Functional examination of vocal muscles

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Advances in diagnoses of laryngeal disorders

Instead
of stroboscopy:

- High speed films
- Kymography
- The prospects of calculation of ”stiffness”
- Phonovibrogram
- Sygyt Software

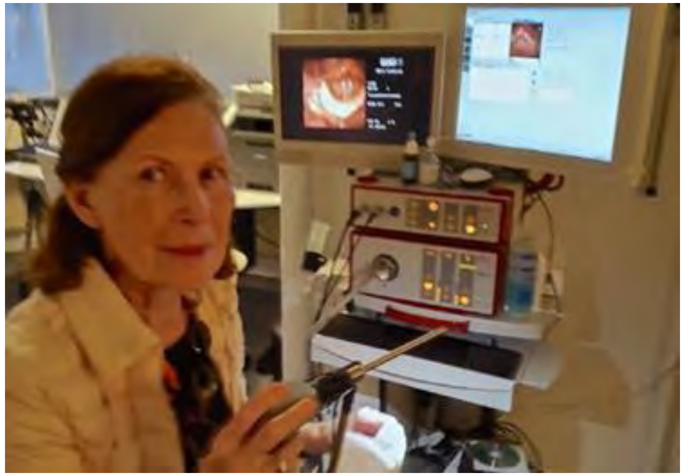
High speed films

- Superior to clinical laryngo-stroboscopy in many areas of voice diagnostics.
- Able to capture 4000 or more images pr. second of the vocal area.
- Data are acquired with a high-speed camera recording in real-time during phonation of the vowel/a/. A rigid endoscope (90^0 optic, 9-mm diameter) is placed into the oropharynx coupled to a high-speed camera.

High speed endocam system

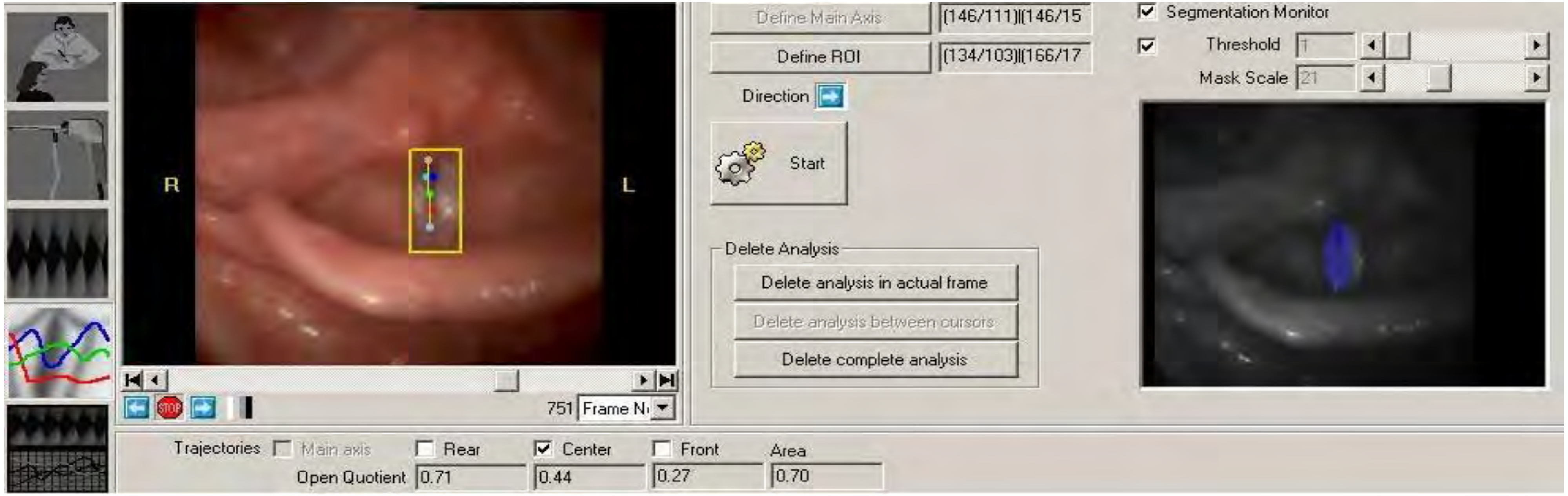
- With the High Speed Endocam system* there has been developed a software reproduction of the stiffness of single vocal fold movements with the Glottis Analysis Tools by M. Döllinger et al.

Wolf Ltd. HRES Endocam 5562 analytic system (Richard Wolf GmbH, Pforzheimer Strasse 32, 75438 Knittlingen, Germany)



High speed films

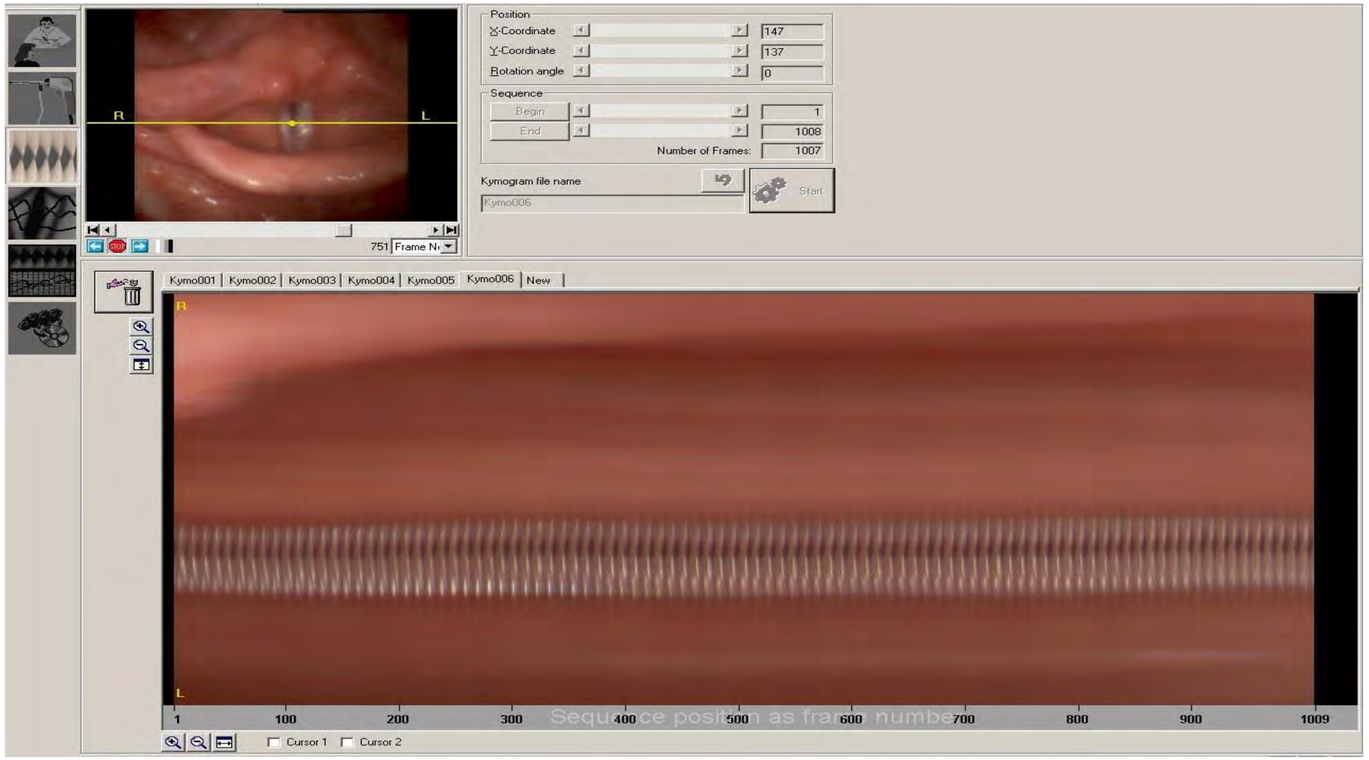
- Segmentation of the open quotients are calculated in front – center – rear area – smaller in front between the vocal folds.



High speed films and kymography

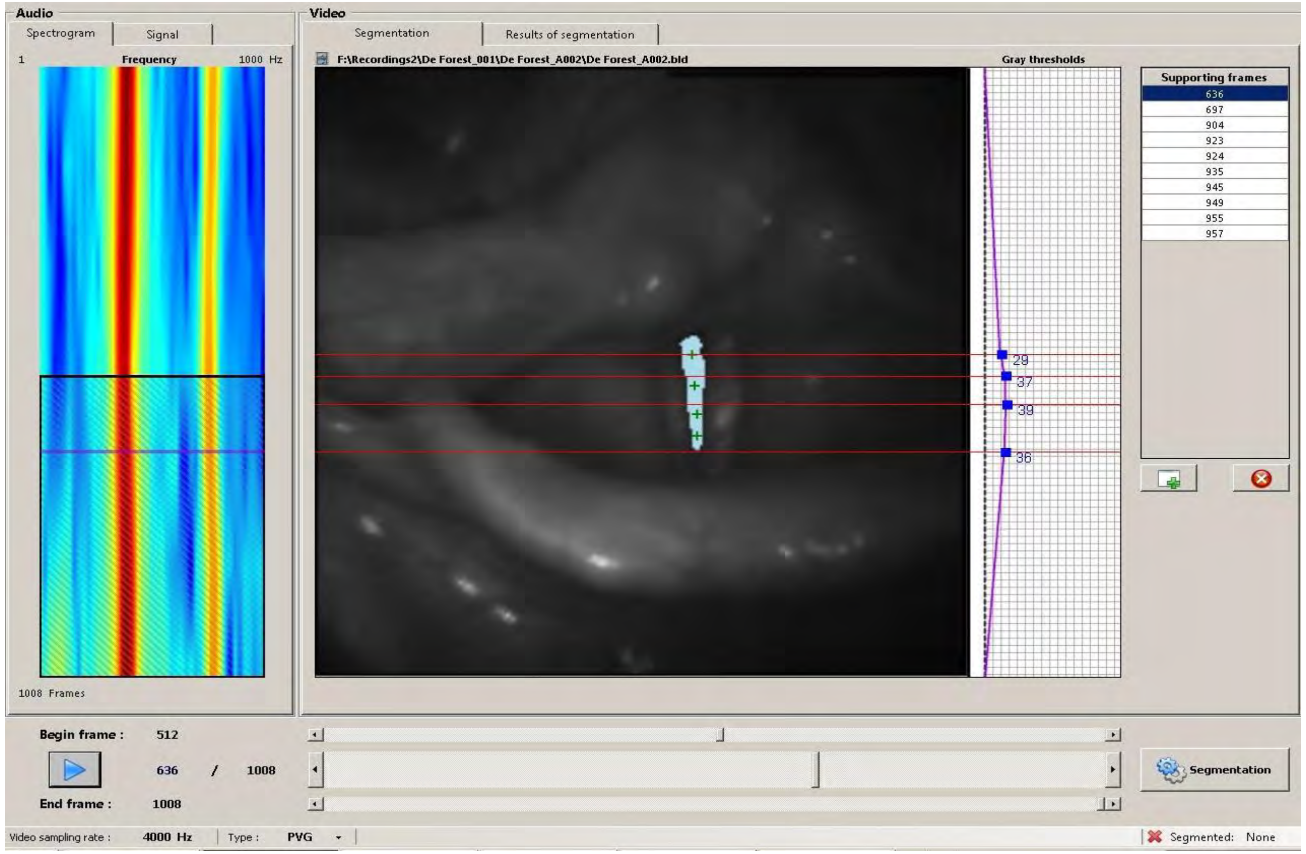
- Kymography shows single movement of the vocal folds from above.

  - here they are regular.



High speed films and mean stiffness

- Segmentation: The set-up for calculation of measurements of mean stiffness of the Glottal Area Wave form (GAW).



The formula for stiffness

$$Stiffness = \frac{max_{t \subset T_i}(s(t))}{A_i}$$

- Where T_i is the duration of i^{th} cycle in miliseconds (ms), A_i is the dynamic range (max-min) for i^{th} cycle and s(t) is the magnitude of the 1st derivative of considered signal for ith cycle (t C (T_i).

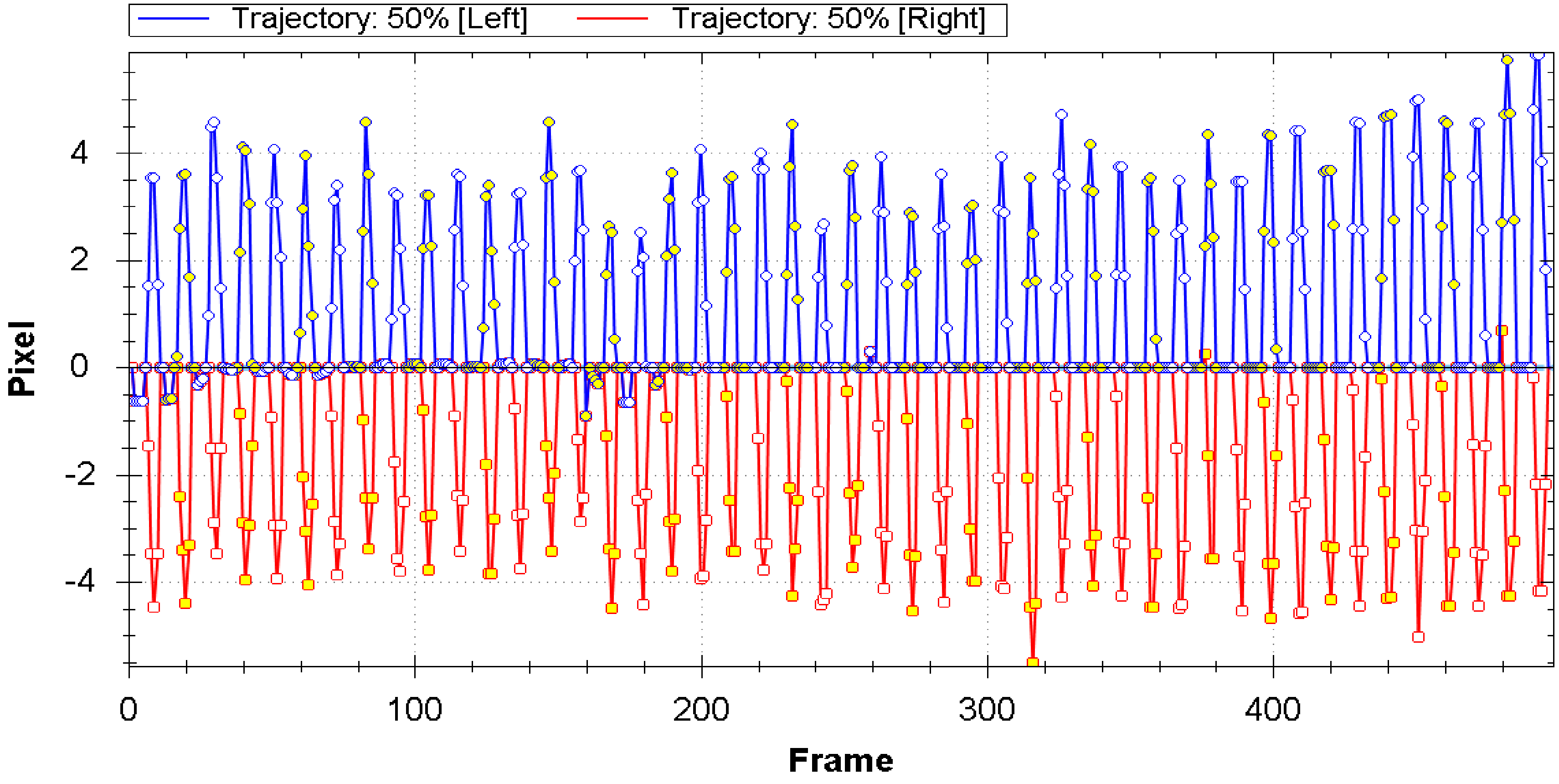
Difference in stiffness

- A difference in stiffness of the vocal folds is measured when comparing trained and non-trained voice users. The objective was in a study to evaluate the method based on software reproduction of the vocal fold movements, that is included in Glottis Analysis Tools used together with high speed films.

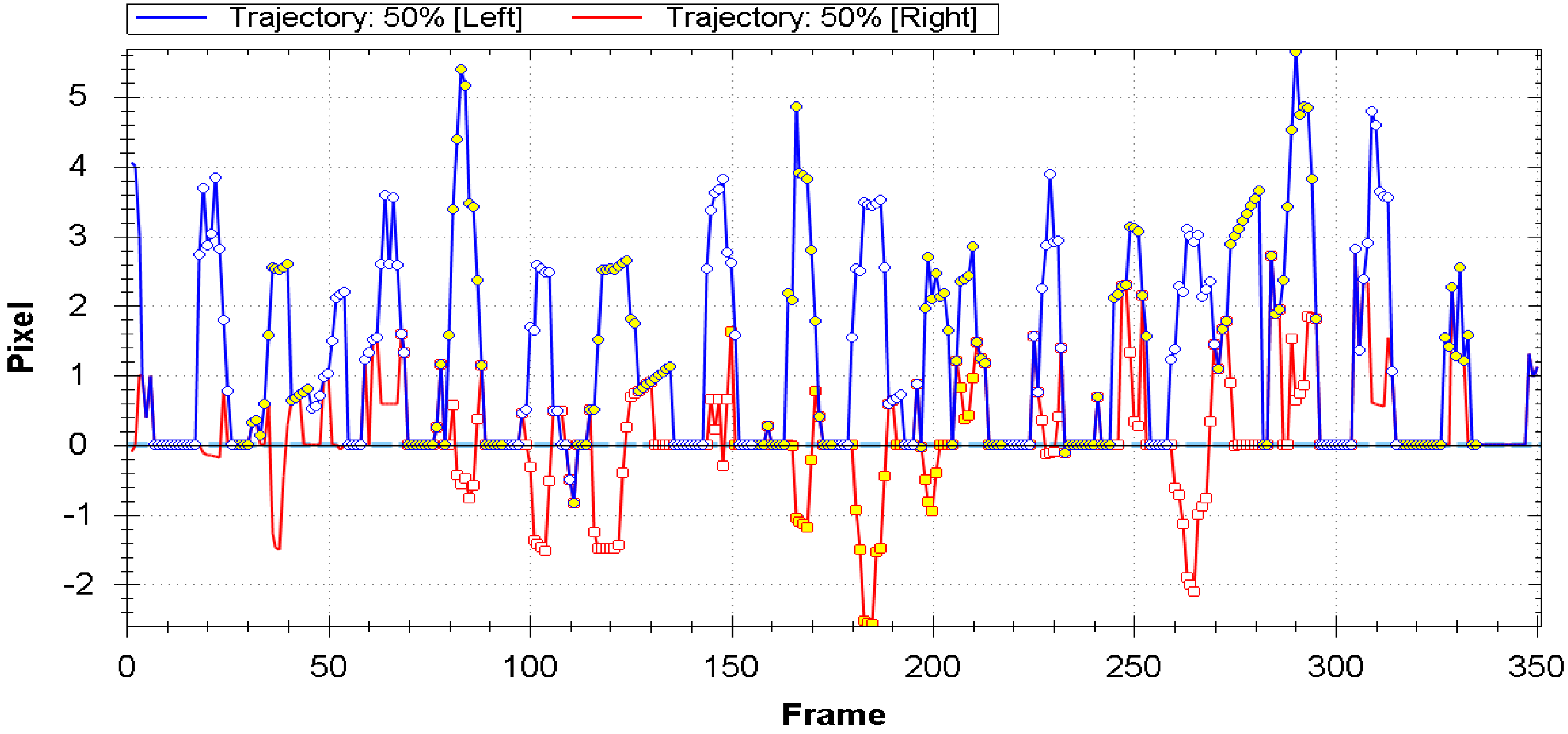
Trajectories

- Trajectories are like kymograms.
- The diagram shows the vocal cords in a 50% distance from the posterior border (therefore called [Traj-50%]).

Trajectories of a contest winning female



Trajectories of a 59 years old male with acute laryngitis



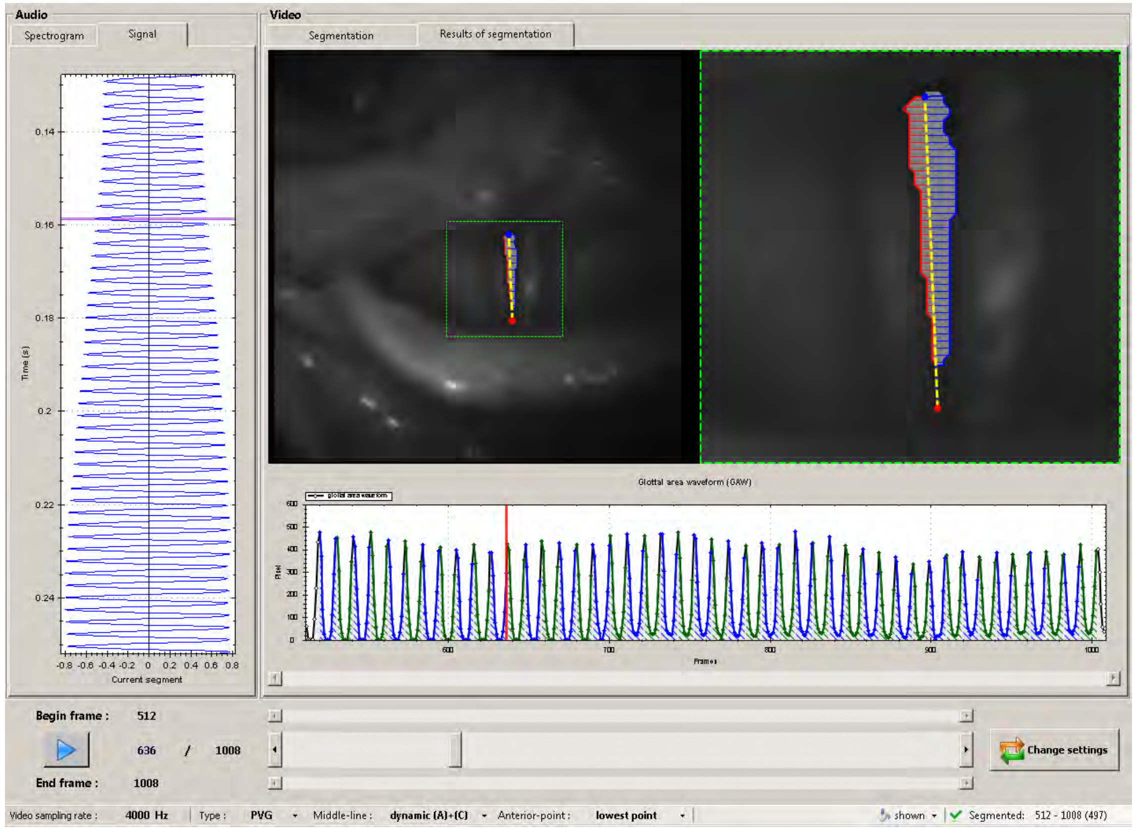
High speed films and phonovibrogram

- The results* of the segmentation.

  The Glottal Area Wave form (GAW)

  are shown with frames on the horizontal

  axis and pixel on the vertical axis.



* the contest winning female.

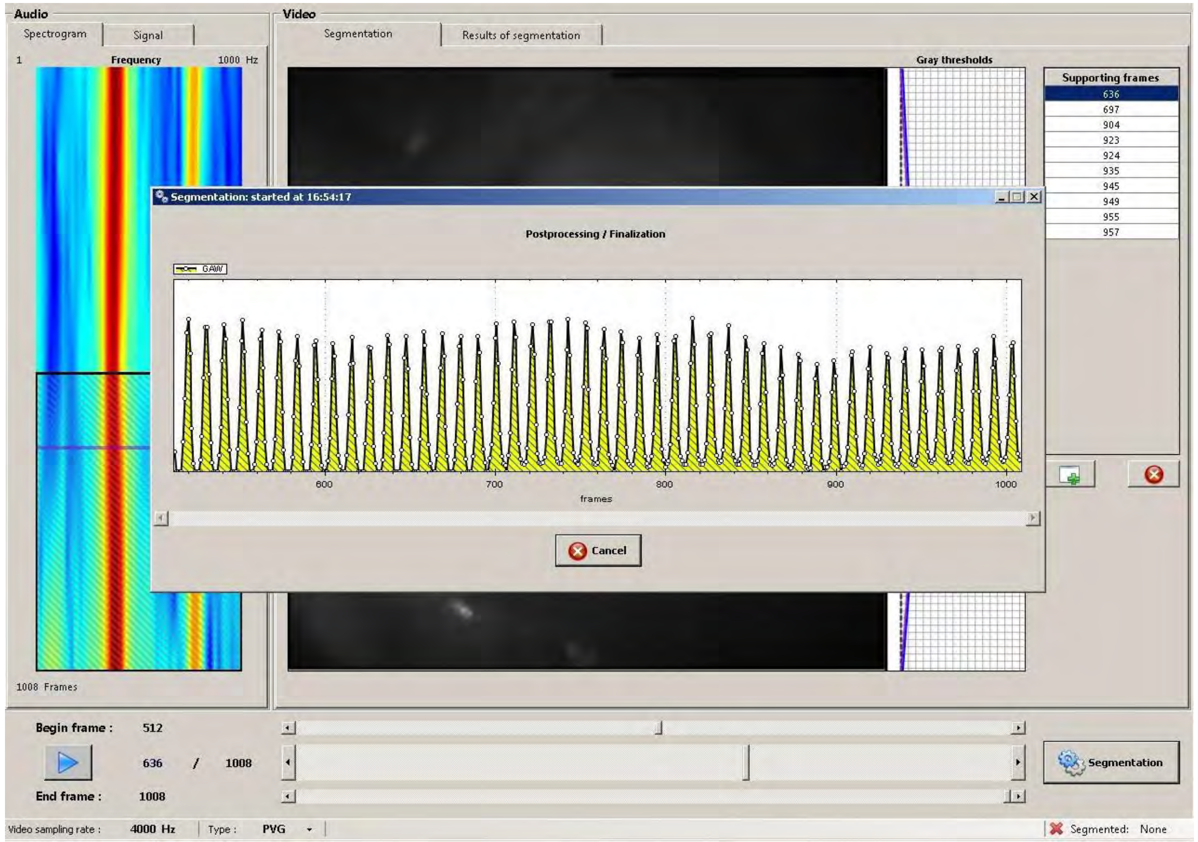
High speed films and phonovibrogram

- The single movements

  presenting the area between the vocal

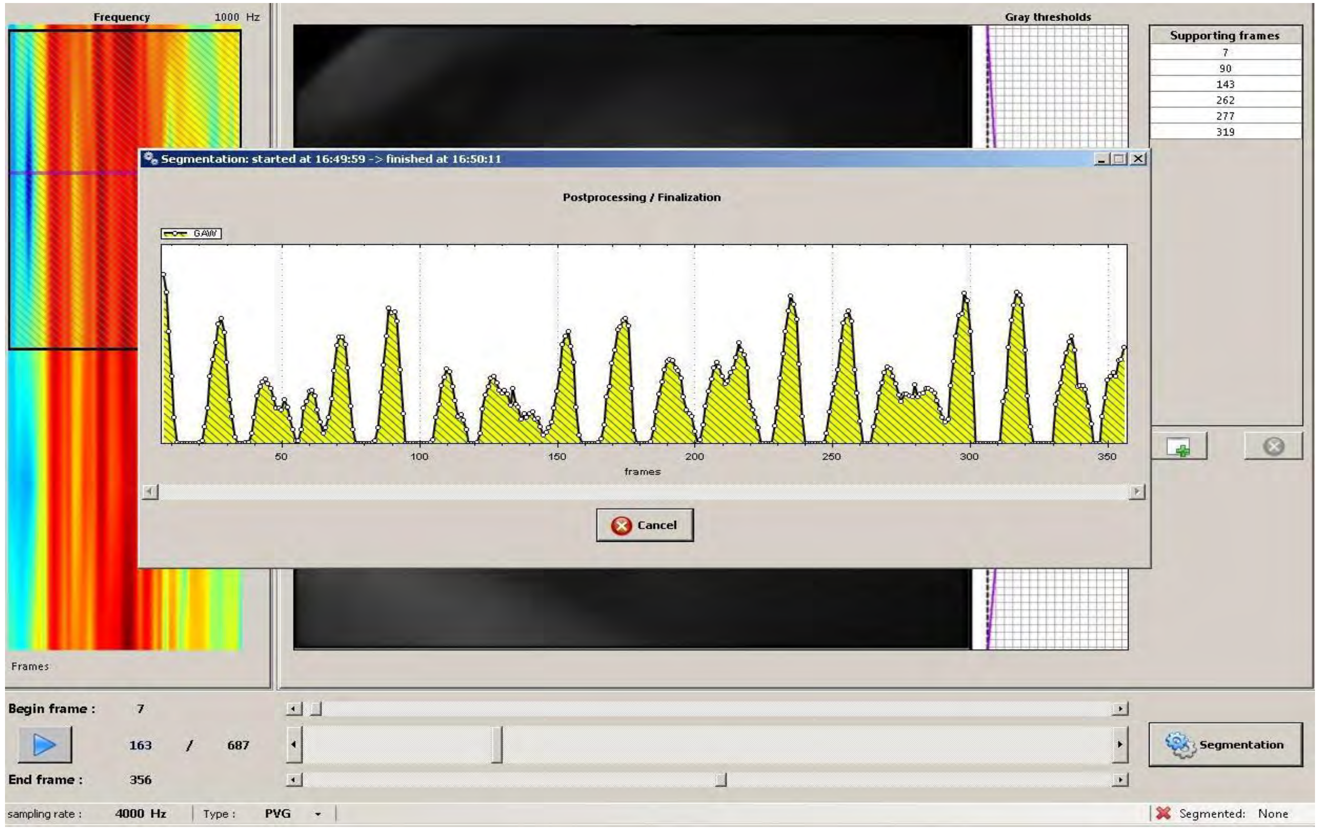
- Folds of the phonovibrogram of a

- contest winning female.



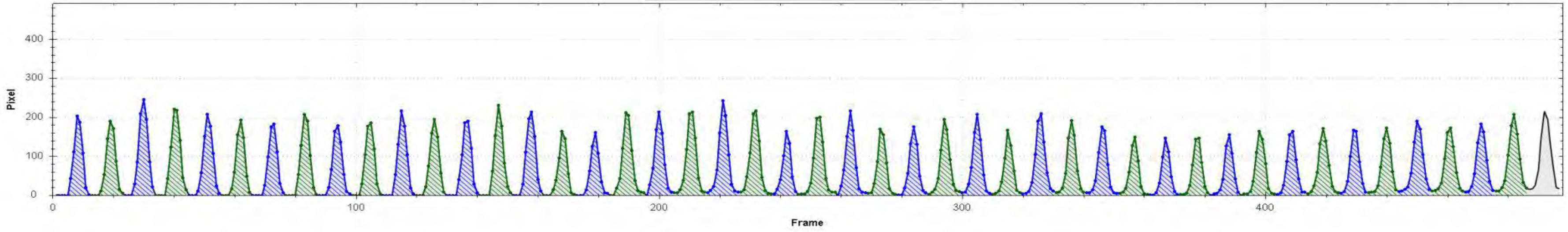
High speed films and phonovibrogram

- Irregularity of the single area measurements are seen of the 59 years old male with acute
- laryngitis.

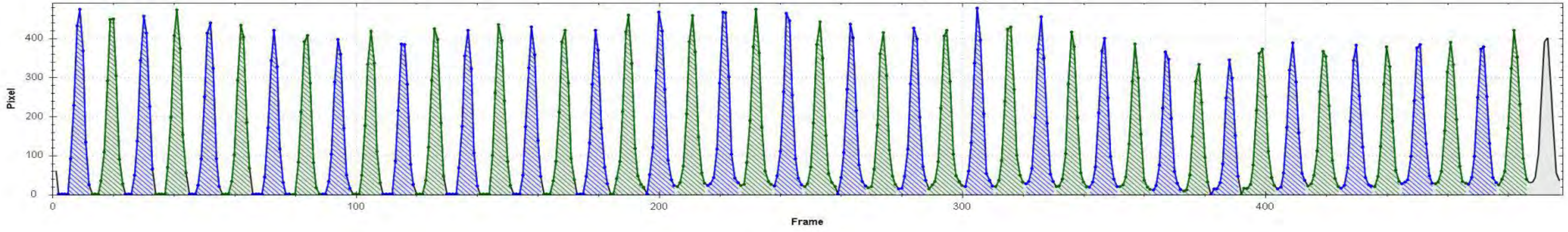


GAW cycles of a contest winning female

[redacted]



[redacted]



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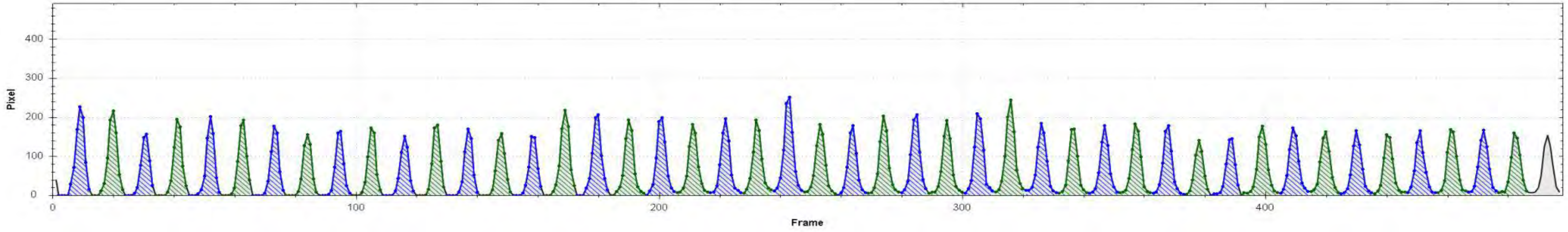
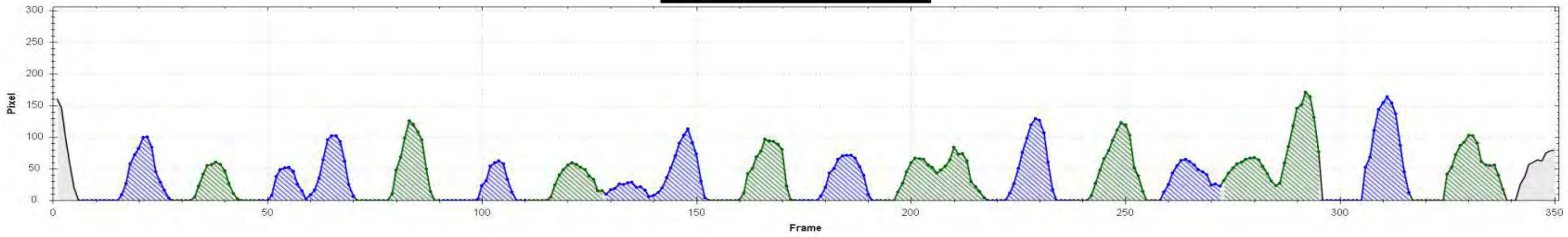
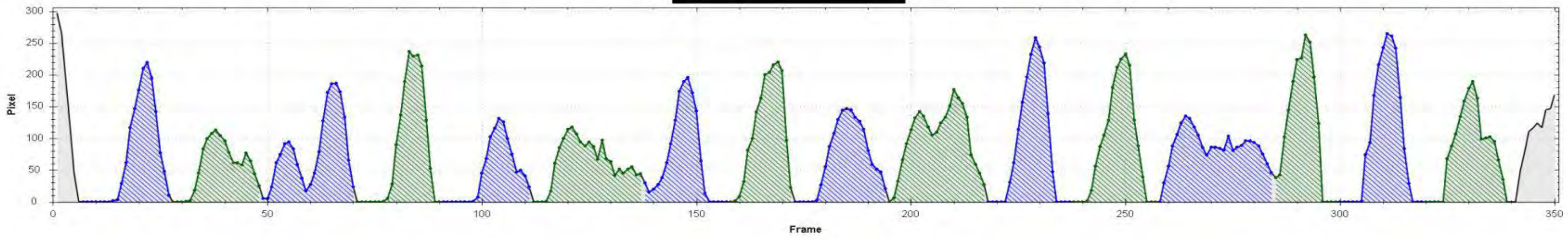


GAW cycles of a 59 years old male with extreme dysphonia

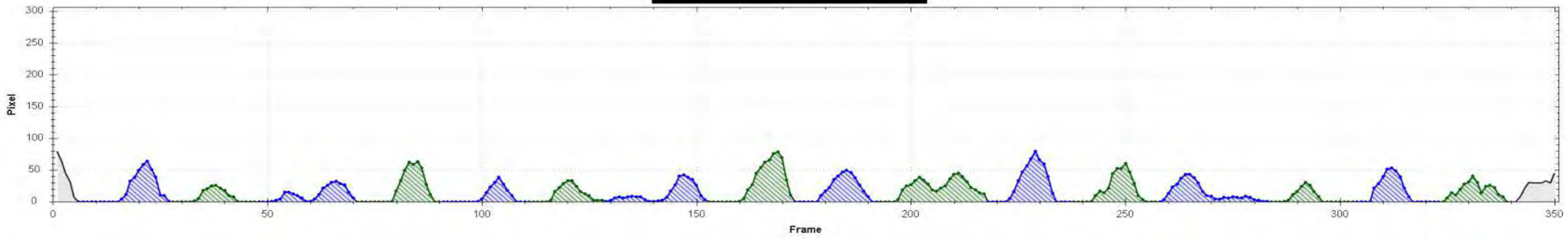
[redacted]



[redacted]

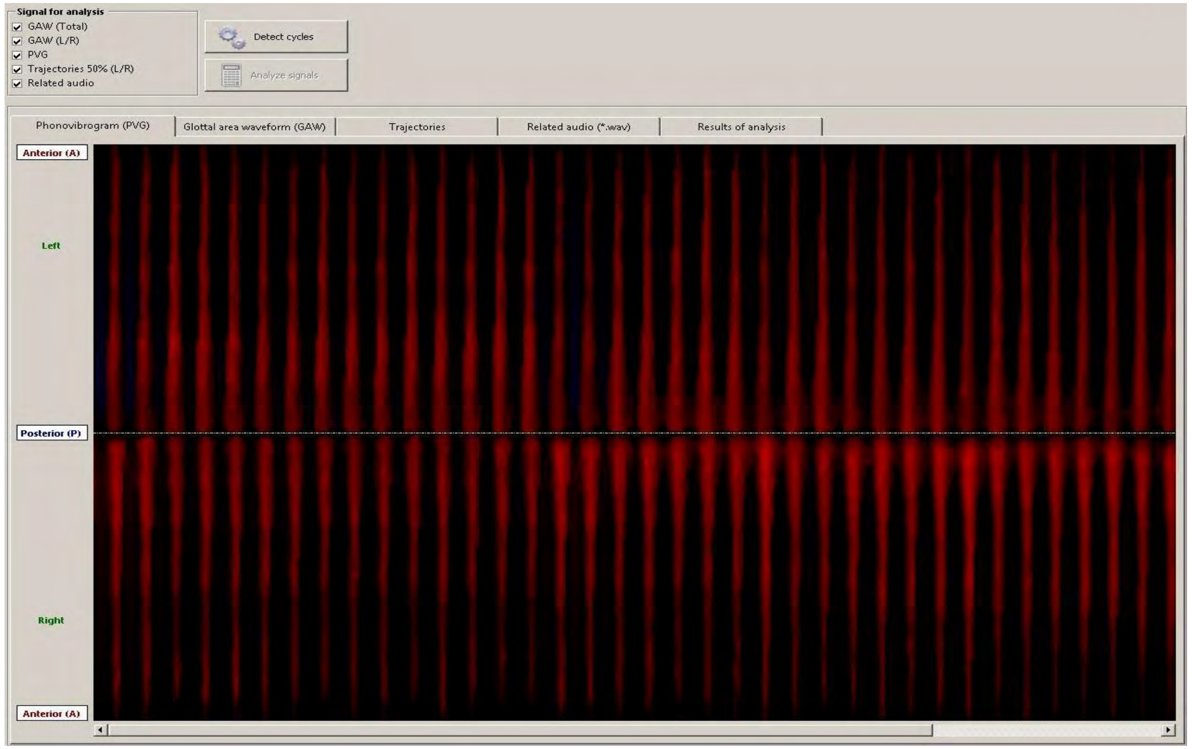


[redacted]



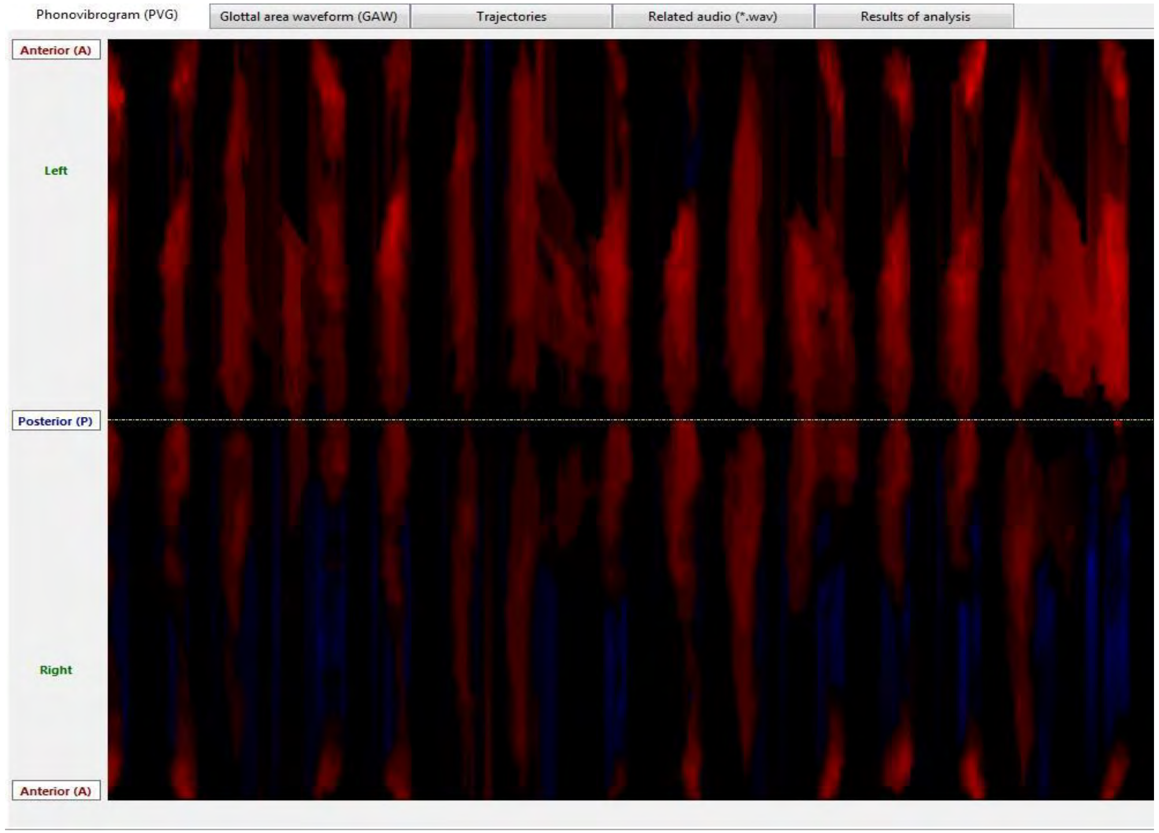
High speed films and phonovibrogram

- Phonovibrogram of the contest winning female, showing the regularity of single movements of the right and left vocal folds.



High speed films and phonovibrogram

- Phonovibrogram of a 59 years old male with extreme dysphonia due to a heavy acute laryngitis.



Calculated measures for the signals of Glottal Area Waveform and Glottal Trajectories

- From a contest winning female:

			[MEAN]	[STD]	[MIN]	[MAX]
Stiffness	[GAW]		0,38	0,02	0,333	0,413
Stiffness	[GAW]	[Left]	0,391	0,024	0,338	0,432
Stiffness	[GAW]	[Right]	0,395	0,024	0,352	0,451
Stiffness	[Traj-50%]	[Left]	0,483	0,043	0,371	0,625
Stiffness	[Traj-50%]	[Right]	0,486	0,029	0,392	0,513

- From a 59 years male with extreme dysphonia due to a heavy acute laryngitis:

			[MEAN]	[STD]	[MIN]	[MAX]
Stiffness	[GAW]		0,29	0,059	0,207	0,418
Stiffness	[GAW]	[Left]	0,313	0,056	0,232	0,444
Stiffness	[GAW]	[Right]	0,298	0,04	0,215	0,376
Stiffness	[Traj-50%]	[Left]	0,356	0,069	0,251	0,479
Stiffness	[Traj-50%]	[Right]	0,288	0,037	0,248	0,323

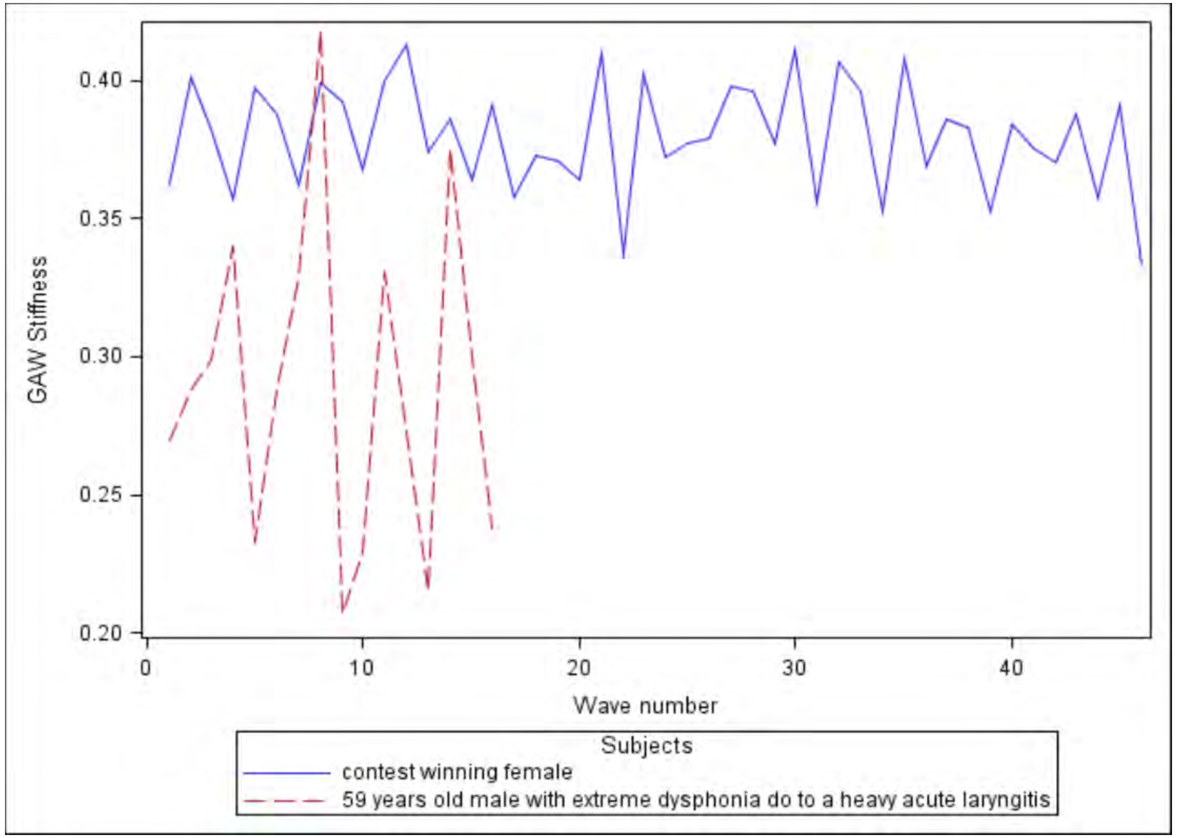
Statistical analysis of stiffness

- A statistical comparison of stiffness measurements of the two subjects can be done under the assumption that all the measurements on the same subject follow the same Normal distribution. The hypothesis that the variation is the same for the two subjects can be tested in the likelihood ratio test, where the -2log likelihood difference is chi-square distributed with 1 degree of freedom, when it is assumed that the measurements have different means for the two subjects.

Statistical model	-2 log likelihood	Likelihood ratio test statistic	P-value (chi-aquare distribution with 1 degree of freedom)
Subjects have different mean and variance	-261.2		
Subejcts have different mean and same variance	-228.6	33.30	$<$ 0.00001

Statistical conclusions

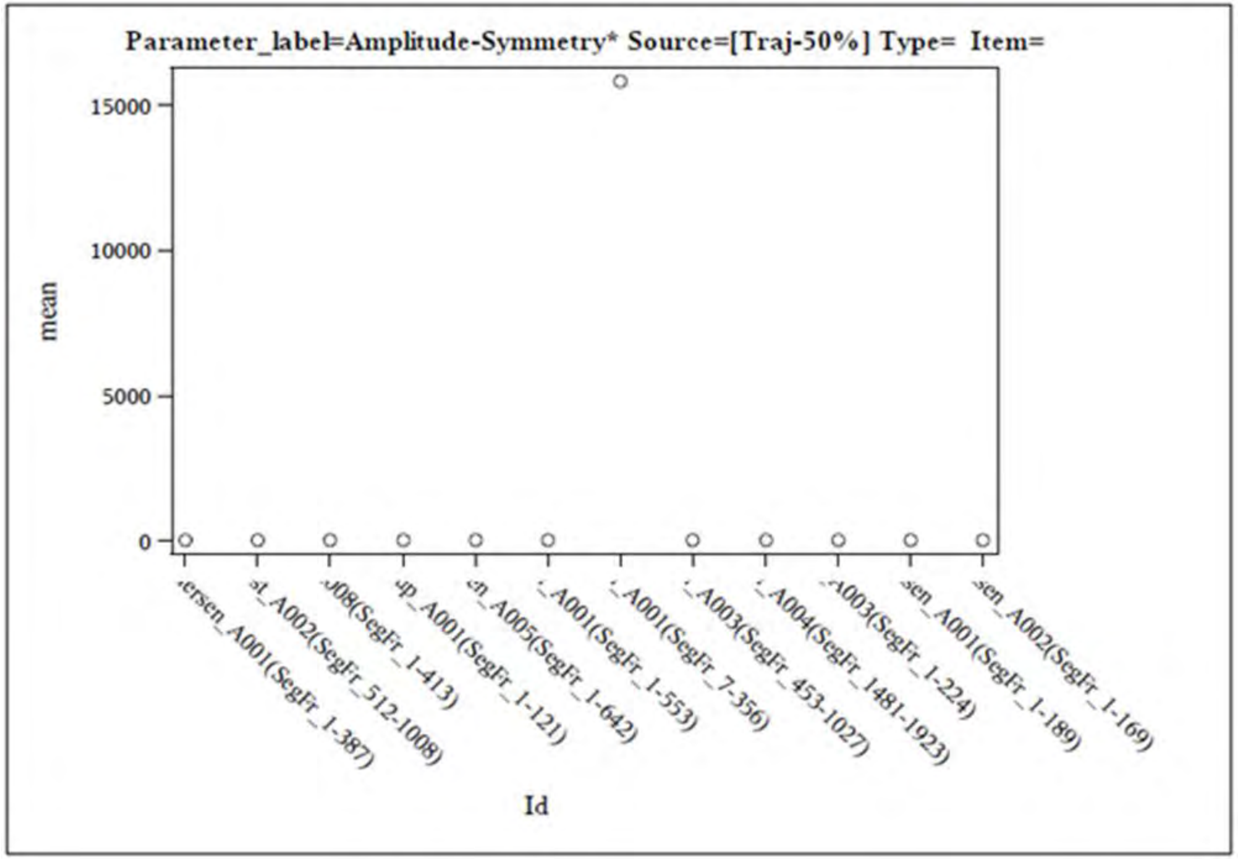
- The statistical model shows that there is a statistical significant difference in the variation of the GAW stiffness between the two subjects.



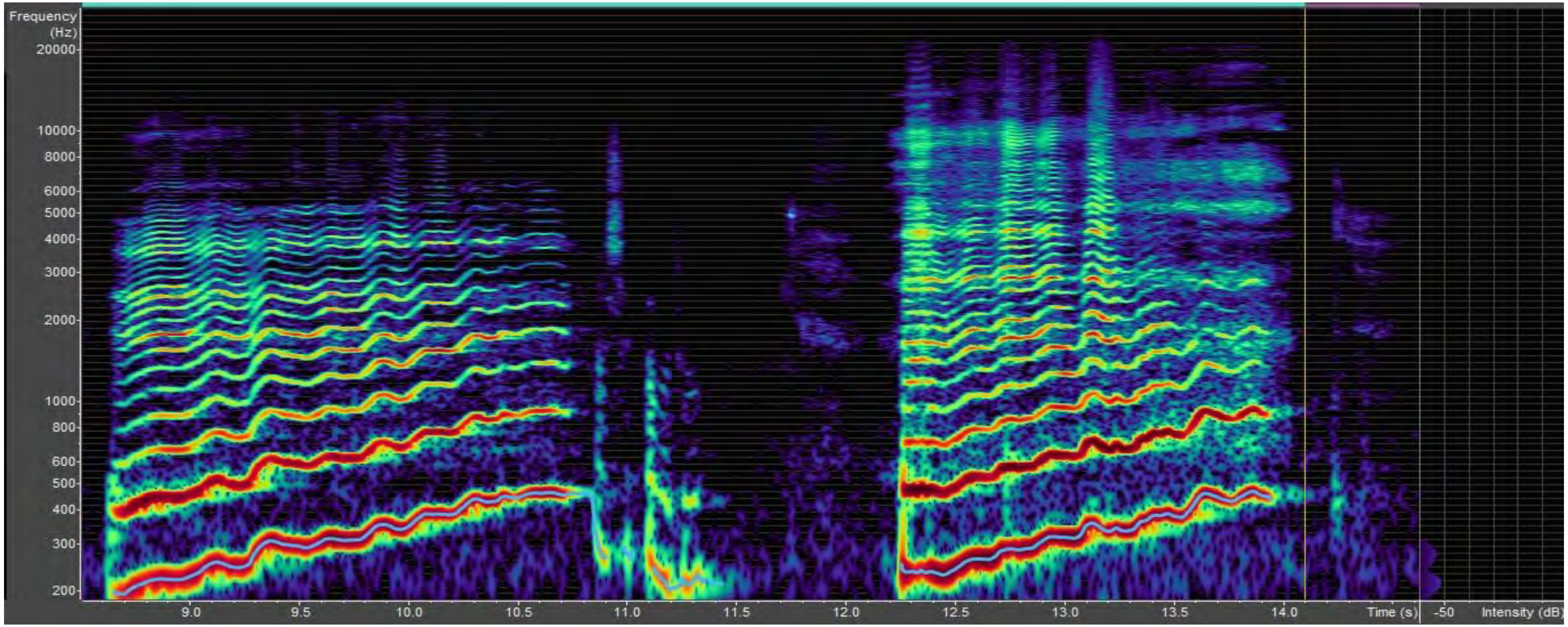
- The data analysis shows the female singer listed as "Singer observation", as well as an average of 12 hoarse patients from an voice data material listed as "Group average", hold up against the man with acute laryngitis (_A001(SegFr_7-356)) listed as "Observation".
- The table shows an Amplitude-Symmetry deviation between the singer and the male with acute laryngitis due to dysphonia and occasional diplophonia as a result of an acute laryngitis. A significant difference in Amplitude – Symmetry- Index is also seen ($p<0,0001$).

Parameter	Source	Person	Laryngitis observation	Group average	Singer observation
Amplitude-Symmetry	[Traj-50%]	_A001(SegFr_7-356)	15796.53	1317.43	0.95
Amplitude-Symmetry-Index	[Traj-50%]	_A001(SegFr_7-356)	0.30	0.71	0.86

The graph shows the discrepancy between the male patient with dysphonia (_A001(SegFr_7-356)) of the parameter amplitude symmetry –Traj 50% compared with the whole group (consisting of 12 patients claiming of chronic hoarseness).



Overtone analysis is another promising software



- A Sygyt Software Ltd. presentation showing a normal female voice compared with a female voice of a singer where the upper register is weakened.

High speed films combined with acoustical measures analyzed with "Sygyt Ltd." of a prospective cohort study of 12 normal persons, the results are on the same level as "VoceVista"

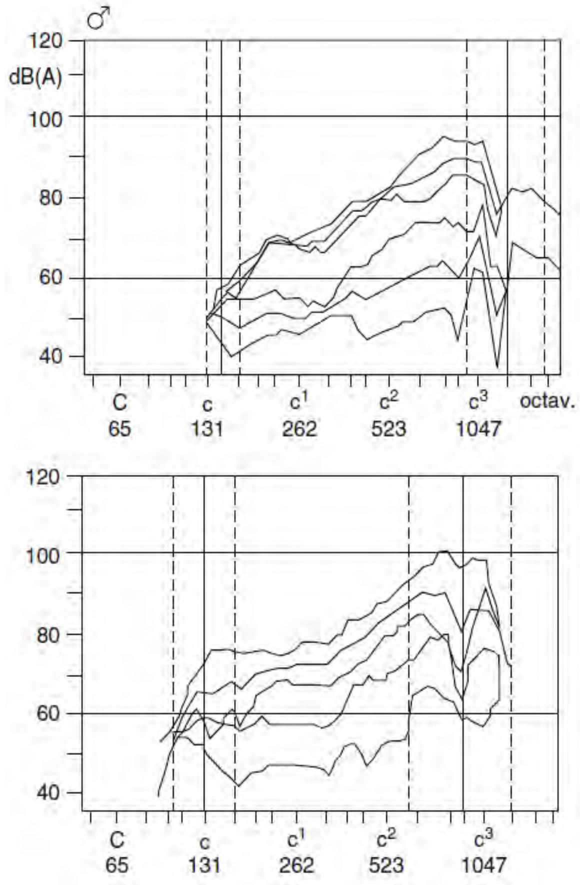
Variation of 3 formants 1000-5000Hz

Nr.	Name	Gender	Age	ms	F0 (Hz)	F0 (dB)	(Fa) (Hz)	(Fa) (dB)	Fx (Hz)	Fx (dB)	Fy (Hz)	Fy (dB)	Fz (Hz)	Fz (dB)
1	MP-A	K	75	520	327	64	[redacted]	[redacted]	1320	35	2312	34	3271	18
2	ACA-A	K	25	70	251	48	[redacted]	[redacted]	1261	33	2241	30	4025	28
3	LTC-A	K	40	1130	329	45	[redacted]	[redacted]	1401	28	2295	20	3357	9
4	KJH-A	K	47	850	142	15	[redacted]	[redacted]	1293	39	2328	24	3028	27
5	SM-A	K	24	900	307	38	[redacted]	[redacted]	1606	38	3206	25	4004	26
6	NBL-A	K	25	640	377	64	[redacted]	[redacted]	1131	23	2258	22	3411	14
7	AJ-A	M	24	120	216	56	[redacted]	[redacted]	1293	48	2371	40	3449	40
8	MSM-A	M	23	1060	158	38	[redacted]	[redacted]	1115	38	2549	29	3341	21
9	BHA-A	M	22	1210	266	47	[redacted]	[redacted]	1320	51	2904	30	4230	20
10	MO-A	M	28	440	211	49	[redacted]	[redacted]	1077	42	2373	28	4694	19
11	AH-A	M	16	430	139	42	[redacted]	[redacted]	1385	23	2500	28	3336	16
12	JJ-B	M	33	160	196	20	[redacted]	[redacted]	1040	12	1697	12	2204	19

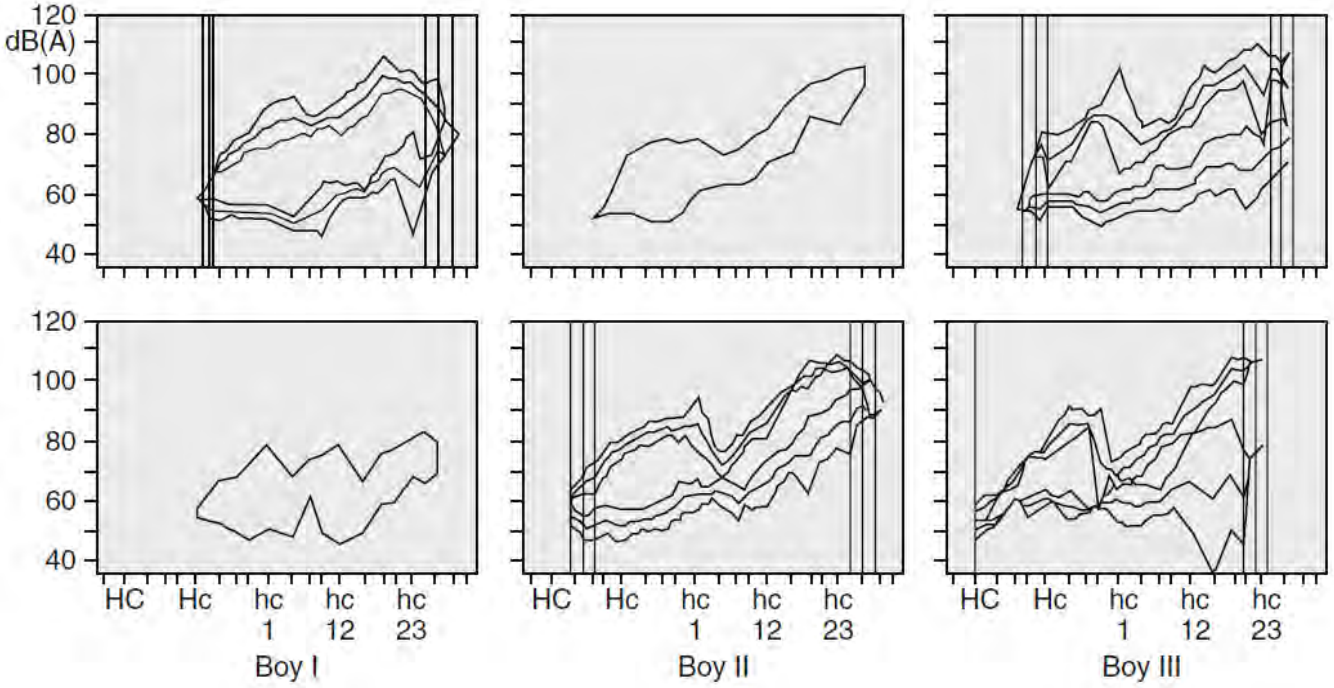
Difference to sygyt sound analysis of 12 normal persons

Coefficient of variation (cv)	mean					1513.5		2548.4		3834.8
	change mean					243.3		128.9		305.7
	std					270.0		632.7		923.4
	cv					18%		25%		24%

Phonetogram of boys and girls

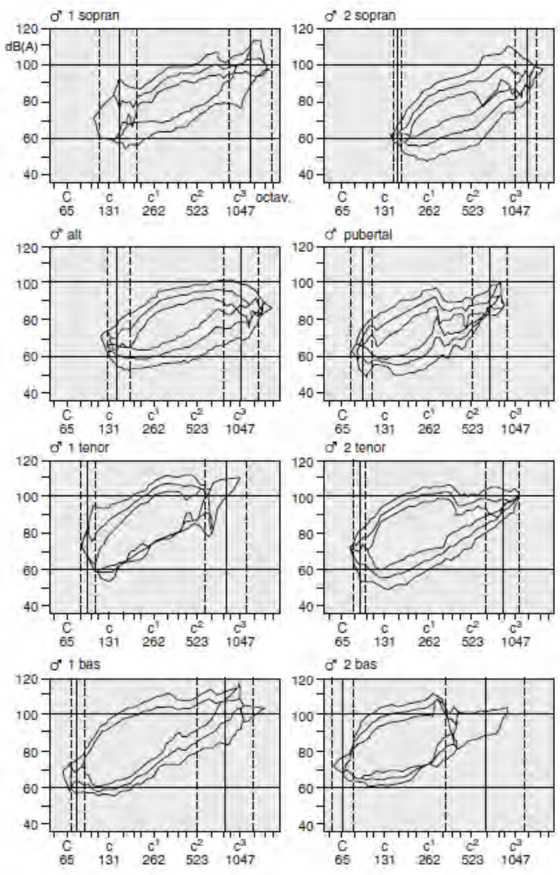


Average phonetograms with standard deviation for the cohort of sopranos and of pubertal change groups (mutants) from the Leipzig Thomaner choir. The hormonal parameters were similar to those of the Copenhagen boys.

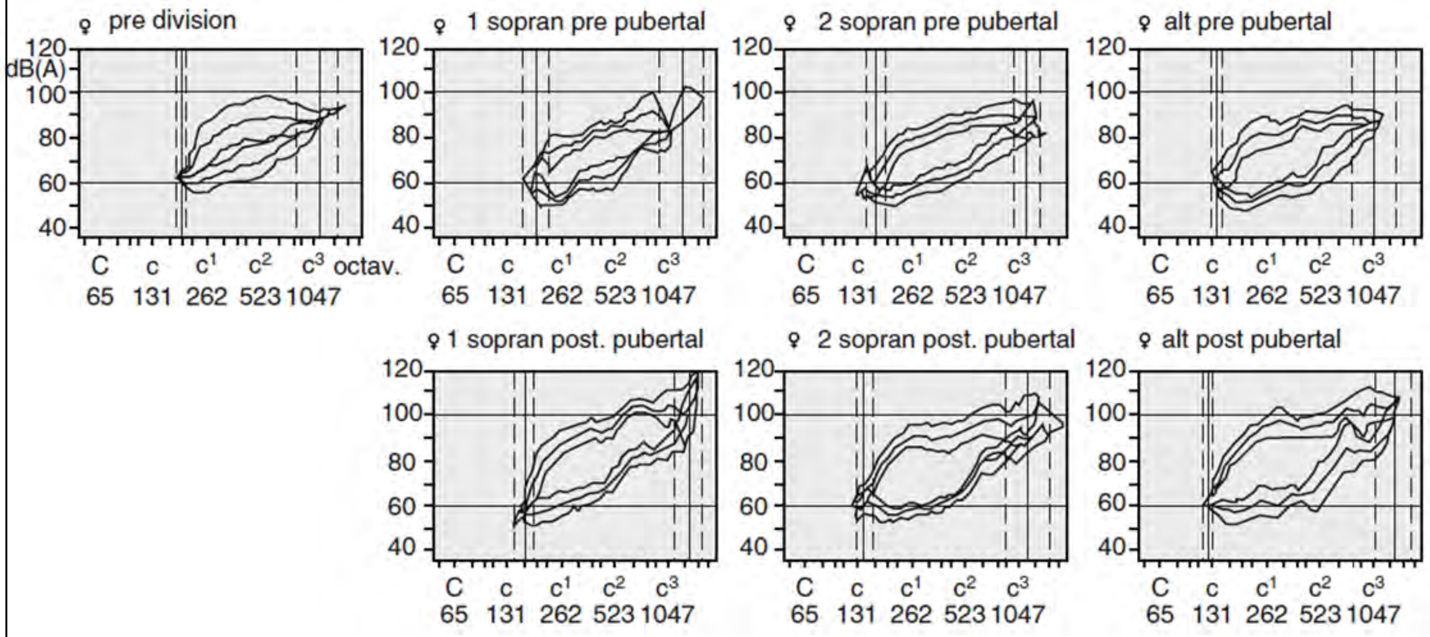


Average phonetograms and standard deviations for the threechoirboys (I–III) involved in the prospective longitudinal study. The phonetograms before and after the change of voice were compared. For test person I and II, only one phonetogram was made in mutation and before mutation respectivetly. For test person III, three phonetograms were measured before and three during the change of voice.

Phonetogram of boys and girls



Average phonetograms with standard deviation for boys and young men from a boys' choir at a Danish choir school, as a function of voice type. (The voice type was determined by the singing teacher.) The abcissa is divided up into semitones, and the frequency in Hertz of each octave is indicated. The scale of the ordinate is dB(A)



Average phonetograms with standard deviation for girls and young women from a girls' choir at a Danish choir school, as a function of voice type. (The voice type was determined by the singing teacher). The abcissa is divided up into semitones, and the frequency in Hertz of each octave is indicated. The scale of the ordinate is dB(A). One group could not be securely defined during puberty

dys-functional voice research

- Pedersen M (1995) Stimmfunktion vor und nach Behandlung von Hirngeschädigten. Mit Stroboskopie, Phonetographie und Luftstromanalyse durchgefürht. Sprache,Stimme,Gehöhr; 19: 84-9.

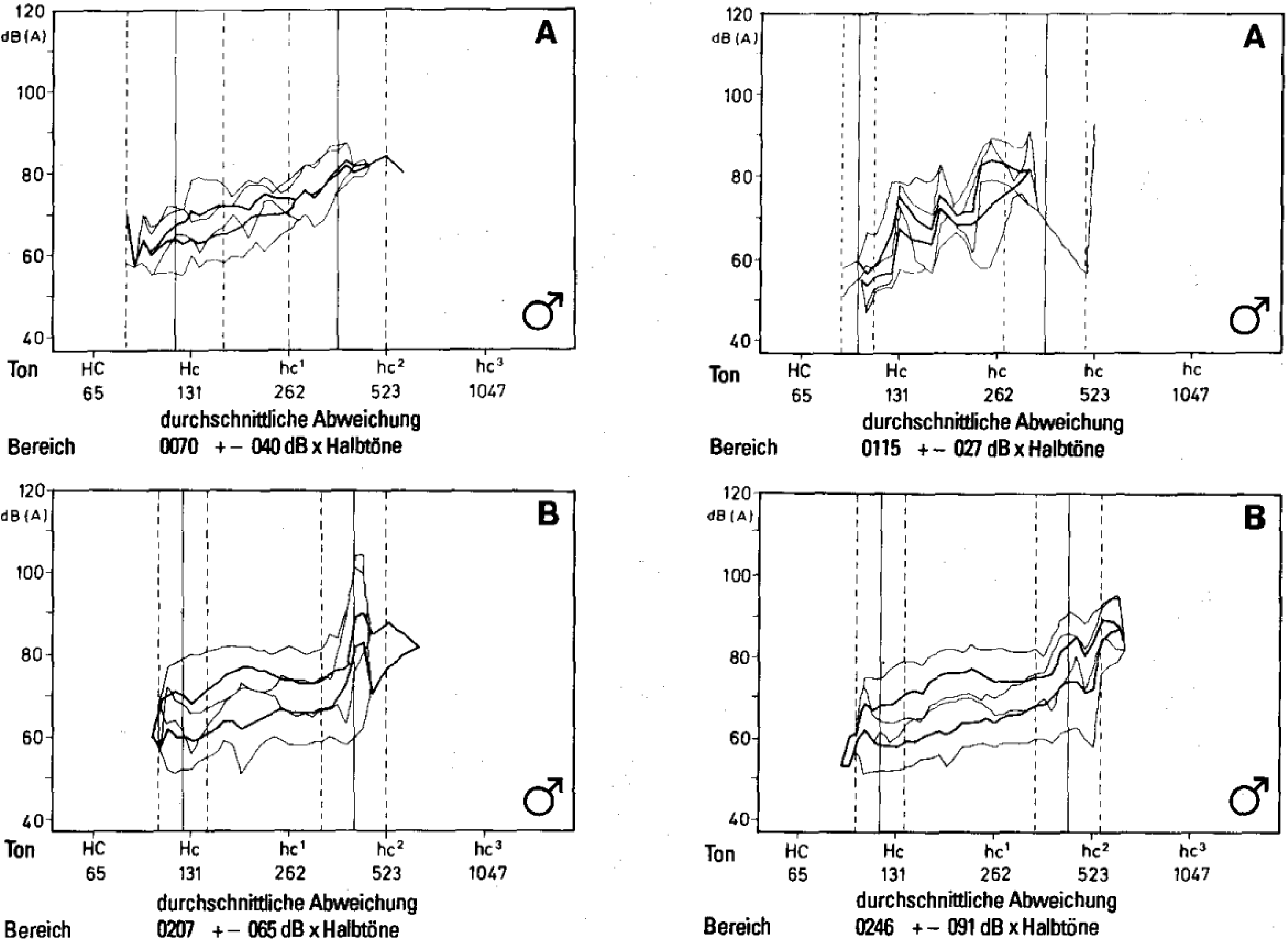


Abb. 3 22 hirngeschädigte Patienten vor (links) und nach Behandlung (rechts). Phonetogrammdurchschnitte und Standarddeviationen.

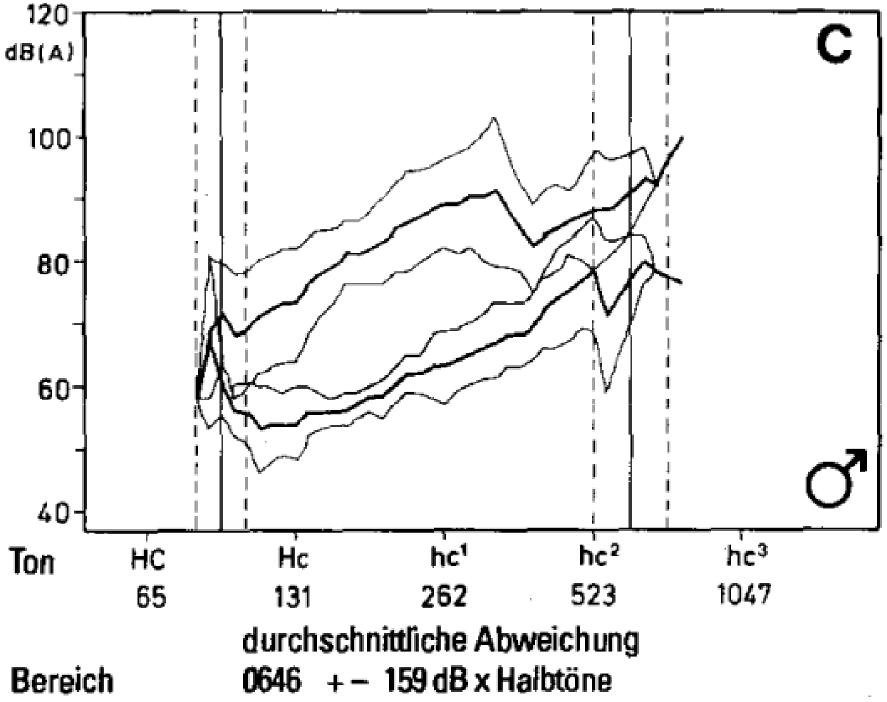
Abb. 3a 5 schwer gestörte Männerstimmen (Phonetogrammfläche verbessert von 70 bis 115 Semitönen × dB).

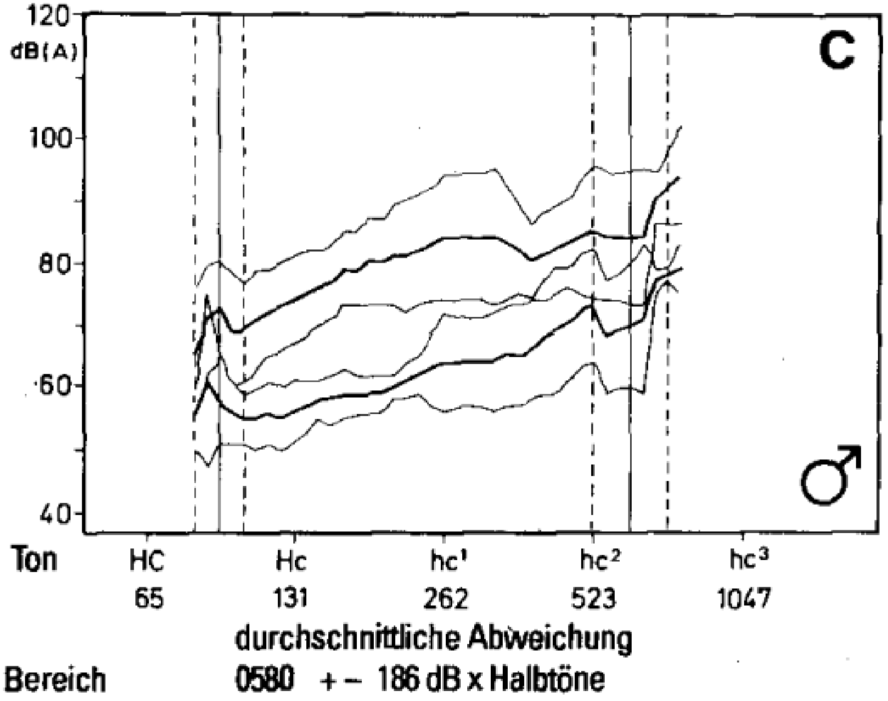
Abb. 3b 5 mittelschwer gestörte Männerstimmen (Phonetogrammfläche verbessert von 207 bis 246 Semitönen × dB).

Abb. 3c 6 nicht gestörte Männerstimmen.

Abb. 3d 4 mittelschwer gestörte Frauenstimmen (Phonetogrammfläche verbessert von 200 bis 301 Semitönen × dB).

Abb. 3e 2 nicht gestörte Frauenstimmen.


C
120
dB(A)
100
80
60
40
Ton
HC 65
Hc 131
hc¹ 262
hc² 523
hc³ 1047
durchschnittliche Abweichung
Bereich
0646 +– 159 dB x Halbtöne


C
120
dB(A)
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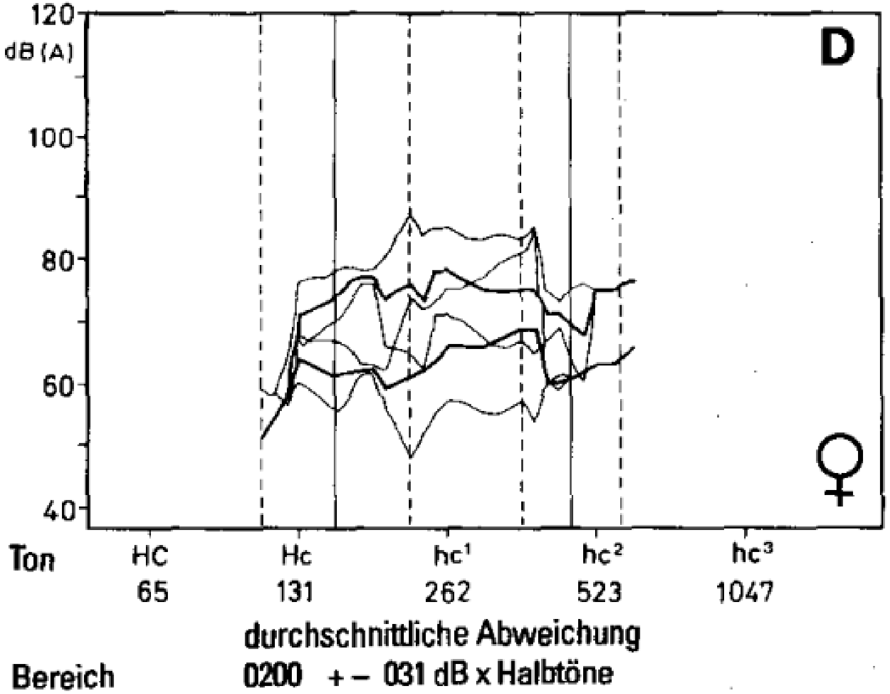
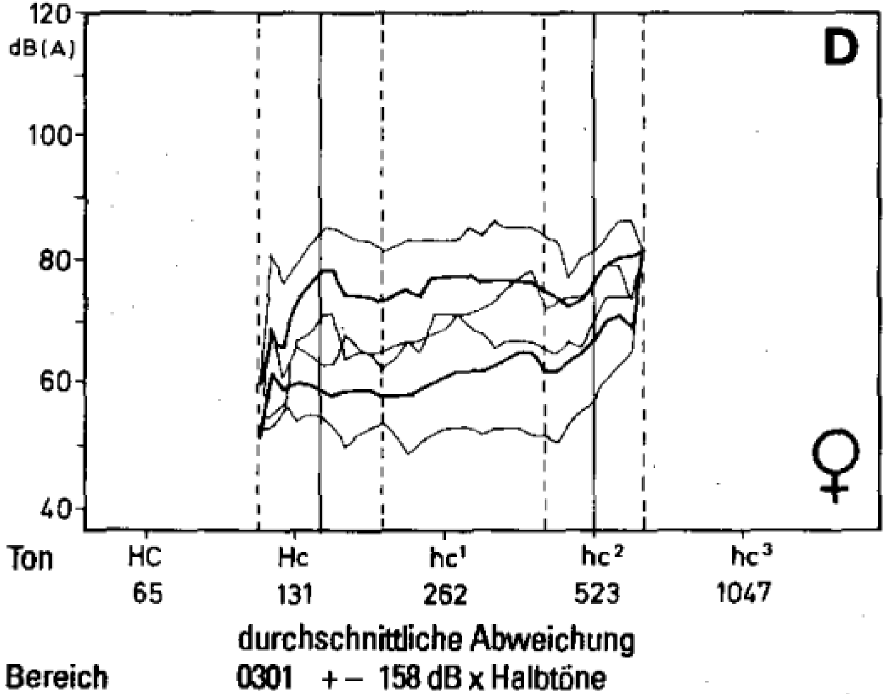
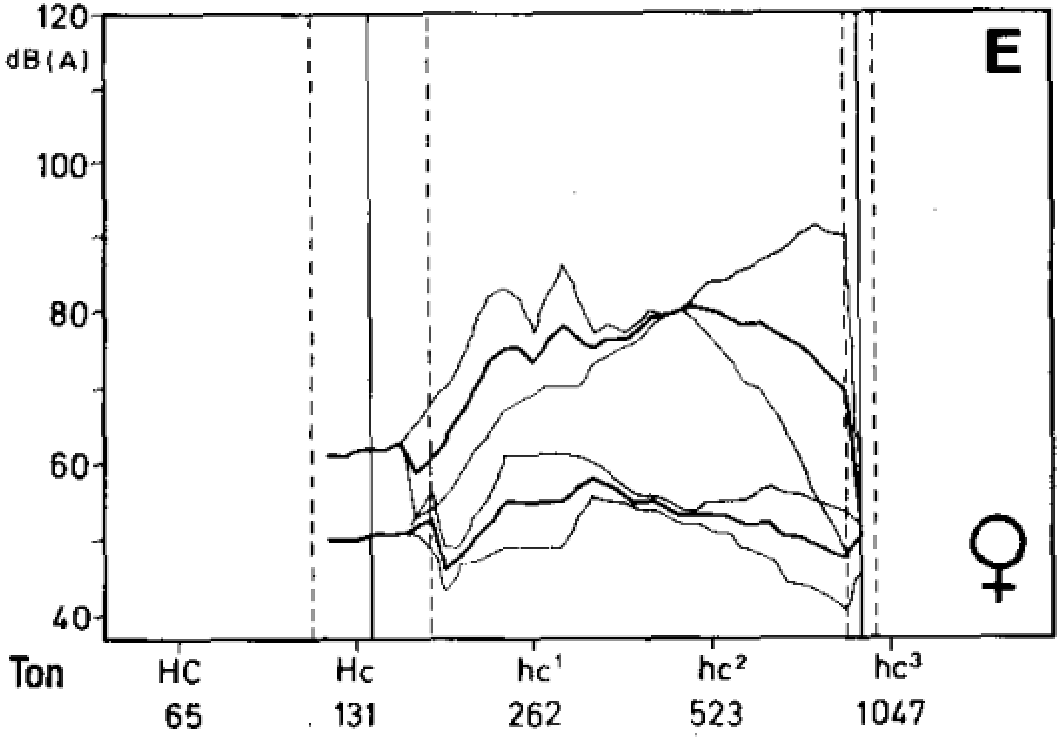
HC 65
Hc 131
hc¹ 262
hc² 523
hc³ 1047
durchschnittliche Abweichung
Bereich
0580 +– 186 dB x Halbtöne

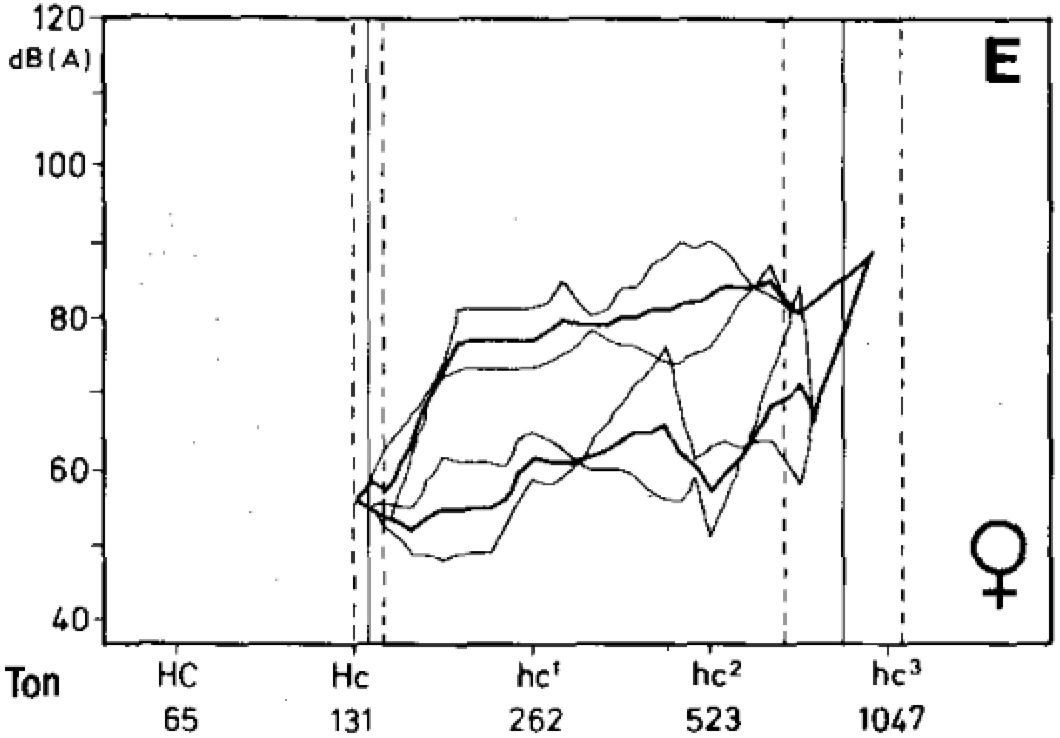

D
120
dB(A)
100
80
60
40
Ton
HC 65
Hc 131
hc¹ 262
hc² 523
hc³ 1047
durchschnittliche Abweichung
Bereich
0200 +– 031 dB x Halbtöne


D
120
dB(A)
100
80
60
40
Ton
HC 65
Hc 131
hc¹ 262
hc² 523
hc³ 1047
durchschnittliche Abweichung
Bereich
0301 +– 158 dB x Halbtöne



durchschnittliche Abweichung

Bereich 0678 +– 362 dB x Halbtöne



durchschnittliche Abweichung

Bereich 0517 +– 045 dB x Halbtöne

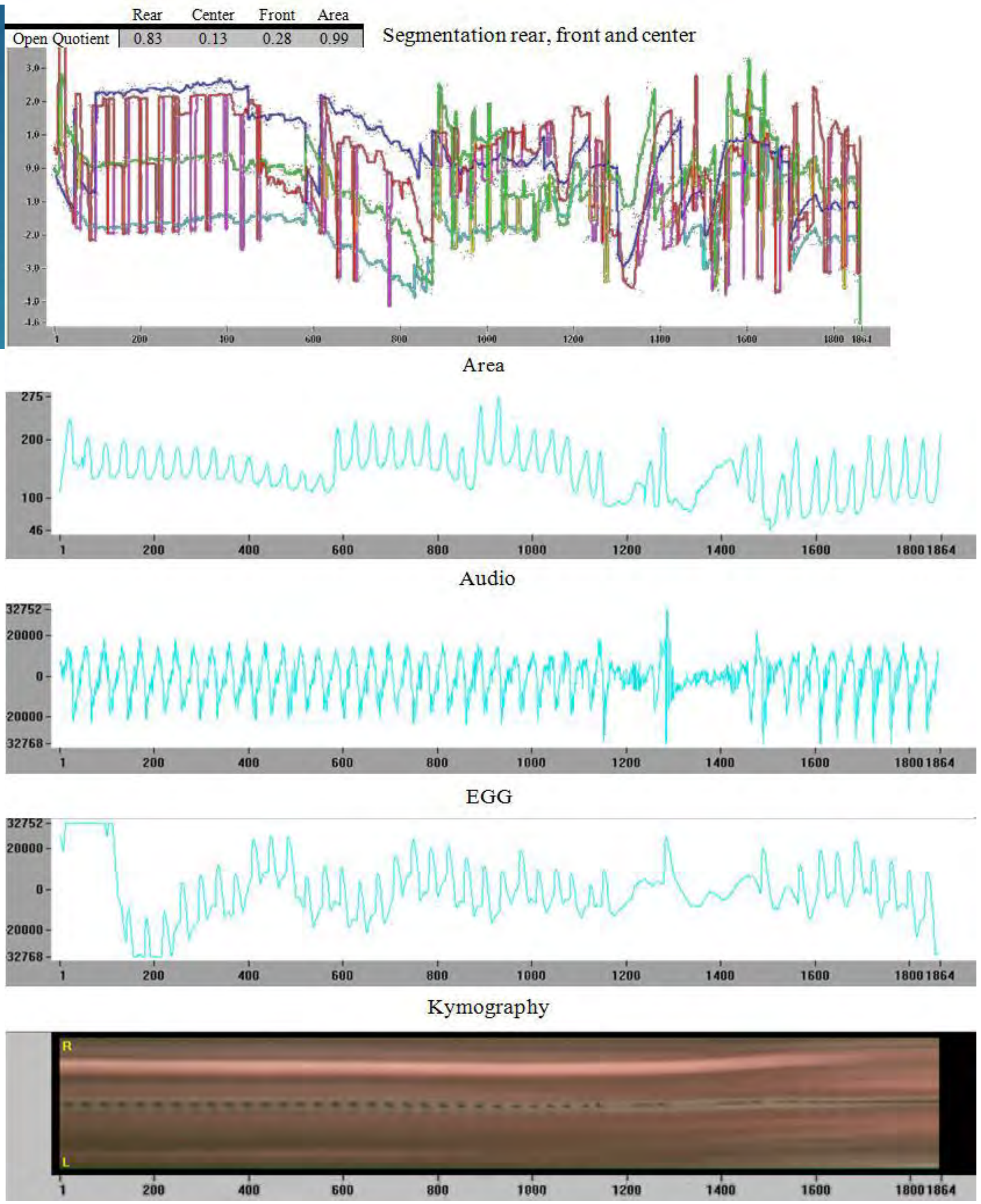
Tab. 6 Multivariante statistische Analyse in 16 männlichen Hirngeschädigten (SAS Statistik).

	Durchschnitt	SD	Korrelationen	von Interesse
1 Alter	35 Jahre		14 (–,48)	15 (–,44)
2 Peakflow	7739 ml/s	1802	4 (,43) 7 (,44)	5 (,47) 10 (,70)
3 Vitalkapazität	4052 ml	947	4 (,88)	5 (,48)
4 Luftvolumen während der maximalen Phonationszeit	3170 ml	989	5 (,48)	10 (,57)
5 Phonationsdauer	17 s	9	6 (–,47) 9 (–,75)	8 (–,69)
6 Stabilität der Grundfrequenz	13,0 %	9,9	11 (–,43)	
7 Stabilität der SPL	0,4 dB	0,2	12 (–,42)	
8 *durchschnittliche Luftstromgeschwindigkeit*	212,8 ml/s	101,2	9 (,96)	11 (–,15)
9 Phonationsquotient	275,8 ml/s	33,0		
10 Quotient von Luftverbrauch (durchschnittliche Luftstrom-geschwindigkeit/Phonations-quotient)	77,5 %	10,1	11 (,31)	
11 *Phonetogramm Areal* in Semitönen × dB	224	177	1 (,67) 13 (,49) 15 (,66)	12 (,49) 14 (,66)
12 maximale Dynamik	19,5 dB	5,4	15 (,60)	14 (,51)
13 niedrigste Ton des Phonetrogrammes (geometrische Durchschnitt)	106 Hz	18	14 (–,45)	
14 Semitönen des Phonetrogrammes	24	8	15 (,95)	
15 höchste Ton des Phoneto-grammes	438 Hz	166		

(p < 0,05 über ,51; P < 0,01 über ,60)

Segmentation curves for high speed film

- Calculations of open quotients in the front, center and rear parts of the vocal cords.
- **Visual irregularities illustrated due to a dystonia spasm** – on movement curves of the vocal cords in front, center and rear, as well as area-, acoustical-, electroglottographical-, and kymographical curves.



Dystonia patient

- Our first dystonia patient where high speed images were used to document changes, had **total elimination of universal dystonia symptoms with local cortison inhaler in the larynx and the antihistamin fexofenadine referring to the research by Ludlow.** In addition high speed films showed regularity of laryngeal actions after the referred treatment. The elimination of dystonia in the larynx and in other parts of the body in some of these patients suggested a relationship between immunological deficiencies of the upper airways and the nature of dystonia, with relapses when the medication was terminated.

Conclusions

- Till now we have seen a difference between high quality voices and other voices and we presented a quantified measure of the vocal fold stiffness calculated from individual vocal cycles as well as average measures during development related to hormones and in pathology of brain damaged patients as well as dystonia.
- It is our impression that the system Glottis Analysis Tools stiffness calculations can be used clinically to differentiate between high and low quality voices.
- In the future, stiffness of phonovibrograms together with overtones might be used to determine the treatment effect in voice pathology. It is easier to use than air flow and phonetograms. Still there might be different options.

- Thank you for your attention!

- Find the slides on: www.mpedersen.org

References

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