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RESEARCH ARTICLES

Acoustic voice analysis in different phonetic contexts after larynx radiotherapy for T1 vocal cord carcinoma

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Abstract
Introduction Radiotherapy for early vocal cord carcinoma affects quality of voice. Nevertheless, most patients refer to having a high satisfaction level with their voice. The few acoustic studies on quality of voice have been performed only in prolonged vowel production, which is not a usual speech situation. The present study has been done with the aim of establishing which phonetic situations reflect a greater alteration in voice production related to irradiation.
Material and methods Eighteen male patients irradiated for Tis-T1 vocal cord carcinoma and a control group of 31 non-irradiated subjects were included in a study of acoustic voice analysis. This analysis was performed one year after radiotherapy. Patients and control group voices were tape recorded in extended vowel production, oral reading of a standard paragraph, spontaneous speech and in a song. Acoustic analysis was performed by a Kay Elemetric's Computerized Speech Lab (model CSL #4300). Fundamental frequency, jitter, shimmer and harmonics-to-noise ratio were obtained in both groups. Statistical test: Lin concordance coefficient and Pearson's correlation coefficient, Student's t-test and ROC curves.
Results Concordance and correlation studies did not allow selection of any subgroup in acoustic parameters and different acoustic situations. Acoustic parameters had higher median values in irradiated patients. Student's t-test showed significant differences for fundamental frequency in sustained vowel production and spontaneous speech; for jitter there was statistical significance in all the acoustic situations and for shimmer in oral reading and song. Jitter showed a cut-off of 2.02% with a sensitivity of 89% and specificity of 97% in classifying irradiated and non-irradiated groups. The ROC curve for jitter correctly classified 94% of subjects into irradiated or non-irradiated groups.
Conclusions The present study showed that jitter obtained from spontaneous speech was the most relevant parameter in discriminating voice in irradiated patients by acoustic analysis. Jitter in spontaneous speech is in need of more analysis in bigger series and in more advanced stages of larynx cancer as its relevance has been demonstrated.

Keywords Acoustic voice analysis · Radiotherapy · Vocal cord carcinoma

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Introduction

Voice quality after treatments is related with quality of life; voice enables people to express feelings and meanings, thus a good modulation of voice is needed in daily life. Although the relevance of voice after treatments for early vocal cord carcinoma is clear, it has been an orphan topic, usually misleading in the context of a patient with cancer. Few studies in the literature show the influence on voice of early vocal cord cancer treatments using perceptual and quantitative analysis, and there is no agreement between the phoniatricians with regard to which of these methods is the more useful to assess the voice quality. Perceptual evaluation will be more adequate to assess the "social voice", whereas the quantitative analysis will give more information on the physiopathology of the vocal defect; thus, these methods are more complementary than mutually exclusive. The quantitative assessment of voice quality can be done using videostroboscopic analysis, aerodynamic tests and laboratory acoustic analysis. Acoustic voice analysis has been described principally in a young American population and it is known that the results of acoustic analysis worsen with age. Early vocal cord carcinoma usually appears between 50 and 70 years; thus, factors other than tumour, age and treatment which can affect quality of voice in these patients are size of biopsy performed and history of smoking [1–10].

Acoustic voice analysis after radiotherapy has been reported in approximately 100 patients [1, 3, 4, 6–8, 11, 12]. These studies show that irradiation affects voice quality and they use parameters such as fundamental frequency, jitter, shimmer and harmonics-to-noise ratio. Fundamental frequency reflects the vocal cord vibrations during phonation, jitter shows the cycle-to-cycle perturbation of fundamental frequency during vocal cord vibration, shimmer indicates the intensity of voice, and harmonics-to-noise ratio reflects the noise in voice production [11, 13–16]. Most of the research in acoustic analysis is done on sustained vowels and there are almost no data available on running speech of pathological speakers, when running speech is better correlated to the pathological conditions than sustained vowels. Speaking is the result of the extremely precise coordination in time of different muscles in the larynx. Spontaneous speech has tone variations of one octave (12 semitones), where alternate and successive variations between acute and grave tones are found, and different subglottic pressures are needed to perform these tone variations. Thus, complexity of spontaneous speech needs a better coordination between the larynx as a vibratory element and the respiratory system. Changes in the articulatory and aerodynamic systems that are secondary to radiotherapy will have an influence on voice and on acoustic parameters [5, 10, 17–23]. All but two studies have only shown modifications of these acoustic parameters in sustained vowel production [1, 3, 4, 6–8, 11, 12]. Taking into account the fact that sustained vowel production is not a usual phonetic situation, we performed a study on voice quality in 18 Spanish males irradiated for Tis-T1N0 vocal cord carcinoma [12]. The study was performed in different acoustic situations to obtain information on voice in sustained vowel production, spontaneous speech, oral reading of a standard paragraph and singing a popular song. The results of this work showed that there was an increase in the values of fundamental frequency and jitter in all the acoustic situations and the worst results were obtained in sustained vowel production. In this study, 78% of the patients referred to having a percentage of their previous voice equal or higher than 90% and 39% referred to having 100%. Taking into account the fact that sustained vowel production is not a usual phonetic situation in daily speech and needs more vocal effort than spontaneous speech, the good percentages of voice reported by the patients should be considered as being related to spontaneous daily speech [12, 24]. The results of this previous analysis led us to believe that more information was needed on voice quality after radiotherapy.

The present study is done with the aim of establishing which acoustic parameters and phonetic situations reflect more alteration in voice production related to irradiation for T1 vocal cord carcinoma in Spanish speakers.

Materials and methods

Approval was obtained from patients, the control group and institution review committee for this prospective observational study.

Eighteen patients irradiated for Tis-T1 vocal cord carcinoma and 31 non-irradiated and non-smoking males as a control group were invited to participate in an acoustic voice analysis study. The age of both groups was similar and the control group was selected by perceptual phoniatric study using the GRBAS scale, where G is the degree of hoarseness, R the degree of roughness, B the breathiness and A the strained quality. The control group had GRBAS scores of 0 or values of 1 in one of the parameters other than G. The characteristics of patients and the control group were described in a previous study [12].

Radiotherapy dose was 66 Gy, 2 Gy/day, 5 days/week and patients were treated using a thermoplastic mask and a 6 MV Linac. A CT-based simulation allowed us to offer treatment areas inferior or equal to 30 cm^2 in 9 patients and 30–35 cm^2 in the rest [12, 25–27].

Voices were registered in a sound-treated room one year after radiotherapy. Samples of sustained vowel production, contextual speech, reading of a phonetically well balanced standard paragraph and singing of popular song were tape recorded on a digital audiotape (Sony WM-GX510). The mouth-to-microphone distance was kept standard at 20 cm and 3 different phoniatrists made an evaluation of the tape recorded voices. Recordings were analysed from a tape recorder connected to a Kay Elemetrics' Computerized Speech Lab (model CSL #4300). Fun-

Table 1 Acoustic analysis values

	Minimum	Mean	Median	Stand. deviation	Maximum	Sample size
Non-irradiated						
VP-Fo	97.51	149.74	142.35	38.69	255.86	31
VP-Jitter	0.45	1.54	0.94	1.78	10.12	31
VP-Shimmer	0.16	1.24	0.85	1.23	6.04	31
VP-H/N	0.04	3.63	3.08	2.65	8.88	31
OR-Fo	110.48	145.18	135.24	28.14	211.62	31
OR-Jitter	0.76	1.21	1.03	0.67	4.38	31
OR-Shimmer	1.12	3.66	1.62	3.64	14.02	31
OR-H/N	0.94	4.37	3.41	2.22	9.15	31
SS-Fo	98.44	137.82	134.04	26.68	209.04	31
SS Jitter	0.80	1.27	1.24	0.36	2.11	31
SS Shimmer	1.32	8.79	9.69	5.15	19.02	31
SS H/N	2.21	6.20	6.02	2.15	11.35	31
PS Fo	112.48	155.51	146.62	33.76	246.29	31
PS-Jitter	0.60	1.01	0.93	0.38	2.27	31
PS-Shimmer	1.14	6.63	6.39	4.38	15.40	31
PS-H/N	0.74	4.14	4.67	2.00	8.89	31
Irradiated						
VP-Fo	97.06	182.41	186.00	51.78	256.26	18
VP-Jitter	0.54	3.54	2.96	2.55	8.67	18
VP-Shimmer	0.51	2.26	1.32	2.50	10.75	18
VP-H/N	0.07	4.21	3.97	2.94	8.90	18
OR-Fo	124.80	156.33	151.47	18.92	191.60	18
OR-Jitter	1.20	2.71	2.36	1.39	6.93	18
OR-Shimmer	1.14	4.18	2.63	3.03	10.52	18
OR-H/N	1.90	6.75	6.31	2.99	11.25	18
SS-Fo	120.13	155.91	151.10	19.10	198.74	18
SS Jitter	1.10	2.97	2.88	1.11	5.70	18
SS Shimmer	2.08	10.65	9.68	5.29	19.07	18
SS H/N	1.87	7.65	8.82	2.84	11.72	18
PS Fo	132.41	168.53	165.22	26.09	230.03	18
PS-Jitter	0.72	2.45	2.34	1.35	5.29	18
PS-Shimmer	1.24	7.72	6.83	5.44	18.88	18
PS-H/N	0.67	6.15	6.19	3.21	10.61	18

VP, vowel production; *SS*, spontaneous speech; *OR*, oral reading; *PS*, song; *Fo*, fundamental frequency; *H/N*, harmonics-to-noise ratio

damental frequency (Hz), jitter (%), shimmer (dB) and harmonics-to-noise ratio (dB) were obtained in all the above reported acoustic situations. CSL measurements met the following conditions [3, 28]: (1) Prolonged vowel production. The vowel /a/ was chosen because it is considered to be the most sensitive indicator of differences in vowel production. Clipping of the initial and final 500 ms of the vowel was performed, where the sample studied lasted 2 s. (2) The sample for spontaneous speech, oral reading and song was 14 s. Clipping of the initial and final second was done. Jitter, shimmer and harmonics-to-noise ratio were evaluated in intervals of similar fundamental frequency (Fo). (3) In the case of oral reading and song the same paragraphs were studied in all the patients. (4) Harmonics-to-noise ratio was studied in a sample of 50 cycles; the same words were used for spontaneous speech, oral reading and song analysis.

The concordance of each acoustic indicator between the different pairs of studied situations was measured using the Lin concordance coefficient, Pearson's correlation coefficient and an estimation of the linear relationship between the variables and the two studied situations. The regression parameters were estimated using the method of standardised principal components. Concordance was considered as acceptable when the concordance and correlation coefficient were more than 0.8, the straight slope was one and the ordinate at the origin was 0. The comparison between the indicators of the two groups studied was done by the Student's *t*-test [28-30].

Validation of diagnostic capacity and a cut-off selection point that maximises the sensitivity and the specificity for each indicator which were different between the two groups was done with ROC curves. The combination of indicators that optimises the classification of voices was done using multivariant logistic regression models.

Statistics analysis was performed by SPSSwin 9.0. Estimations by interval were calculated with a confidence interval of 95% and a significance level of 5%.

Table 2 Concordance study

	VP. *vs.* OR	VP *vs.* SS.	VP. *vs.* PS	OR. *vs.* SS.	OR *vs.* PS	SS. *vs.* PS
Fo						
Concordance	0.39 (0.20; 0.58)	0.42 (0.23; 0.60)	0.46 (0.25; 0.66)	0.79 (0.69; 0.90)	0.74 (0.62; 0.86)	0.67 (0.51; 0.82)
Correlation	0.48 (–0.21; 0.85)	0.54 (–0.13; 0.87)	0.49 (–0.19; 0.86)	0.81 (0.37; 0.95)	0.8 (0.38; 0.95)	0.75 (0.23; 0.94)
Intercept	94.31 (79.5–; 109.6)	84.35 (68.56; 100.1)	82.24 (61.12; 103.3)	–4.87 (–30.51; 20.76)	–33.06 (–65.9; –0.2)	15.82 (–12.4; 44.1)
Slope	0.34 (0.25–; 0.42)	0.37 (0.28; 0.46)	0.48 (0.36; 0.60)	1.00 (0.83; 1.17)	1.30 (1.08; 1.51)	1.00 (0.81; 1.19)
Jitter						
Concordance	0.20 (–0.01; 0.42)	0.3 (0.11; 0.50)	0.22 (0.02; 0.41)	0.63 (0.46; 0.80)	0.61 (0.43; 0.79)	0.69 (0.53; 0.84)
Correlation	0.25 (–0.03; 0.50)	0.40 (0.13; 0.61)	0.30 (0.02; 0.54)	0.64 (0.44; 0.78)	0.62 (0.41; 0.77)	0.72 (0.55; 0.83)
Intercept	1.34 (0.98; 1.70)	1.35 (1.03; 1.68)	1.12 (0.79; 1.45)	0.39 (–0.03; 0.81)	0.03 (–0.41; 0.46)	–0.37 (–0.82; 0.08)
Slope	0.18 (0.13; 0.24)	0.24 (0.17; 0.30)	0.18 (0.13; 0.23)	0.85 (0.66; 1.04)	0.86 (0.66; 1.05)	1.01 (0.81; 1.21)
H/N						
Concordance	0.24 (–0.09; 0.48)	0.07 (–0.11; 0.24)	0.13 (–0.14; 0.39)	0.36 (0.13; 0.57)	0.34 (0.08; 0.59)	0.32 (0.11; 0.53)
Correlation	0.27 (–0.01; 0.51)	0.11 (–0.11; 0.44)	0.13 (–0.15; 0.40)	0.41 (0.15; 0.62)	0.34 (0.06; 0.57)	0.40 (0.14; 0.62)
Intercept	1.34 (–0.10; 2.78)	4.96 (4.04; 5.88)	1.76 (0.48; 3.04)	2.56 (1.25; 3.87)	0.08 (–1.48; 1.63)	–2.99 (–5.23; –0.7)
Slope	1.01 (0.73; 1.29)	0.46 (0.32; 0.59)	0.81 (0.58; 1.00)	0.79 (0.58; 1.01)	0.92 (0.67; 1.16)	1.17 (0.86; 1.47)
Shimmer						
Concordance	0.06 (–0.12; 0.23)	0.02 (–0.03; 0.08)	0.01 (–0.08; 0.09)	0.15 (0.003; 0.29)	0.27 (0.07; 0.47)	0.32 (0.08; 0.55)
Correlation	0.09 (–0.20; 0.36)	0.10 (–0.18; 0.37)	0.17 (–0.12; 0.43)	0.30 (0.02; 0.54)	0.37 (0.11; 0.59)	0.36 (0.09; 0.58)
Intercept	–20.01 (–30.3; –9.6)	–29.88 (–46.9; –12.8)	–201.9 (–293.1; –10.8)	–2.96 (7.54; 1.62)	–1.68 (–4.83; 1.5)	–0.33 (–2.7; 2.1)
Slope	14.73 (10.5; 18.9)	24.34 (17.4; 31.3)	129.28 (92.1; 166.4)	3.32 (2.34; 4.11)	2.26 (1.66; 2.86)	0.78 (0.57; 0.99)

VP, vowel production; *SS,* spontaneous speech; *OR,* oral reading; *PS,* song; *Fo,* fundamental frequency; *H/N,* harmonics-to-noise ratio
( ), confidence interval 95%

Results

The results of fundamental frequency, jitter, shimmer and harmonics-to-noise ratio in the four acoustic situations studied are shown in Table 1. Although they have been previously reported, they are the basis of our analysis [12].

Table 2 shows the results of the concordance analysis for each of the four indicators in acoustic analysis in the four experimental situations. The results show that there was no concordance between indicators with the exception of fundamental frequency between the oral reading and spontaneous speech, where the concordance and correlation coefficients are higher than 0.80.

The correlation study in the different acoustic situations is shown in Table 3. In sustained vowel production, spontaneous speech and song there was a positive correlation between fundamental frequency and jitter. In oral reading, spontaneous speech and song there was correlation between fundamental frequency and jitter, and between jitter and shimmer; nevertheless the values of correlation coefficients did not surpass 0.65.

The concordances and correlation between the 16 indicators did not show evidence that allows selection of one subgroup to discriminate the irradiated group. Thus, those indicators that had mean values with statistical differences in the irradiated and the control group were used to continue the present study.

The comparison between the values of fundamental frequency, jitter, shimmer and harmonics-to-noise ratio in the four acoustic situations studied is shown in Table 4. In all cases the mean values were higher in the irradiated group; nevertheless, statistical significance was found for fundamental frequency in spontaneous speech, for jitter in all the acoustic situations studied and for shimmer in oral reading and song.

Analysis of the ROC curves was performed to find a value to correctly separate voices between irradiated pa-

Table 3 Correlation study

	VP			OR			SS			PS		
	Fo	Jitter	Shimmer	Fo	Jitter	Shimmer	Fo	Jitter	Shimmer	Fo	Jitter	Shimmer
Jitter	**0.52****			0.24			**0.39****			**0.32***		
Shimmer	0.24	0.42		**0.65****	0.13		**0.51****	0.19		**0.34***	–0.9	
H/N	0.18	0.23	0.32	–0.14	**0.58****	–0.11	–0.15	0.38**	–0.12	0.03	**0.54****	0.02

VP, vowel production; *SS,* spontaneous speech; *OR,* oral reading; *PS,* song; *Fo,* fundamental frequency; *H/N,* harmonics-to-noise ratio
*p-value<0.05; ***p*-value<0.01

Table 4 Comparison between irradiated and non-irradiated

	Student's t	*p*-value	Difference mean	Confidence interval	
				Lower limit	Upper limit
VP					
Fo	2.51	**0.015**	32.67	6.51	58.8
Jitter	2.94	**0.007**	2.00	0.60	3.39
Shimmer	1.63	0.118	1.02	–0.27	2.32
H/N	0.71	0.483	0.57	–1.07	2.22
OR					
Fo	1.493	0.142	11.15	–3.87	26.17
Jitter	4.269	**<0.001**	1.49	0.767	2.21
Shimmer	0.508	0.614	0.52	–1.53	2.56
H/N	3.31	**0.003**	2.38	0.87	3.89
SS					
Fo	2.52	**0.015**	18.09	3.66	32.52
Jitter	6.29	**<0.001**	1.70	1.13	**2.27**
Shimmer	1.21	0.232	1.87	–1.23	4.97
H/N	1.89	0.070	1.46	–0.13	3.04
PS					
Fo	1.41	0.166	13.02	–5.58	31.62
Jitter	4.43	**<0.001**	1.44	0.75	2.12
Shimmer	0.77	0.445	1.09	–1.76	3.94
H/N	2.39	**0.025**	2.00	0.28	3.73

VP, vowel production; *OR,* oral reading; *SS,* spontaneous speech; *PS,* song; *Fo,* fundamental frequency; *H/N,* harmonics-to-noise ratio

tients and the control group. In Table 5 the area under the curve and the point of cut-off that maximises the values of sensitivity and specificity to classify irradiated patients are shown for each parameter.

The logistic regression models performed to find the combination of indicators that maximise the classification between the irradiated and the control group show that using only jitter in spontaneous speech 94% patients are correctly classified. The ROC curve for jitter in spontaneous speech is shown in Fig. 1.

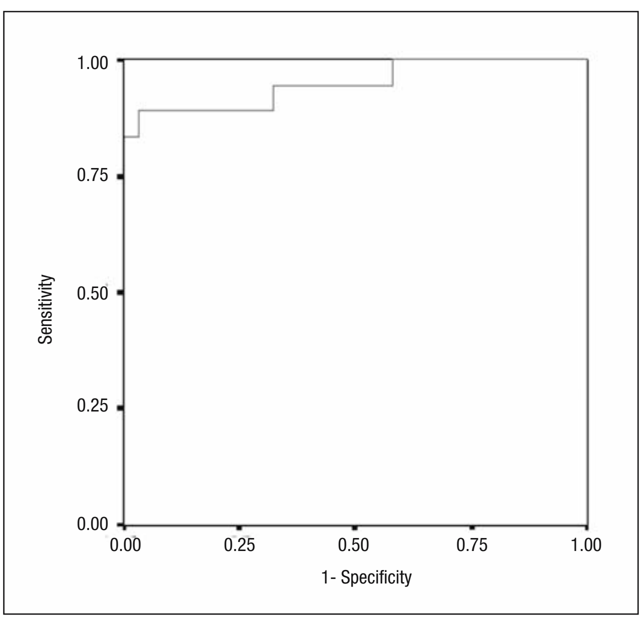

Fig. 1 ROC curve of jitter in spontaneous speech

Discussion

Voice after radiotherapy for early vocal cord carcinoma normally improves and the result is a good useful voice for daily use. Although the voice is considered as normal or almost normal by the patients, it is obvious that several changes in voice are produced which are reflected by GRBAS scores, different scales of voice reported in the literature, acoustic analysis, and videostroboscopic and aerodynamic studies. Difficulty in singing or shouting, fatigue of the voice with much usage, reduced loudness and hoarse quality are referred to by patients. Changes in the larynx after irradiation that explain these problems in voice are strain in vocal cords, stiff mucosa wave dynamics, hyperventricule fold activity, chronic inflammation, radiation fibrosis with consequent inelasticity and glottal incompetence. Moreover, radiation-related complications such as synechia of anterior commisure, false vocal cord voice and hypomobility of vocal cords will cause problems in voice. Nevertheless, more than 80% of the irradiated patients are considered in different studies as having a normal voice [5, 9, 10, 12, 31–36].

Objective acoustic studies in irradiated voice have been done in few patients. All but two have been performed in sustained vowel production [7, 12]. Variations in fundamental frequency, jitter, shimmer and harmonics-to-noise ratio in irradiated patients for early vocal cord carcinoma are re-

Table 5 ROC curve results

		ROC area	Cut-off point	Sensitivity (%)	Specificity (%)
VP	Fo	0.68 (0.52; 0.85)	161	67	71
	Jitter	0.78 (0.63;0.82)	1.73	67	78
OR	Jitter	0.93 (0.85; 1.00)	1.18	100	75
	H/N	0.74 (0.59; 0.89)	6.13	50	78
SP	Jitter	0.95 (0.87; 1.00)	2.02	89	97
PS	Jitter	0.86 (0.75; 0.98)	1.20	77	78
	H/N	0.68 (0.52; 0.86)	5.28	61	72

VP, vowel production; *OR,* oral reading; *SP,* spontaneous speech; *PS,* song; *Fo,* fundamental frequency; *H/N,* harmonics-to-noise ratio
( ), confidence interval 95%

ferred to in acoustic voice analysis studies; but there are differences between the alteration of these indicators according to different authors. Fundamental frequency increases, is normal or diminishes. Jitter and shimmer increase or are normal and a diminution of harmonics-to-noise ratio values is frequently reported. Thus, a wide variation in results can be found [1, 3, 4, 6–8, 11–14, 16]. McGuirt et al. [7] found similar values in the control group in vowel production and an increase in jitter only when the acoustic analysis was performed on spontaneous speech. In a previous study, we found a significant increase of fundamental frequency and jitter in all the acoustic situations studied; acoustic parameters were worse in the vowels, which is a stressful situation not usual in daily speech [12]. The present study was performed with the aim of detecting which parameters and phonetic situations best reflect the radiation damage in T1 vocal cord carcinoma in a Spanish population.

Sustained vowel seems more characteristic of singing rather than speaking. Thus, only examining the vowels might not reflect the real situation of vocal cords in irradiated patients, where combined phonetics shows more complex changes in the physiology of the larynx. Although in a population without specific education in vocal technique, prolonged vowel production seems to be produced comfortably, it is a situation that causes a regularly maintained tension in the vocal muscle and increase in subglottic pressure. The apparent preference for sustained vowels in the different studies may have several explanations. The production of sustained vowels is more easily controlled, stable and standardised than the production in running speech in which articulatory features and dialect influences may vary from speaker to speaker. Supraglottal anatomy and physiology participate in the phonatory process and contribute to contextual speech efforts; thus if there are underlying larynx problems, they will be reflected in the acoustic analysis. Nevertheless, several authors state that although running speech has more disturbances due to articulatory aspects, sustained vowel production is unnatural and its study questionable. A higher fundamental frequency in vowels than in reading or spontaneous speech has been described. A higher variability of pitch has also been reported in vowels, which may have an impact on the results of the rest of the acoustic parameters and, as a consequence, it is suggested that jitter should be interpreted with caution in vowels. Fundamental frequency in spontaneous speech and reading may be more representative of the individual habitual pitch [10, 19, 37–39].

In the present series, the lack of correlation and concordance between acoustic parameters and acoustic situations is probably due to the wide heterogeneity of values in the irradiated group. Sustained vowel production and song are not usual phonetic situations in daily speech and are more stressful than oral reading and spontaneous speech. Variations between people in vocal cord tension when they sing or perform sustained vowel production might be important, and moreover, there are people who are not in the habit of singing. Thus, there can be a wide dispersion between different acoustic parameters that makes it difficult to find significant results between the irradiated and the control group. In the case of fundamental frequency, shimmer and harmonics-to-noise ratio there was also a wide dispersion in values in both studied groups.

In the present study fundamental frequency increased significantly in vowels and spontaneous speech, but jitter increased in all the acoustic situations in the irradiated group. The laryngeal fibrosis caused by irradiation affects the larynx muscles, vocal muscle and vocal cord cover and thus fibrosis means rigidity of these structures. In fact, after radiotherapy for early vocal cord carcinoma most of the patients developed an increase in strain of vocal cords, which is within normal limits in 89% of the cases [3, 40]. The result is a diminution in the capacity of elongation and widening of vocal cords and as a consequence in the capacity to modify the vibratile vocal mass necessary to perform the quick changes needed in spontaneous speech. Thus, a greater deviation in fundamental frequency and an increase in jitter percentage as a consequence should appear [20, 21]. Jitter reflects the difficulty in obtaining quick variations of tone and a certain loss of the capacity of the vocal movements needed to adapt both quickly and precisely in daily spontaneous speech.

When the ROC curves were studied we found that jitter in spontaneous speech is the best discriminator in irradiated patients. A cut-off of 2.02 with a sensitivity of 89% and a specificity of 97% was found. Oral reading is an acoustic situation that can be similar to spontaneous speech; in this case values of 100% for sensitivity and 75% for specificity were seen. The low specificity found could perhaps be explained by age-related difficulties in oral reading. The study of jitter in spontaneous speech was the main discriminator of changes of voice secondary to irradiation in early vocal cord carcinoma. Thus, acoustic studies of voice after radiotherapy should consider this acoustic parameter. Moreover, voice assessment shows better results after radiotherapy compared with laser cordectomy and, as a consequence, voice outcome should be carefully considered between both treatments [41]. The study of the different parameters between laser cordectomy and radiotherapy should be considered.

Conclusions

Considering these data and the results of the present study we believe that jitter obtained in spontaneous speech was the main indicator of larynx damage after irradiation for Tis-T1 vocal cord carcinoma. More studies on jitter are needed to determine their usefulness in quality of voice after larynx radiotherapy. Acoustic analysis on more advanced stages of larynx cancer are also needed to establish what happens to the acoustic parameters when the given radiotherapy dose and size of the fields are increased. Although quality of voice after radiotherapy for early vocal cord carcinoma is quite good, we consider that videostroboscopic and acoustic voice analysis are necessary to obtain more information on possible treatment-related problems. In this way, rehabilitation vocal techniques can be used in those patients with problems. Few patients with relevant problems after radiotherapy for early vocal cord carcinoma need vocal rehabilitation. However, as life expectancy has increased and we live in the era of communications, quality of voice is an asset that should be maintained to the maximum.

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