Effect of vocal cord polyp on monophthongs with Mandarin tones[1]

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Abstract—**This paper investigates effect of unilateral vocal cord polyp on different monophthongs ([-ʌ], [-ɤ], [-o], [-u]) with Mandarin tones. First, acoustically, Praat was used to extract F0 contour in Mandarin tones to analyze how vocal cord polyp affects F0 contour of different monophthongs with Mandarin tones. Second, perceptually, identification test was used to analyze how vocal cord polyp influences identification rate of different monophthongs with Mandarin tones. In this research, the main findings are as follows: first, vocal cord polyp does not affect tone pitch, F0 contour and identification rate of [-o] with Tone 1. Second, vocal cord polyp has an effect on tone pitch of [-ʌ] with Tone 2 and Tone 3, [-ɤ] with Tone 2 and Tone 4, [-u] with Tone 4 and [-o] with Tone 4. Third, vocal cord polyp influences F0 contour of [-ʌ] with Tone 1 and Tone 4, and [-ɤ] with Tone 1 significantly. Fourth, vocal cord polyp has an effect on tone pitch and significantly affects F0 contour of [-ɤ] with Tone 3, [-u] with Tone 3 and [-o] with Tone 2 and Tone 3. Fifth, vocal cord polyp affects tone pitch and has a significant effect on identification rate of [-u] with Tone 2. Sixth, vocal cord polyp influences tone pitch, and significantly affects F0 contour and identification rate of [-u] with Tone 1. It is concluded that although vocal cord polyp has an effect on tone pitch and F0 contour of monophthongs with Mandarin tones, and has little influence on intelligibility of Mandarin monophthongs except of [-u] with Tone 1 and Tone 2.**

Keywords- acoustics; perception; vocal cord polyp;monophthongs; Mandarin tones

I. INTRODUCTION

Vocal cord polyp [1] is a benign proliferative lesion in superficial layer (of the lamina propria of) of the vocal cord. Its evaluation [1] contains subject auditory evaluation, objective tests and self-evaluation by patient. The research of vocal cord polyp is mainly on medical science. Domestically, analysis of vocal cord polyp was usually based on the recording of sustained monophthongs (articulated by patients), which were [e] [2], [æ] [3], [a], [i] [4], /o:/, /u:/ and /ü:/ [5] with a duration of three seconds generally. Chinese is a tone language. There are few research results on monophthongs with Mandarin tones with vocal cord polyp.

Phonetics contains three branches, i.e., articulatory phonetics, acoustic phonetics, and auditory phonetics. Here, we focus on acoustic and auditory phonetics. Provided that there is a polyp on vocal cord(s), speech sound must be affected acoustically, and may or may not be influenced perceptually. In our preliminary work, *Effect of vocal cord polyp on Mandarin tones recognition by native Chinese speakers* [6], before and after the surgeries, acoustic results showed that vocal cord polyp affects Tone 1 and Tone 3 in F0 contour. Perceptual results were that vocal cord polyp has an effect on Tone 1 and Tone 2 in identification rate.

There has a question in the above research which is why the vocal cord polyp significantly affects Tone 1 in F0 contour and identification rate before and after the surgeries. In Mandarin, the speech sounds we perceive usually contains three components which are consonants, vowels and lexical tones. And the stimuli in perception experiment are Chinese characters in CV syllables with plosives ([p], [p^h], [t], [t^h], [k], [k^h]) as their consonants and monophthongs ([-ʌ], [-ɤ], [-o], [-u]) as their vowels. The previous research was analyzed from the perspective of Mandarin tone category. Then, we hypothesized that before and after the surgeries of vocal cord polyp the significant differences of Tone 1 in F0 contour and identification rate might have distinctive performances in monophthongs with Mandarin tones. And we need to confirm which monophthong with Tone 1 has the significant difference in F0 contour and identification rate.

This paper investigates effect of unilateral vocal cord polyp on different monophthongs with Mandarin tones, and finds out before and after the surgeries whether all monophthongs with Tone 1 or one of the monophthongs with Tone 1, in F0 contour and identification rate, is significantly affected by vocal cord polyp.

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II. EXPERIMENT

A. Devices

A laptop (ThinkPad E570c), an external sound card (SBX Sound 5.1 Pro), an audio mixing console (XENYX 302USB), a microphone (SHURE SM58S), and an EGG (ElectroGlottograph 7050A) were used in recording. The recording software was Adobe Audition 3.0 with 16 bits quantization using a 22050 Hz sampling rate. The dual-channel recording was used with the left channel as EGG signal and the right channel as speech signal.

B. Procedure

Procedure in this research mainly contained two sections. The first step is acoustic analysis. Before and after the surgeries of vocal cord polyp, a patient was recruited to record his reading of Chinese characters in CV syllables. And F0 extracted by Praat was used to analyzed the effect of vocal cord polyp on monophthongs with Mandarin tones. The second step is perception test. 20 Chinese participants were recruited to listen to stimuli before and after the surgeries of vocal cord polyp randomly. And perceptual results were analyzed to find out the impact of vocal cord polyp on monophthongs with Mandarin tones.

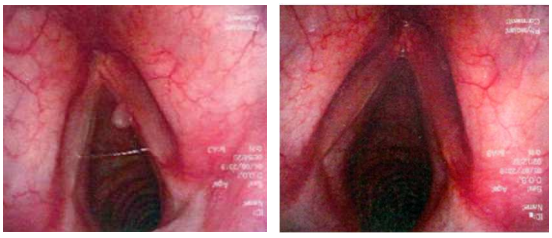
C. Participants

A 38-year-old male patient, who had vocal cord polyp, is from Macau, China, and proficient in Mandarin and Cantonese. And the recordings before and after the surgeries of vocal cord polyp were in a quiet room.

20 Chinese participants, whose ages are between 25 and 39, attended the identification test. And there were 10 male and 10 female participants. They all could speak Mandarin fluently and did not have hearing impairment. And they were paid for their work.

D. The images of vocal cord polyp

The images of vocal cord polyp before and after the surgeries which were from the patient's diagnosis report by Beijing Haidian Hospital. They were provided by the patient himself. See below.



(a) (b)

Figure 1. Images of vocal cord polyp before (a) and after (b) the surgeries

In Figure 1, the original images were reversed. And it was a unilateral polyp. It could be seen that before the surgery (see Figure 1(a)) the left vocal cord was smooth, while there was a small polyp in the front part of right vocal cord, causing a gap in vibration. After the surgery (see Figure 1(b)), the left and right vocal cords were smooth.

E. Reading list

The reading list for acoustic analysis and identification test were chosen from Contemporary Chinese [7]. And they are Chinese characters in CV syllables with plosive ([p], [p^h], [t], [t^h], [k], [k^h]) as their initial consonants and [-ɑ], [-ɤ], [-o] and [-u] as their following vowels. Here, [-i] is excluded because several Chinese characters with [-i] as their vowels were forgotten to list in recording. See below.

TABLE I. READING LIST FOR ACOUSTIC ANALYSIS AND IDENTIFICATION TEST

	Tone Types	**Chinese Characters in CV Syllable**
Tone 1	high level	bɑ, dɑ, gɑ, bo, po, ge, ke, bu, pu, du, tu ([pɑ], [tɑ], [kɑ], [po], [p^ho], [kɤ], [k^hɤ], [pu], [p^hu], [tu], [t^hu])
Tone 2	high rising	
Tone 3	low falling rising	
Tone 4	high falling	

In the above table, the tone pitches from Tone 1 to Tone 4 are 55, 35, 214, and 51 respectively. 1 is the lowest pitch, and 5 the highest. Chinese characters are in the form of *pinyin*, and their corresponding phonetic transcription are in the brackets.

The Chinese characters in TABLE I were read twice. Totally, there were 176 valid samples before and after the surgeries of vocal cord polyp. And the samples had been segmented in Adobe Audition 3.0. The first recording of each character in TABLE I was used in acoustic analysis and identification test. In totality, there were 88 samples before and after the surgeries of vocal cord polyp. We had recorded these in dual-channel with the left channel as EGG signal and the right channel as speech signal. And 88 samples in speech signal were used in acoustic analysis and identification test.

F. Extraction of acoustic parameters

In acoustic analysis Praat was used to extract F0 in normalization of which 20 points from initial point to final point were evenly extracted. The pitch range (Hz) is from 75 Hz to 500 Hz in pitch settings. The initial point we selected to measure depended on pulses shown in Praat. Normally, we chose the second pulse [8]. The final point was before the end of intensity contour. And in measuring, offset-section and onset-section in F0 were not in the range of extraction.

Then F0 would be converted to semi-tone [9] to transcribe in tone pitch. And the formula of semi-tone is seen below.

$$Semi - tone = 12 * \log 2 \left(\frac{f1}{f2}\right) \quad (1)$$

where f1 is F0 of measured points, and f2 is the lowest F0.

G. Perceptual test

The stimuli were not changed acoustically. The perception experiment in E-Prime 1.1 was identification test programmed by Linguistic Lab at Department of Chinese Language and Literature, Peking University. 20 participants were required to wear headphones to listen to 88 stimuli which were played twice randomly in E-Prime 1.1. Each time a stimulus was played, then an option interface appeared to require the participant to identify the stimulus he / she heard as one of the four Mandarin tones

within 5 seconds. Participants chose "←" (the left arrow), "→" (the right arrow), "↑" (the upper arrow), and "↓" (the lower arrow), which were shown on the screen, in the keyboard as Tone 1, Tone 2, Tone 3 and Tone 4 respectively. The test, which had exercise section before formal test, was conducted in a laptop in a quiet room. And each test lasted approximately 15 minutes.

H. Data analysis

Excel was used to draw two-dimensional line chart for acoustic data. In acoustic analysis, the Y-axis is semitone converted from F0, and the X-axis is the duration of tone. Then in a chart, the pitch and duration of tones could be seen clearly. [10]

In SPSS 19, paired samples T test would be used to find out whether F0 and identification rate before and after the surgeries of vocal cord polyp are significant or not. F0 of 20 points, and identification rate of each participant would be the data in T test.

III. Acoustic Analysis

A. Analysis of [-ʌ]

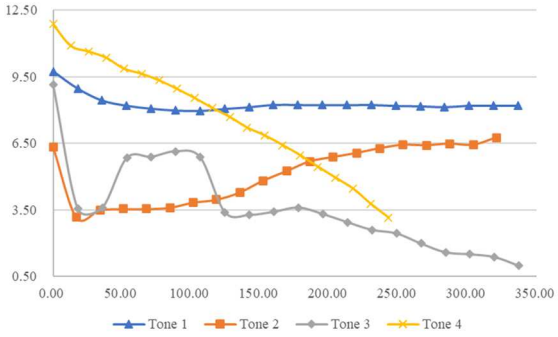


Figure 2. Semi-tone and duration of [-ʌ] before the surgery

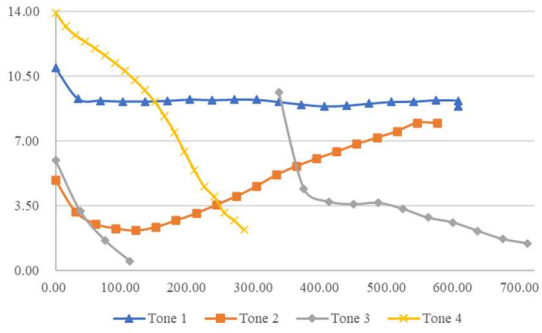


Figure 3. Semi-tone and duration of [-ʌ] after the surgery

It could be seen from Fig. 2 and Fig. 3 that in terms of duration, four tones after the surgery are longer than those before the surgery. Tone 1, Tone 2 and Tone 3 before the surgery are approximately half of those after the surgery. In respect of pitch, before the surgery, the range is between 0.5 and 12.5 with the interval of 3. After the surgery, the range is between 0.5 and 14 with the interval of 3.5. [-ʌ] with Tone 1 before and after the surgeries are level tones, transcribed as 44. [-ʌ] with Tone 2 before and after the surgeries are rising, and the former could be transcribed as 323 and the latter as 23. Their differences are that before the surgery the first two points of [-ʌ] with Tone 2 declines dramatically from 6.5 to 3.5, then rises steadily, while after the surgery it descends gradually then ascends notably. [-ʌ] with Tone 3 before and after the surgeries differ greatly. Before the surgery, Tone 3 is in a downward trend generally. The first two points drop dramatically from 9.5 to 3.5. There is an arch contour (from the third point to the eighth point) in the front section. And from eighth point to eleventh point it is level and then it is falling. [-ʌ] with Tone 3 before the surgery could be transcribed as 231. After the surgery, [-ʌ] with Tone 3, with breakpoints in the middle part, is low falling. It could be transcribed as 212. [-ʌ] with Tone 3 is creaky voice so five points (from fifth point to ninth point) could not be extracted. And the tenth point could be seen as a outlier. [-ʌ] before and after the surgeries are high falling, both transcribed as 52. And their differences are that the former falls more gradually than the latter.

B. Analysis of [-ɤ]

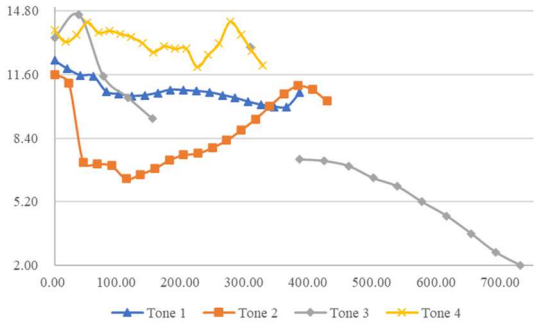


Figure 4. Semi-tone and duration of [-ɤ] before the surgery

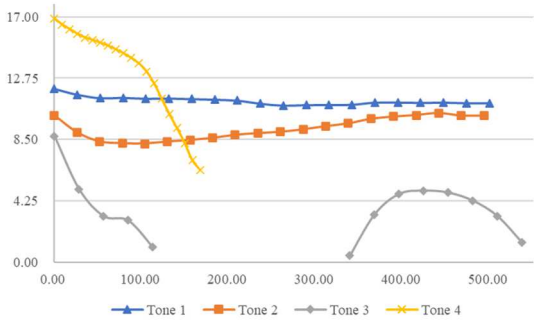


Figure 5. Semi-tone and duration of [-ɤ] after the surgery

It could be seen from Fig. 4 and Fig. 5 that in terms of duration, Tone 1 and Tone 2 before the surgery are shorter than those after the surgery. Tone 3 and Tone 4 before the surgery are longer than those after the surgery. In respect of pitch, before the surgery, the range is between 2 and 14.8 with the interval of 3.2. After the surgery, the range is between 0.5 and 17 with the interval of 4.25. [-ɤ] with Tone 1 before and after the surgeries are level tone, transcribed as 44. However, Tone 1 before the surgery falls a little bit. [-ɤ] with Tone 2 before and after the surgeries differ greatly, and the former is transcribed as 424 and the latter is 33. Before the surgery Tone 2 falls and then rises, while after the surgery it still falls then rises a little bit but within the interval (of 3.2). [-ɤ] with Tone 3 before and after the surgeries differ greatly. Before the surgery, Tone 3 falls dramatically with creaky voice (from sixth point to tenth point),

transcribed as 51. After the surgery, [-ɤ] with Tone 3, with breakpoints in the middle part, is mid falling and there is an arch contour in the final section. It could be transcribed as 312. [-ɤ] with Tone 3 is creaky voice so seven points (from sixth point to twelfth point) could not be extracted. [-ɤ] with Tone 4 before and after the surgeries have a great difference. Before the surgery, it falls with fluctuation in the middle part, transcribed as 54. After the surgery, it is falling gradually and then abruptly, transcribed as 52.

C. Analysis of [-u]

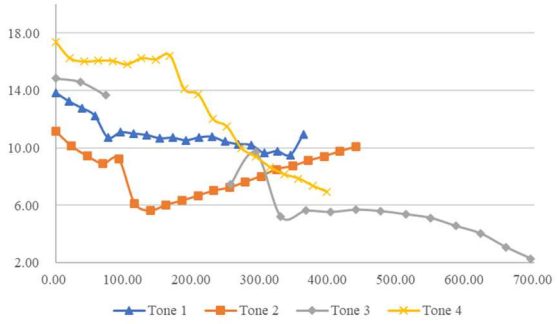


Figure 6. Semi-tone and duration of [-u] before the surgery

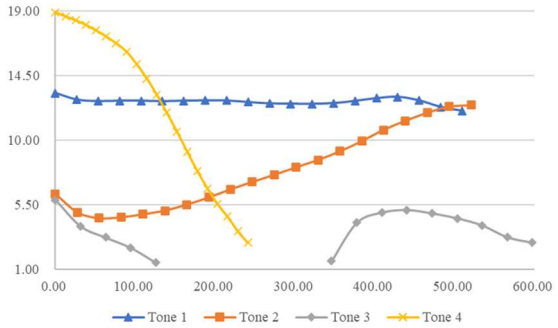


Figure 7. Semi-tone and duration of [-u] after the surgery

It could be seen from Fig. 6 and Fig. 7 that in terms of duration Tone 1 and Tone 2 before the surgery are shorter than those after the surgery. Tone 3 before the surgery is longer than that after the surgery. Tone 4 after the surgery is approximately half of that before the surgery. In respect of pitch, before the surgery, the range is between 2 and 18 with the interval of 4. After the surgery, the range is between 1 and 19 with the interval of 4.5. [-u] with Tone 1 before and after the surgeries differ dramatically. Before the surgery, it is falling with an abrupt drop in the front part, transcribed as 43; after the surgery, it is high level, transcribed as 44. [-u] with Tone 2 before and after the surgeries differ notably. Before the surgery, it falls and then rises with an obvious inflection point, transcribed as 323. After the surgery, it is rising, transcribed as 24. [-u] with Tone 3 before and after the surgeries differ greatly. Before the surgery, Tone 3 is a falling tone, transcribed as 421. After the surgery, [-u] with Tone 3, with breakpoints in seven points, is low falling. And it then rises and falls in the final section. It could be transcribed as 212. [-u] with Tone 3 is creaky voice so five points (from sixth point to eleventh point) could not be extracted. [-u] before and after the surgeries are high falling, and the former could be transcribed as 52 and the latter as 51. And their differences are that the former is level and then falling with a noticeable inflection point in ninth point, and the latter falls gradually.

D. Analysis of [-o]

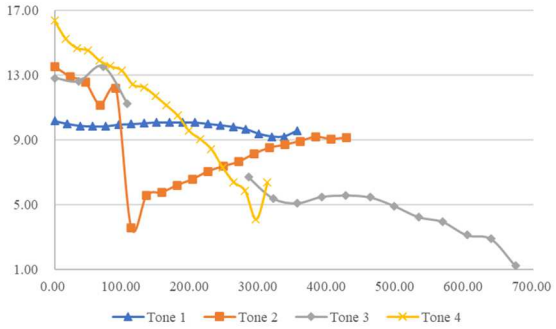


Figure 8. Semi-tone and duration of [-o] after the surgery

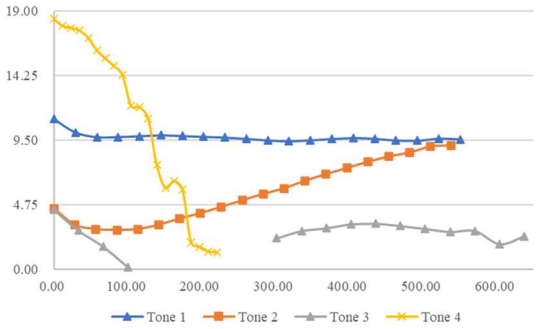


Figure 9. Semi-tone and duration of [-o] after the surgery

It could be seen from Fig. 8 and Fig. 9 that in terms of duration, four tones before the surgery are longer than those after the surgery. In respect of pitch, before the surgery, the range is between 1 and 17 with the interval of 4; after the surgery, the range is between 0.16 and 19 with the interval of 4.75. [-o] with Tone 1 before and after the surgeries are level tone, transcribed as 33. [-o] with Tone 2 before and after the surgeries differ obviously. Before the surgery, it falls and then rises with an obvious inflection point, transcribed as 423. After the surgery, it is mid rising, transcribed as 23. [-o] with Tone 3 before and after the surgeries differ greatly. Before the surgery, Tone 3 is falling, transcribed as 421. After the surgery, it is low falling. And then it rises and falls with breakpoints in the front part, transcribed as 212. [-o] with Tone 3 is creaky voice so five points (from fifth point to ninth point) could not be extracted. [-o] before and after the surgeries are high falling, and the former could be transcribed as 52 and the latter as 51. And their differences are that the former falls gradually and the latter descends abruptly.

E. Summary

Based on the analysis mentioned above, we would like to summarize monophthongs with Mandarin tones in terms of tone pitch and F0 contour.

TABLE II. TONE PITCH OF MONOPHTHONGS WITH MANDARIN TONES BEFORE AND AFTER THE SURGERIES

	Normal voice	**[-ʌ]**		**[-ɤ]**		**[-u]**		**[-o]**	
		B	***A***	***B***	***A***	***B***	***A***	***B***	***A***
T1	55	44	44	44	44	43	44	33	33
T2	35	323	23	424	33	323	24	423	23

T3	214	231	212	51	312	421	212	421	212
T4	51	52	52	54	52	52	51	52	51

In TABLE II, *B* is before the surgery, and *A* is after the surgery. T1, T2, T3 and T4 are Tone 1, Tone 2, Tone 3 and Tone 4 respectively.

In terms of tone pitch, before and after the surgeries, [-A] with Tone 1 and Tone 4, [-ɤ] with Tone 1, and [-o] with Tone 1 are similar. And the rest of monophthongs with Mandarin tones differ. Generally, before and after the surgeries of vocal cord polyp, Tone 2 and Tone 3 differ obviously. Tone pitches after the surgery in TABLE II reflect individual characteristics, which are different from those of standard tone pitch. Before and after the surgeries, in respect of tone pitch, vocal cord polyp does not have an effect on [-A] with Tone 1, and Tone 4, [-ɤ] with Tone 1, and [-o] with Tone 1. It affects [-A] with Tone 2 and Tone 3, [-ɤ] with Tone 2, Tone 3 and Tone 4, [-u] with Tone 1, Tone 2, Tone 3 and Tone 4, [-o] with Tone 2, Tone 3 and Tone 4.

From Fig. 2 to Fig. 9, F0 contour could be discussed as follows. In terms of F0 contour before and after the surgeries of vocal cord polyp, we analyzed F0 in SPSS 19. And paired samples T test showed [-A] with Tone 1 (t(19)=-17.389, p=0.000) and Tone 4 (t(19)=-3.467, p=0.003), [-ɤ] with Tone 1 (t(19)=-4.182, p=0.001) and Tone 3 (t(12)=3.366, p=0.006), [-u] with Tone 1 (t(19)=-6.925, p=0.000) and Tone 3 (t(11)=2.256, p=0.045), [-o] with Tone 2 (t(19)=3.593, p=0.002) and Tone 3 (t(14)=3.295, p=0.005) have significant differences. And [-A] with Tone 2 (t(19)=1.09, p=0.289) and Tone 3 (t(14)=-0.275, p=0.787), [-ɤ] with Tone 2 (t(19)=-1.994, p=0.061) and Tone 4 (t(19)=-0.168, p=0.869), [-u] with Tone 2 (t(19)=-0.361, p=0.722) and Tone 4 (t(19)=0.001, p=0.999), [-o] with Tone 1 (t(19)=1.271, p=0.219) and Tone 4 (t(19)=-1.174, p=0.255) do not differ significantly.

IV. Perceptual Analysis

TABLE III. Identification rate of monophthongs in Mandarin tones before and after the surgeries

		T1	**T2**	**T3**	**T4**
[-A]	B	96.67%	91.67%	92.50%	96.67%
	A	91.67%	95.83%	97.50%	94.17%
[-ɤ]	B	96.25%	95.00%	100.00%	87.50%
	A	95.00%	98.75%	98.75%	93.75%
[-u]	B	80.63%	86.25%	95.63%	95.00%
	A	95.63%	95.00%	96.25%	95.00%
[-o]	B	90.00%	96.25%	95.00%	93.75%
	A	92.50%	97.50%	95.00%	96.25%

In TABLE III, *B* is before the surgery, and *A* is after the surgery. T1, T2, T3 and T4 are Tone 1, Tone 2, Tone 3 and Tone 4 respectively.

In the above table, it could be seen that, except that of [-ɤ] with Tone 4 before the surgery and [-u] with Tone 1 and Tone 2 before the surgery, the identification rates of the other monophthongs are above 90%. And the identification rate of [-ɤ] with Tone 3 before the surgery is the highest, while that of [-u] with Tone 1 before the surgery is the lowest. In mean value of identification rate of four tones, [-A] before the surgery is 94.38%, and after the surgery 94.79%; [-ɤ] before the surgery is 94.69%, and after the surgery 96.56%; [-u] before the surgery is 89.38%, and after the surgery 95.47%; [-o] before the surgery is 93.75%, and after the surgery 95.31%. Before and after the surgeries of vocal cord polyp, [-A] has no difference in mean value of identification rate, while [-u] differs a lot.

From the perspective of difference before and after the surgeries of vocal cord polyp, [-u] with Tone 1 differs greatly, [-o] with Tone 3 and [-u] with Tone 4 have no difference.

And we analyzed identification rate of each participant before and after the surgeries of vocal cord polyp in SPSS 19, and paired samples T test showed that [-A] with Tone 1 (t(19)=1.674, p=0.11), [-A] with Tone 2 (t(19)=-2.032, p=0.056), [-A] with Tone 3 (t(19)=-1.552, p=0.137), [-A] with Tone 4 (t(19)=1.371, p=0.186) , [-ɤ] with Tone 1 (t(19)=0.438, p=0.666), [-ɤ] with Tone 2 (t(19)=-1.831, p=0.083), [-ɤ] with Tone 3 (t(19)=1, p=0.33), [-ɤ] with Tone 4 (t(19)=-1.228, p=0.234), [-o] with Tone 1 (t(19)=-1, p=0.33), [-ɤ] with Tone 2 (t(19)=-0.567, p=0.577), [-ɤ] with Tone 3 (t(19)=-0.438, p=0.666), [-o] with Tone 4 (t(19)=-1, p=0.33), [-u] with Tone 3 (t(19)=-0.37, p=0.716), and [-u] with Tone 4 (t(19)=0, p=1) do not differ significantly. While, [-u] with Tone 1 (t(19)=-4.188, p=0.000), and [-u] with Tone 2 (t(19)=-2.774, p=0.012) differ significantly.

In a summary, vocal cord polyp does not have an effect on identification rate of [-A, -ɤ, -o] with Mandarin tones, and significantly affects [-u] with Tone 1 and Tone 2 but not with Tone 3 and Tone 4.

V. Discussion

The effect of vocal cord polyp on monophthongs with Mandarin tones analyzed above could be classified into two categories. One is that vocal cord polyp has an effect on some aspects of different monophthongs with Mandarin tones, and the other is that vocal cord polyp does not affect some aspects of different monophthongs with Mandarin tones. Here, we mainly discuss that vocal cord polyp has an effect on monophthongs with Mandarin tones.

Acoustically, before and after the surgeries, in terms of tone pitch, vocal cord polyp affects [-A] with Tone 2 and Tone 3, [-ɤ] with Tone 2, Tone 3 and Tone 4, [-u] with Tone 1, Tone 2, Tone 3 and Tone 4, [-o] with Tone 2, Tone 3 and Tone 4. And for F0 contour, vocal cord polyp has an effect on [-A] with Tone 1 and Tone 4, [-ɤ] with Tone 1 and Tone 3, [-u] with Tone 1 and Tone 3, [-o] with Tone 2 and Tone 3 significantly.

Perceptually, vocal cord polyp significantly affects [-u] with Tone 1 and Tone 2 in identification rate before and after the surgeries.

TABLE IV. Statistical significance of monophthongs with Mandarin tones in acoustic and perception

	[-A]		**[-ɤ]**		**[-u]**		**[-o]**	
	Aco	***Per***	***Aco***	***Per***	***Aco***	***Per***	***Aco***	***Per***
Tone 1	√		√		√	√		
Tone 2						√	√	
Tone 3			√		√		√	
Tone 4	√							

In TABLE IV, Aco refers to acoustics, and Per refers to perception. Here, significant differences in acoustics refers to F0 contour.

From the above table, before and after the surgeries, it could be seen that only [-u] with Tone 1 is affected acoustically and perceptually by vocal cord polyp. Vocal cord polyp does not have an effect on [-ᴀ] with Tone 2 and Tone 3, [-ɤ] with Tone 2 and Tone 4, [-u] with Tone 4, and [-o] with Tone 1 and Tone 4 before and after the surgeries acoustically and perceptually. Although [-ᴀ] with Tone 1 and Tone 4, [-ɤ] with Tone 1 and Tone 3, [-u] with Tone 3, and [-o] with Tone 2 and Tone 3 differ significantly in acoustics, and in perception they are not influenced by vocal cord polyp before and after the surgeries.

Normally, Tone 1 in Mandarin is level tone which is not difficult to perceive. But [-u] with Tone 1 before the surgery (See Fig. 6 (a)) is a falling tone, transcribed as 43. Acoustically, it could be seen that its first five points are in a downward trend, and from the sixth point to the sixteenth point it is level. Then the following three points fall a little bit, and the last point rises. In respect of choices by 20 participants, each stimulus was played twice randomly. Then, a stimulus has 40 choices. And [-u] with Tone 1 has four Chinese characters. So, it has 160 choices in totality. In identifying [-u] with Tone 1 before the surgery, there are 5 choices for Tone 2, 6 choices for Tone 3 and 19 choices for Tone 4, except 1 invalid option. That is to say, most of the choices identified as Tone 4 in the case of misjudgment. But, 129 choices were still identified correctly. We reckon that those identified correctly might focused on the steady part (from sixth point to sixteenth point), and those identified incorrectly may concentrated on the front part of the tone.

As for [-u] with Tone 2, there are 4 choices for Tone 1, 13 choices for Tone 3, 2 choices for Tone 4, except 3 invalid options. And 138 choices identified correctly. Among the incorrect choices, thirteen choices are for Tone 3. The inflection point at seventh point in Fig.6 (a) might be the cue for judging as Tone 3.

Statistical difference in F0 contour of [-u] with Tone 1 causes an effect in identification rate significantly. As for identification of [-u] with Tone 2, significant difference in identification rate is not influenced by insignificant difference in F0 contour.

VI. Conclusion

In this research, the main findings are as follows:

First, vocal cord polyp does not affect tone pitch, F0 contour and identification rate of [-o] with Tone 1. Second, vocal cord polyp has an effect on tone pitch of [-ᴀ] with Tone 2 and Tone 3, [-ɤ] with Tone 2 and Tone 4, [-u] with Tone 4 and [-o] with Tone 4. Third, vocal cord polyp influences F0 contour of [-ᴀ] with Tone 1 and Tone 4, and [-ɤ] with Tone 1 significantly. Fourth, vocal cord polyp has an effect on tone pitch and significantly affects F0 contour of [-ɤ] with Tone 3, [-u] with Tone 3 and [-o] with Tone 2 and Tone 3. Fifth, vocal cord polyp affects tone pitch and has a significant effect on identification rate of [-u] with Tone 2. Sixth, vocal cord polyp influences tone pitch, and significantly affects F0 contour and identification rate of [-u] with Tone 1.

It is concluded that although vocal cord polyp has an effect on tone pitch and F0 contour of Mandarin monophthongs, and has little influence on intelligibility of Mandarin monophthongs except of [-u] with Tone 1 and Tone 2.

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