	19.8	2/2	0/0	1/1	0/0	16
5	M/50	bil atrophy with r't sulcus	5.4	10.0	3/2	1/1	1/2	0/1	16
6	M/25	bil atrophy with bil sulcus	12.7	15.3	2/1	1/1	1/1	0/0	14
7	F/40	bil atrophy	7.0	11.3	3/3	0/0	2/2	0/0	14
8	M/38	r't atrophy	11.6	14.0	2/2	0/0	1/1	0/0	13
9	M/62	bil atrophy	6.0	14.0	3/3	1/1	1/1	1/1	12
10	F/30	bil atrophy with bil sulcus	10.8	10.0	3/3	1/1	2/2	0/0	12
11	F/54	r't atrophy	5.0	6.0	1/1	1/0	3/3	1/1	12
12	F/42	bil atrophy with bil sulcus	7.0	6.0	1/1	1/1	3/2	2/1	12
13	M/21	bil atrophy	10.0	11.4	2/2	1/1	1/2	0/0	12
14	F/26	bil atrophy	5.8	9.0	2/2	0/0	1/2	0/0	12
15	M/24	bil atrophy with bil sulcus	4.0	8.6	3/2	2/1	1/2	0/1	12
16	M/28	bil atrophy with bil sulcus	19.0	18.0	1/2	1/1	1/1	0/0	12
17	M/74	l't atrophy	3.2	3.5	3/3	2/2	2/2	1/1	10
18	M/25	bil atrophy with r't sulcus	8.8	9.0	2/2	2/2	1/1	1/1	7
19	M/77	bil atrophy	2.8	5.6	4/4	2/2	3/3	1/0	7
20	F/45	bil atrophy with bil sulcus	5.0	12.0	4/4	1/1	2/2	1/1	6
21	M/52	bil atrophy with r't sulcus	5.0	16.0	3/3	1/1	3/3	2/2	6
22	M/33	bil atrophy	7.8	14.0	2/2	1/1	1/1	0/0	6
23	M/62	bil atrophy	4.8	23.0	2/2	0/0	1/1	0/0	6
24	F/46	bil atrophy	4.5	5.9	2/2	1/1	2/2	1/1	6
25	F/50	bil atrophy	6.8	6.0	2/2	1/1	1/1	1/1	6
26	F/57	r't atrophy	3.9	5.0	2/2	1/1	1/1	1/1	3
27	M/37	bil atrophy with r't sulcus	14.5	25.0	2/2	0/0	1/2	0/0	3

Glottal gap: 0 – complete closure; 1 – minimal gap; 2 – small gap; 3 – moderate gap; 4 – complete gap.
Voice grading: 0 – normal; 1 – mild dysphonia; 2 – moderate dysphonia; 3 – severe dysphonia; 4 – aphonia.
*Statistically significant.
Preop – preoperative; Postop – postoperative; E1 – evaluator 1; E2 – evaluater 2; bil – bilateral; r't – right; l't – left.

TABLE II.
Comparison of Pre- and Postoperative Measures of Acoustic and Aerodynamic Parameters.

Variables	Patient No.	Preoperative (Mean ± SD)	Postoperative (Mean ± SD)	Time	*P* Value
F0 (Hz)	25	199.12 ± 64.18	197.58 ± 53.19	−0.19	.854
MPT (sec)	25	7.96 ± 3.92	12.04 ± 5.47	4.47	<.001*
JITT (%)	25	2.93 ± 2.25	1.67 ± 0.93	−2.83	.009*
SH (dB)	25	0.51 ± 0.49	0.44 ± 0.19	−0.66	.516
NHR	25	0.18 ± 0.13	0.13 ± 0.03	−1.98	.059
MAR (L/sec)	25	0.19 ± 0.10	0.09 ± 0.05	−5.81	<.001*

*Statistically significant at $P < .05$.
Fo = fundamental frequency; MPT = maximum phonation time; JITT = jitter percent; SH = shimmer; NHR = noise-to-harmonic ratio; MAR = mean airflow rate.

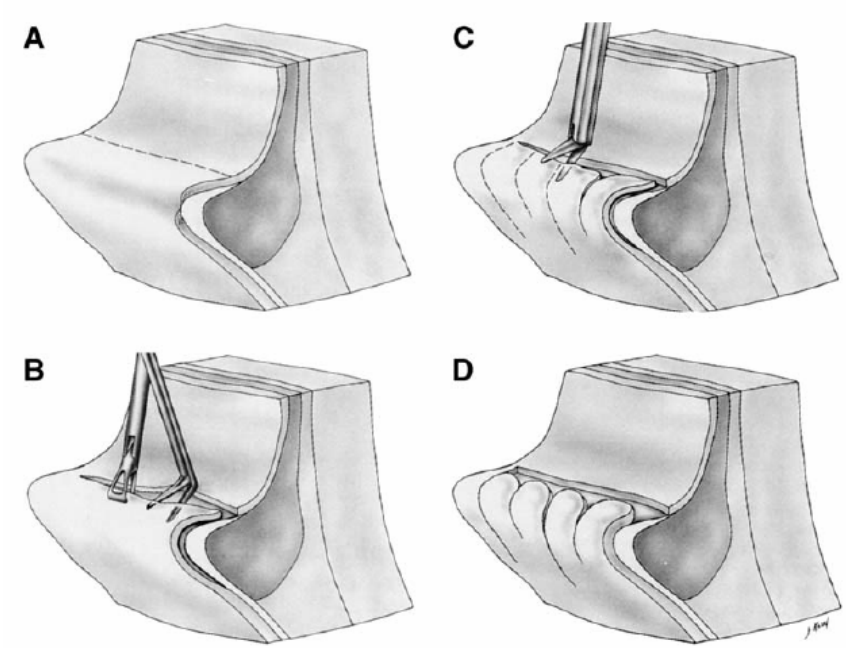
TABLE III.
Nonparametric Analysis of GRBAS Perceptual Assessment Pre- and Postoperatively.

Variable	Patients No.	Two Related Samples Test	Z	*P* Value (two-tailed)
Grading	27	G1-post/G1-pre	−4.59	<.001*
		G2-post/G2-pre	−4.96	<.001*
Roughness	27	R1-post/R1-pre	−4.85	<.001*
		R2-post/R2-pre	−5.07	<.001*
Breathiness	27	B1-post/B1-pre	−4.67	<.001*
		B2-post/B2-pre	−4.11	<.001*
Asthenia	27	A1-post/A1-pre	−1.40	.162
		A2-post/A2-pre	−1.74	.081
Strain	27	S1-post/S1-pre	−4.94	<.001*
		S2-post/S2-pre	−3.88	<.001*

*Statistically significant at $P < 0.05$ (Wilcoxon signed-rank test).
1 = evaluator 1; 2 = evaluator 2; pre = preoperative; post = postoperative.

Treatment--Prevention of the rescarring

- Avoiding recurrance--Difficult
- Dissection must be performed carefully and sparingly
- covering the vocal ligament with mucosa
  - By microsuture with 6–0 suture or by fibrin glue
- Pontes and Belhau
  - Slicing mucosa technique
  - Treat type II sulcus vocalis
  - Undermining 2 mm inferior to sulcus →
  - 4~ 5 vertical counter-incisions to obtain 3~4 mucosal flaps
  - Free mucosal attachment and break up the linear contracture



- voice therapy
  - Useful and safe adjuvant treatment
  - started before surgical treatment
  - continues after a period of strict vocal rest lasting from 48 h to 10 days
  - 20–30 sessions at a rate of 1–2 per week
  - improve the timbre of the voice while remaining attentive to choice of tone and intensity
- Suppression of LPR

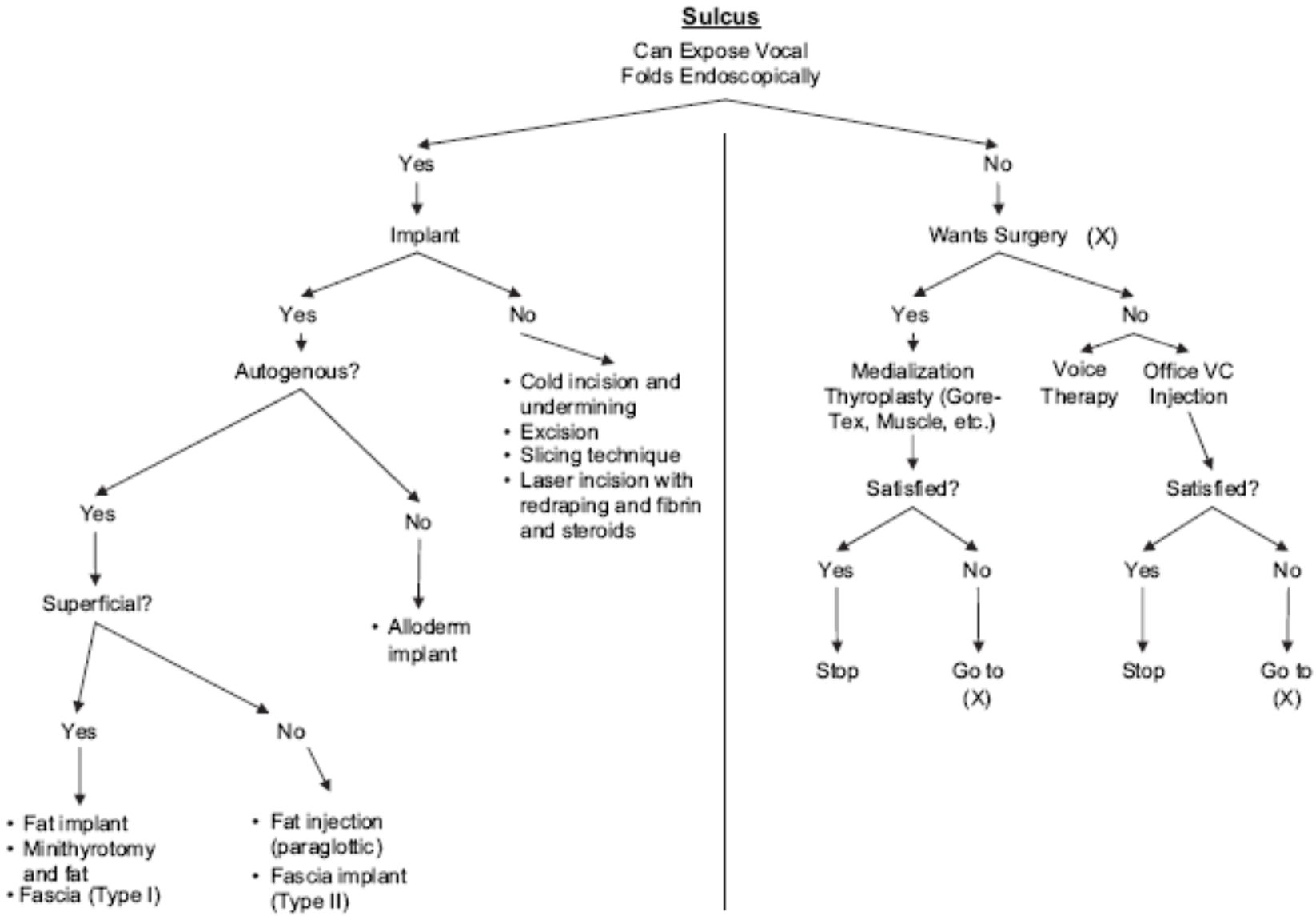


Fig. 8. Decision-making for surgical approaches to sulcus vocalis/scar.

Implications of research

- HA posses viscoelastic qualities closer to native vocal fold mucosa
- Hertegard
  - Inject collagen vs. Hylan B gel(cross-linked HA) with 2-year follow-up
  - Less resorption was noted in the Hylan B gel group
- Molecular intervention
  - HGF(hepatocyte growth factor)
    - Increase HA
  - Synthetic extracellular matrix (fibronectin, HA, HA associated with gelatin-Carbylan GSX)
  - Stem cell
    - Autologous cultured fibroblast
    - Autologous mesenchymal stem cells

Conclusions

- A challenging disorder for both diagnosis and treatment
- Dissection is difficult, results are often disappointing
- It is frequent for the mucosa at the bottom of the pouch to be torn and to be stripped of the vocal ligament or even muscle
  - lead to recurrent adherence
- The postoperative voice may be worse than the pre-operative voice
- Poor results in difficult cases
- The goal must be only to reduce glottic leakage
- Voice re-education therapy
  - useful for patients with moderate dysphonia

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