

THE RESPONSE OF FOUR GROUPS OF VOCAL FOLD PARALYSIS TO PERCUTANEOUS NEURO-MUSCULAR ELECTRICAL STIMULATION: A COMPARATIVE STUDY

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ABSTRACT

Objective: To compare the response of four groups of vocal fold paralysis with different etiologies to percutaneous electrical stimulation and at reanalyzing the outcome according to duration of the condition.

Methods: Medical files of 60 patients referred to the Speech Clinic, Royal Rehabilitation Center during the last eight years, complaining of weak breathy voice due to vocal fold paralysis, were reviewed and classified according to etiology, gender, and duration of onset. Patients received daily sessions of electrical stimulation, applied percutaneously, for 2-7 weeks. The initial and follow-up phonation times and perceptual acoustic analyses were tabulated for each patient. A separate 10-point rating scale on the clarity and loudness of the patient's voice was given by the patient, the otorhinolaryngologist, and the speech pathologist, before and after the administration of electrical stimulation. The responses to therapy were statistically analyzed and compared according to etiology and duration of onset.

Results: A paired T-test for both the phonation time and the rating of voice quality, before and after electrical stimulation, showed significant differences ($p < 0.001$) in all four etiologies. Analysis of variance showed that there was no statistical difference according to etiology and, with certain limitation, according to duration of onset of the paralysis.

Conclusion: The outcome and time course of recovery of vocal fold paralysis by implementing electrical stimulation are similar in different etiologies of the paralysis regardless of the duration of the condition.

Key words: Vocal fold paralysis, Electrical stimulation, Loudness, Noise, Phonation time.

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Introduction

Vocal fold paralysis (VFP) is a probable complication following thyroidectomy, neck or chest surgery intended to remove a tumor, penetrating trauma, viral infections, or due to idiopathic etiologies, as well as due to central causes⁽¹⁾. Symptoms range from transient aphonia to breathiness and hoarseness of voice with occasional diplophonia, along with aspiration of liquids. Acoustic signs include a periodicity, limited pitch range, increased noise levels, and limited intensity range^(2,3).

These symptoms may resolve gradually in 40%⁽⁴⁾ to 50%⁽⁵⁾ patients within six months following

thyroidectomy. Surgical procedures to improve vocal fold valving include, among other techniques, nerve anastomosis⁽⁶⁾, Teflon injection⁽⁷⁾, fat injection⁽⁸⁾, and medialization⁽⁹⁻¹¹⁾. These techniques remain an option if symptoms persist and if traditional voice therapy fails to satisfy the patient's needs.

Percutaneous neuromuscular electrical stimulation (ES) was effectively used and became a common practice in the conservative management of VFP in Germany and Russia^(4,12-22). Also, it was used following surgical management of the glottis in patients with bilateral adductor VFP^(18,22) and in the management of functional aphonias and dysphonias⁽¹⁸⁾, and

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hypokinetic dysphonias, including myasthenia's (13,18-21). Comparative studies (20-23) showed that combined ES with voice therapy gave superior results when compared to traditional voice therapy.

Electrical stimulation aid in managing VFP as it promotes nervous recovery, counteracts muscular atrophy, and induces desirable hyperemia. It also stimulates adjacent healthy muscles, including the external strap muscles, and the bilaterally innervated interarytenoid and the cricothyroid muscles to an increased compensatory activity (12,13,16).

The responses of the vocal folds to direct or percutaneous ES can be evaluated via a balloon inserted in the larynx (24-28), by direct visual inspection of a gauge needle inserted through the epiglottis (29,30) or through the vocal fold, (30), by direct laryngoscopy (31) or stroboscopy (13,14,19), using spectrographic analysis (20), using magnifying mirror (13), or by videotaping (32). The technique of ES as a diagnostic and therapeutic tool in VFP was found to be safe (18,29).

The aim of this study was to compare the course of recovery after vocal fold paralysis according to different etiologies and duration of the condition. Recovery was assessed by recording changes in phonation time and vocal quality ratings.

Methods

The medical records of a convenient sample of 60 patients (Appendices 1-4) with dysphonias following vocal fold paralysis and received electrical stimulation at the speech clinic in the Royal Rehabilitation Center during the period 1996 – 2004. Cases of VFP due to central etiologies were excluded from the total pool. The subjects were 33 males (age range 19-69 year; mean 41.4 ± 14.5 years) and 27 females (age range 16-66 years; mean 39.6 ± 13.8 years). The etiology of the unilateral vocal fold paralysis were 21 cases following partial or total thyroidectomy, 16 cases following neck or chest surgery*, 11 cases post viral infections, and 12 cases with idiopathic VFP. The affected side was the right vocal fold in 20 cases, the left vocal fold in 38 cases, and bilateral in two cases. The duration of the paralysis was one month or less in 14 (23.3%) patients, from five weeks to five months in 29 (48.3%) patients, from six to eleven months in 10 (16.7%) patients, and one year or more in 7 (11.7%) patients.

The treatment technique included percutaneous application of triangular faradic modulated current, with around 12 to 24 slow rising surges per minute (13) at 100Hz, with current intensity slightly above the sensation level by the individual patient range (2.6-6.0 milli Amperes (mA); mean (3.8 ± 0.8) and was then increased gradually from session to session according to the patient's adaptation range (4.0-9.0 mA); mean=(5.7 ±

1.1 mA). Neuroton 726s {Siemens} muscle stimulating unit was used in all patients. Depending on the case, a total of 14-52 sessions were given, initially on daily basis and followed by differently spaced sessions according to the individual need but with a minimum of 3 sessions per week. Inpatients and some outpatients received ES twice per day. In each session, three 50 trains of pulses applied, timed with prolonged phonations, alternating from the effected side to the intact side and back to the effected side. The maximum duration of each session was 15 minutes. ES was interrupted whenever the signs of discomfort appeared on the patient or when his voice became weaker. Relatively severe cases received a warming stage at the beginning of initial sessions by applying a 5 minute of 'rectangular' current aiming at increasing the blood flow due to its warming effect (13) and they were asked to tilt their heads downward a little during the ES sessions. Before the application of ES, each patient received full explanation about the technique that included demonstration of the technique in front of the patient. Some patients and few normal subjects were hooked to a pulse meter and their pulse rates were recorded before and during ES. None of these showed remarkable increases in the pulse rate, and only one case showed negligible decrease.

Voice Therapy

When patients achieved reasonable improvement in vocal quality, they were instructed to do phonation exercises (15) at home, five sessions per day, around one to three minutes each according to the individual's capacity. They were asked to keep daily records of their phonation time in seconds. Every patient was counseled to avoid vocal strain or abuse in order to prevent unnecessary muscular tension. Voice therapy was initiated at the appropriate time in order to increase the pitch and the respiratory support. This was timed with instructing the patients to raise the pitch of their voice during ES application, and then, to fluctuate their pitch up and down. Furthermore, the patients were instructed to prolong and inflect voiced words, such as 'ema' and 'deema', at rising and then falling intonation.

Measurement

Two types of measurements** were used to record improvement following ES, phonation time and rating scales. The latter is composed of a 10-point scale; with 1 refers to complete aphonia, and 10 refers to normal quality. Ratings were collected from the client or a family member, the referring otorhinolaryngologist (ENT), and the speech pathologist. As a result six ratings were gathered for each client, three before the application of ES and three after. For the sake of the

*These surgeries were done after Bullet injury or to remove a tumor: Bullet injury (3), neoplastic invasion of the recurrent laryngeal nerve (2), esophagectomy (2), neck or chest mass removal (6), aortoplasty (2), left carotid tumor (1), glomus jugular tumor (1).

**Instrumentation that objectively record acoustic and physiological signs of vocal folds' adduction and vibration was received only by our department.

present analysis, each of the accumulated three ratings given before and after ES were averaged into one rating and then this figure was approximated to the nearest 'full digit'. The ratings given by the patients or their family members correlated relatively higher (0.81) with the ratings given by the speech pathologist than with those given by the ENT (0.77). The results of s/z ratio*** were not included in the present study due to the fact that most clients who suffer from vocal fold paralysis tend to devoice the /z/ sound after the first few seconds of phonation. The phonation time was the average of three consecutive prolongations of the vowel /i/ on deep breath, with enough period of rest in between.

The reliability of both the phonation time and the ratings done by the speech pathologist were measured by having another qualified speech pathologist measure the phonation time and rate the vocal quality of at least 25% of the cases. In order to find inter-rater reliability, the number of agreements between the researchers and the second speech pathologist was calculated. These figures were divided by the sum of both agreements and disagreements⁽³⁵⁾. The reliability measures for both the phonation time and the ratings of vocal quality were 0.93 and 0.90, respectively.

Results

As shown in Table I and Appendices 1-4, there was a remarkable increase in both phonation time and the average rating following voice therapy combined with percutaneous neuro-muscular electrical stimulation. The mean of the initial phonation times for the total sample was $(3.85 \pm 2.81$ seconds) range (0.0 – 13 seconds), while the final mean phonation times was $(12.27 \pm 5.76$ seconds) range (3.0 – 32 seconds). The mean difference in the phonation time was significant at $p = 0.001$ for the total sample and for each of the four groups (Table II). The mean of the initial ratings for the total sample was $(4.32 \pm 1.32$ second) range (2 – 7 seconds), while the mean of the final ratings was $(8.23 \pm 1.41$ seconds) range (5 – 10 seconds). This difference in the rating was significant at $p = 0.001$ for the total sample and for each of the four groups (Table II). Analysis of variance (Table III) shows that there was no statistical significant difference in the gains achieved between the four different etiologies of vocal fold paralysis.

Reanalyzing the data according the duration of onset (Table IV) shows that the gain in both parameters of the study was statistically significant for each duration of onset subgroup. Analysis of variance (Table V) shows that there was no statistical significant difference between the four different duration of onset of the vocal fold paralysis. Multiple Tukey's HSD Post Hoc comparisons showed that the only statistical significant

difference was between the first 'duration of onset' subgroup (i.e. less than one month) and the fourth 'duration of onset' subgroup (i.e. more than one year) in both the gain in the 'duration of phonation' ($p=0.023$) and the gain in the 'averaged rating' ($p=0.012$), where the first group benefited the most from electrical stimulation.

Figures 1- 4 below show graphic presentations for both the 'phonation time' and the 'averaged rating' for selected subjects from the four 'etiology subgroups'. It is obvious from the graphs that the improvement in both parameters of the study is coincided with the initiation of ES and the slope of the spontaneous recovery, if in process, became steeper after the application of ES.

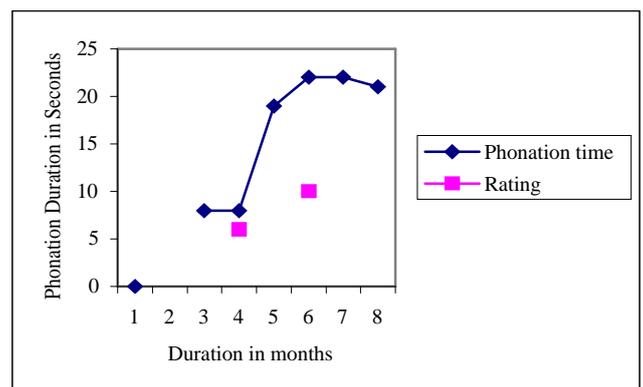


Fig. 1. A graphic presentation of the gain in phonation time by subject OZ. Therapy started on week 17 and extended over 5 weeks. Follow up was done on months 7 & 8.

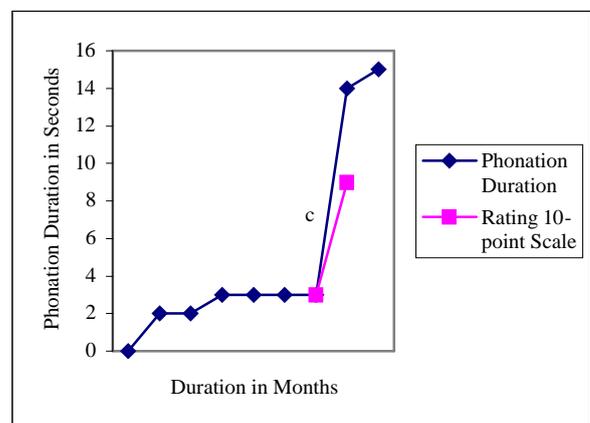


Fig. 2. A graphic presentation of the gain in phonation time by subject AG. Therapy started on week 30 and extended over 4 weeks. Follow up was done on month 9.

***The s/z ratio is a clinical evaluation of vocal fold function by contrasting the maximum phonation time with a sustained expiration without phonation (33,34)

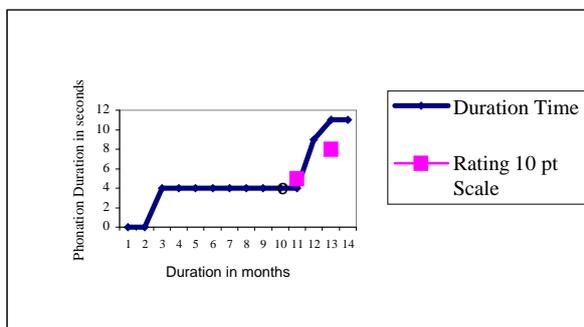


Fig. 3. A graphic presentation of the gain in phonation time by subject YY. Therapy started on week 47 and extended over 6 weeks. Follow up was done on months 13 & 14.

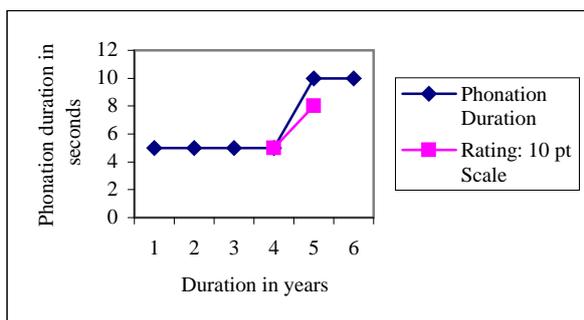


Fig. 4. A graphic presentation of the gain in phonation time by subject AZ. Therapy started on the end of year 4 and extended for 4 weeks. Follow up was made six months later.

Discussion

The results of the present study are in concordance with the published European studies ^(4,12-22), which implemented neuromuscular electrical stimulation, in conjunction with traditional voice therapy, for both unilateral and bilateral adductor vocal fold paralysis. However, this study is different in sample size and by including clients with various etiology and duration. The vast majority of the subjects benefited to varying degree from ES. One of the subjects, who recovered only partially over four years after hemithyroidectomy, improved remarkably with ES. Previous studies targeted on subjects immediately after the onset of the illness.

Additional notes can be driven. First, the gain in phonation time does not seem comparable to the increase

in the rating scales or vice versa for many patients, which can render for many explanations. Some patients, mainly younger subjects and those with heavy job speaking demands, are seeking full recovery of premorbid voice. They, and even the otolaryngologists, seem to be influenced by the presence of mild hoarseness of voice. Twelve of the subjects of the present study were experiencing premorbid voice abuse and/or excessive muscular tension as documented by their case histories. Endolaryngoscopies for two of them showed hypertrophied false folds. Second, the improvement in phonation time, loudness, and vocal clarity that exceeds endolaryngoscopic findings might be due to ES that enhanced compensatory behavior in addition to its influence on the effected VF.

Limitations of the present study are: 1. Choosing subjective rating and mean phonation time as outcome indicators, 2. Matching groups according to age and gender was not done, and 3. A control group was not included, to enable relevant comparisons.

Several conclusions are inherited in the present study. First, ES is an efficient technique to improve vocal loudness and quality following VFP. Second, the described technique helps to prevent the unnecessary muscle tension that develops when using some traditional approaches. Finally, this study clearly documents that certain laryngeal neuropathologies, such as vocal fold adduction and tension problems, can be dealt with using this technique regardless of the etiology and duration.

Voice therapists are urged to implement this procedure without waiting for the possible spontaneous recovery. It is also recommended to replicate this study with a larger sample and to compare with the outcomes and course of recovery of using traditional approaches.

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Table I. Descriptive statistics for both pre-post phonation time and ratings for the total sample.

Factor	No.	Minimum	Maximum	Mean \pm SD in seconds
Initial Phonation Time	60	0.00	13.00	3.85 \pm 2.81
Final Phonation Time	60	3.00	32.00	12.27 \pm 5.76
Initial Mean Rating	60	2.00	7.00	4.32 \pm 1.32
Final Mean Rating	60	5.00	10.00	8.23 \pm 1.41

Table II. Paired-samples t-test for both parameters of the study, the phonation time and the ratings of vocal behavior for the total sample and for each etiology group.

	Factor	Group	Paired differences between means	Significance (2-tailed)
Pair 1	Phonation time 1 Phonation time 2	Group 1	-9.43	.000
		Group 2	-6.25	.000
		Group 3	-9.36	.001
		Group 4	-9.36	.001
		Total	-8.48	.000
Pair 2	Rating 1 – Rating 2	Group 1	-4.57	.000
		Group 2	-3.62	.000
		Group 3	-3.91	.000
		Group 4	-3.91	.000
		Total	-3.92	.000

Table III. Analysis of Variance for both parameters of the study according to the four etiology study groups.

Factor	Analysis	Sum of squares	df	Mean square	F	P value
Gain in Phonation Time	Between Groups	104.705	3	34.902	1.470	.233
	Among Groups	1329.879	56	23.748		
	Total	1434.583	59			
Gain in Mean of Ratings	Between Groups	15.804	3	5.268	2.364	.081
	Among Groups	124.779	56	2.228		
	Total	140.583	59			

Table IV. Paired-samples t-test for both parameters of the study, the phonation time and the ratings of vocal behavior according to each duration.

	Factor	Group	Paired differences between means	Significance (2-tailed)
Pair 1	Phonation time 1 Phonation time 2	1 month	-10.86	.000
		1 – 5 month	-9.07	.000
		6 – 11 month	-6.20	.000
		1 year	-4.29	.025
		Total	-8.45	.000
Pair 2	Rating1 - Rating2	1 month	-4.86	.000
		1 – 5 month	-3.90	.000
		6 – 11 month	-3.80	.000
		1 year	-2.71	.001
		Total	-3.97	.000

Table V. Analysis of Variance for both parameters of the study according to the four duration study.

Factor	Analysis	Sum of squares	df	Mean square	F	Significance
Gain in Phonation Time	Between Groups	248.678	3	82.893	3.914	.013
	Within Groups	1185.905	56	21.177		
	Total	1434.583	59			
Gain in Mean of Ratings	Between Groups	22.853	3	7.618	3.650	.018
	Within Groups	116.881	56	2.087		
	Total	139.733	59			

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Appendix 1

Group I. Unilateral vocal fold paralysis following total or partial unilateral Thyroidectomy

Case	Name	Age/Sex	Side	Duration	No. of Sessions	Pre-post Phonation	Pre-post Ratings
1	NZ	50 F*	Rt [^]	1 week	52	3-22 Sec ^{oo}	3 – 10
2	RW	44F	Rt	9 mo. ^o	30	2 - 5 Sec	2 – 6
3	HQ	27 F	Lt ^{^^}	2.5 mo.	23	4 – 15 Sec	4 – 9
4	YY	59 F	Rt	11 mo.	29	4 – 11 Sec	4 – 8
5	AH	40 F	Lt	2 mo.	14	5 – 9 Sec	3 – 6
6	BH	42 F	Rt	3 mo.	17	6 – 19 Sec	6 – 10
7	AN	50 F	Lt	3 mo.	30	0 – 14 Sec	2 – 9
8	ND	38 F	Bil. [‡]	2 weeks	49	0 – 13 Sec	2 – 10
9	ZH	21 F	Lt	2 mo.	20	2 – 20 Sec	4 – 10
10	MS	42 M**	Rt	3 mo	19	4 – 8 Sec	4 – 7
11	BI	37 M	Lt	4.5 mo.	29	7 – 15 Sec	7 – 9
12	OL	35 M	Rt	3 week	26	3 – 6 Sec	4 – 8
13	OH	44 M	Lt	15 mo.	35	4 – 7 Sec	3 – 6
14	IB	19 M	Rt	2 mo.	15	0 – 12 Sec	2 – 9
15	AZ	25 M	Rt	4 yrs	17	5 – 10 Sec	5 – 8
16	MJ	30 F	Rt	2 mo.	22	5 – 11 Sec	4 – 8
17	WE	41 F	Lt	3 mo.	21	7 – 14 Sec	6 – 8
18	ZR	58 F	Rt	1 week	35	0 – 17 Sec	3 – 10
19	DN	34 F	Rt	3 week	21	4 – 17 Sec	4 – 10
20	MM	62 M	Lt	1 mo.	19	8 – 17 Sec	7 – 10
21	NN	16 F	Rt	1 mo.	33	6 – 15 Sec	5 – 9

*F: Female **M: Male ^Rt: Right ^^ Lt: Lift ‡Bil: ^omo: month
^{oo}Sec: Second

Appendix 2

Group II. Unilateral vocal fold paralysis following neck and thoracic surgery (Bullet injury, tumor removal, etc.)

Case	Name	Age/Sex	Side	Duration	No. of Session	Pre-post Phonation	Pre-post Ratings
1	MF	52M*	Lt ^{^^}	1 year	12	3 – 3 Sec ^{oo}	4 – 5
2	MS	65M	Lt	5 mo. ^o	20	5 – 6 Sec	4 – 6
3	AG	69M	Lt	7 mo.	20	2 – 13 Sec	3 – 9
4	AR	44 M	Lt	6 mo.	18	8 – 13 Sec	5 – 8
5	JW	49 M	Lt	5 mo.	21	1 – 7 Sec	3 – 7
6	OL	30 M	Rt [^]	2 week	30	0 – 8 Sec	3 – 9
7	SL	52M	Lt	6 mo.	17	4 – 11 Sec	3 – 7
8	FA	25 M	Lt	7 mo.	15	4 – 5 Sec	6 – 8
9	SF	27 F**	Lt	2.5 mo.	29	2 – 10 Sec	5 – 8
10	KB	28 F	Lt	2 mo.	36	0 – 8 Sec	2 – 7
11	HS	40M	Lt	4 mo.	19	2 – 11 Sec	4 – 7
12	IZ	34M	Lt	4 mo.	19	4 – 12 Sec	5 – 10
13	LY	29F	Lt > Rt	2 mo.	19	0 – 9 Sec	2 – 6
14	RT	59M	Lt	8 mo.	19	3 – 8 Sec	5 – 8
15	JH	66M	Lt	1.5 mo	31	1 – 10 Sec	5 – 8
16	OD	53 M	Lt	1.2 year	20	3 – 8 Sec	4 – 8

*F: Female **M: Male ^Rt: Right ^^ Lt: Lift ^omo: month ^{oo}Sec: Second

Appendix 3

Group III. Unilateral vocal fold paralysis following viral infection

Case	Name	Age/Sex	Side	Duration	No. of Sessions	Pre-post Phonation	Pre-post Rating
1	IN	30 F*	Lt^^	6 years	28	4 – 6 Sec ^{oo}	5 – 7
2	ZS	57 F	Lt	7 mo ^o	29	4 – 14 Sec	6 – 10
3	OR	27 M**	Lt	3 weeks	17	5 – 9 Sec	6 – 9
4	GF	66 F	Rt^	3 mo	23	0 – 17 Sec	4 – 10
5	FR	45 M	Lt	8 mo	20	3 – 12 Sec	4 – 8
6	FZ	40 M	Lt	1 mo	18	1 – 9 Sec	3 – 8
7	SH	38 F	Lt	7 mo	17	4 – 8 Sec	5 – 9
8	AW	63 M	Lt	3 weeks	29	4 – 18 Sec	5 – 10
9	KF	20 M	Lt	1 mo	16	3 – 12 Sec	4 – 8
10	YR	38 M	Lt	1 mo.	22	10 – 32 Sec	6 – 10
11	KZ	24 M	Rt	3 mo	19	4 – 8 Sec	4 – 6

*F: Female **M: Male ^Rt: Right ^^ Lt: Lift ^omo: month ^{oo}Sec: Second

Appendix 4

Group IV. Idiopathic unilateral vocal fold paralysis

Case	Name	Age/Sex	Side	Duration	No. of Sessions	Pre-post Phonation	Pre-post Rating
1	AK	40 M**	Lt^^	2 mo ^o	15	8 – 24 Sec ^{oo}	4 – 9
2	HM	34 M	Lt	5 mo	14	2 – 7 Sec	4 – 7
3	AL	59 F*	Rt^	3.5 mo	25	6 – 19 Sec	6 – 10
4	IB	24 F	Lt	2 year	22	3 – 6 Sec	4 – 6
5	NS	22 M	Rt	2 mo.	21	13 – 20 Sec	5 – 9
6	OZ	23 F	Rt	4 mo.	24	8 – 22 Sec	6 – 10
7	NH	25 M	Rt.	2 mo.	30	8 – 20 Sec	7 – 9
8	RS	35 F	Lt	2 mo	21	2 – 13 Sec	4 – 8
9	HL	49 F	Lt	5 mo	15	4 – 6 Sec	5 – 7
10	MR	33 M	Lt	1 mo	16	2 – 6 Sec	5 – 7
11	NW	60 F	Lt.	2 mo.	27	2 – 11 Sec	4 – 8
12	TS	50 M	Rt.	18 mo.	32	10 – 22 Sec	6 – 10

*F: Female **M: Male ^Rt: Right ^^ Lt: Lift ^omo: month ^{oo}Sec: Second