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SOME CLINICAL DATA ON AERODYNAMIC EXAMINATION USING THE AIRWAY INTERRUPTION METHOD

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1. Introduction

For clinical purposes, we developed a system to measure expiratory lung pressure during phonation using the airway interruption method combined with measurements of the air flow rate, vocal pitch and intensity. This system is now in use for clinical data collection. In this paper, we examine the relationships between vocal intensity, air flow rate and expiratory lung pressure in some of the clinical data in order to establish an appropriate format for evaluating aerodynamic conditions in phonation.

2. Procedures

A description of the principles of the system have been reported elsewhere.[1)-3)] Measurements were made in a sound-proof room in the outpatient clinic of the Department of Otolaryngology, University of Tokyo Hospital.

Subjects were normal and pathologic cases examined at the special clinic for voice disorders. They were classified into 3 groups: control, vocal cord polyp and recurrent nerve paralysis. The control group consisted of 20 males and 29 females with normal voice or only slightly pathologic voice. The vocal cord polyp group consisted of 16 males and 21 females with moderate to severe pathologic voice. The recurrent nerve paralysis group consisted of 17 males and 10 females with moderate to severe pathologic voice. Measurements were made for a sustained phonation of 3 to 4 seconds at habitual vocal pitch and intensity.

3. Results and Comments

Table 1 shows the raw data obtained from each of the subjects in the 3 groups. For each group, from the left-most column to the right, the case number, fundamental frequency of voice (Fo) in Hz, intensity of voice (I) in SPL, flow rate (FR) in ml/sec and expiratory lung pressure (EP) in mmH_2O are listed. Female subjects are indicated by underlined case numbers. The ranges of the values of I, FR and EP in the control group were 66 to 88 dB, 82 to 355 ml/sec and 28 to 148 mmH_2O, respectively. Those in the vocal cord polyp group were 72 to 88 dB, 112 to 459 ml/sec and 29 to 176 mmH_2O. Those in the recurrent nerve paralysis group were 68 to 89 dB, 79 to 1,235 ml/sec and 36 to 153 mmH_2O.

There appeared to be no systematic difference in these

values between males and females. Thus, we used the pooled data of both the males and females for further analysis.

The logarithms of the flow rate and pressure values were calculated as follows:

$$U = 10\mathrm{Log}_{10}\ u\ \mathrm{ml/sec}$$

$$P = 10\mathrm{Log}_{10}\ p\ \mathrm{mmH_2O}$$

The relationships between I(intensity), U(flow rate) and P(pressure) were then examined.

Table 1 Results of measurements in the 3 groups. No: case number(females are underlined); Fo: fundamental frequency of voice(Hz); I: intensity of voice(dB SPL); FR: air flow rate(ml/sec); EP: expiratory lung pressure(mmH_2O).

NO	F0	I	FR	EP
Control				
001	205	78	242	67
002	175	80	183	42
003	111	80	96	34
004	210	75	167	45
005	208	77	155	45
006	185	71	167	40
007	137	81	212	57
008	216	79	120	54
009	169	73	153	49
010	118	73	177	31
011	135	81	205	70
012	139	80	106	60
013	164	75	91	46
014	146	82	164	43
015	164	85	177	65
016	142	82	150	69
017	219	80	82	32
018	108	81	170	38
019	152	81	118	75
020	171	80	201	60
021	213	75	158	32
022	219	81	86	50
023	231	85	144	65
024	130	84	212	83
025	123	81	237	48
026	169	74	187	42
027	195	73	120	38
028	259	78	118	67
029	299	80	144	71
030	256	84	197	90
031	208	66	142	45
032	118	82	164	69
033	125	83	209	58
034	231	77	167	48
035	295	81	355	95
036	253	75	255	70
037	94	80	216	49
038	144	73	158	42
039	202	66	246	72
040	228	81	161	62
041	231	69	102	28
042	273	86	155	52
043	246	68	112	27
044	111	75	132	54
045	114	83	275	109
046	118	74	106	50
047	148	87	265	148
048	150	79	90	54
049	150	88	242	127
V.C.P.				
001	154	77	153	41
002	156	81	190	53
003	122	80	224	61
004	112	76	158	42
005	195	78	246	105
006	173	84	161	67
007	125	80	296	84
008	208	83	139	84
009	133	84	147	35
010	180	73	177	42
011	180	80	190	42
012	112	72	112	30
013	213	88	164	69
014	169	83	233	81
015	133	81	104	37
016	187	80	194	62
017	115	77	155	42
018	169	83	220	42
019	130	76	177	42
020	219	84	190	93
021	202	76	233	76
022	142	78	237	80
023	208	85	153	65
024	190	85	459	123
025	222	78	183	46
026	130	80	260	59
027	137	85	382	98
028	118	81	301	70
029	158	78	194	42
030	146	82	132	55
031	228	85	270	176
032	185	83	150	69
033	192	81	164	65
034	89	79	153	29
035	150	80	229	66
036	137	85	177	73
037	195	80	255	143
R.N.P.				
001	133	78	229	72
002	114	73	312	36
003	208	78	650	98
004	185	82	132	65
005	130	80	434	76
006	111	76	251	95
007	140	88	604	84
008	146	83	1235	134
009	70	68	627	84
010	99	75	476	125
011	154	85	739	153
012	295	79	201	92
013	200	85	209	54
014	231	78	246	49
015	195	76	522	63
016	175	75	220	55
017	142	74	582	57
018	210	77	79	37
019	122	77	713	62
020	142	78	1106	129
021	146	87	170	93
022	135	81	229	63
023	171	86	662	127
024	185	89	476	113
025	96	72	522	59
026	162	89	531	103
027	237	81	177	79

3-1. Control Group

The relationship between I and U is shown in Fig. 1, where the ordinate indicates I and the abscissa U. The ellipse in the figure circumscribes an area which includes 90 % of the data points. The distribution of these data points shows fairly large individual variation, and there appears to be no systematic relationship between vocal intensity and flow rate.

The relationship between I and P is shown in Fig. 2. The ellipse in the figure circumscribes an area including 90 % of the data points. The figure appears to indicate a positive correlation between vocal intensity and expiratory lung pressure, but the data points show a considerable amount of individual variation.

It is known that the efficiency of converting aerodynamic power to acoustic power at the glottis is variable in normal phonation and increases with vocal intensity. Thus, it is believed that air flow rate and expiratory pressure would correlate more consistently to vocal intensity if we took into account those values which represent glottal efficiency. We may say that the value I-U represents the glottal efficiency in the air flow rate, and I-P that in the expiratory lung pressure. Then, the values I-U and I-P can be considered to be more consistently correlated to I than U and P.

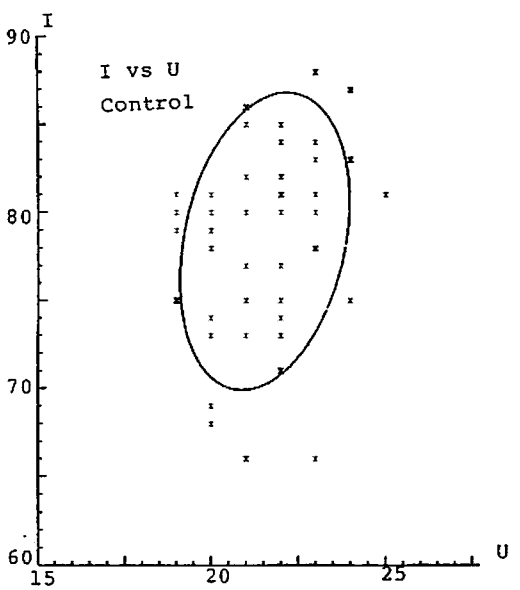

Fig. 1 Relationship between I and U for the control group.

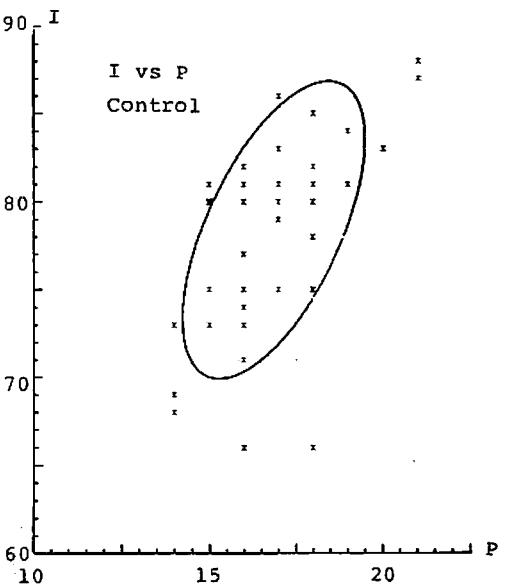

Fig. 2 Relationship between I and P for the control group.

In Fig. 3, the values of I-U are plotted in relation to I. The ellipse in the figure circumscribes an area which includes 90 % of the data points. The distribution of the data points shows a linear relationship between I-U and I with very small individual variation. It can be clearly seen that the acoustic output per unit flow rate, i.e., the efficiency in the flow rate, increases consistently with vocal intensity.

The relationship between I and I-P is shown in Fig. 4. In this figure, it can also be clearly seen that the efficiency in the lung pressure increases consistently with vocal intensity, with only very small individual variation. There is a linear correlation between I and I-P. The ellipse circumscribes an area including 90 % of the data points.

Fig. 5 shows the relationship between I and I-(U+P). The value U+P represents the aerodynamic power of the expiratory air, and I-(U+P) corresponds to the efficiency of converting expiratory air to acoustic output. There is a linear correlation between I and I-(U+P), with some individual variation.

Assuming that the data of the control group represents the range of values in normal subjects, the ellipses in Figs. 3 to 4 may be considered to be reasonable references for evaluating aerodynamic data obtained in pathologic cases. The leftward shift in the data points outside the ellipse indicates an abnormal reduction in efficiency.

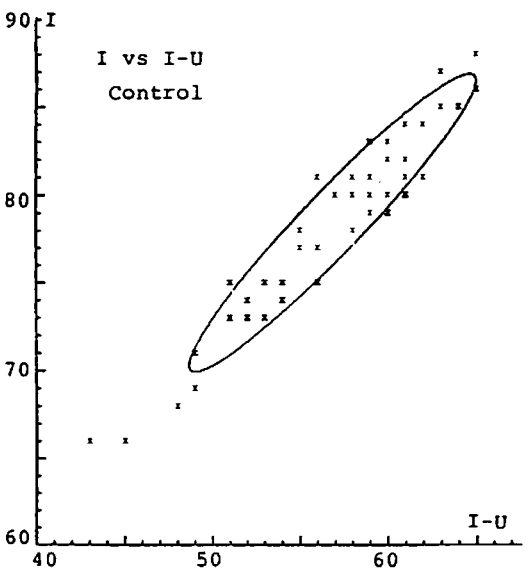

Fig. 3 Relationship between I and I-U for the control group.

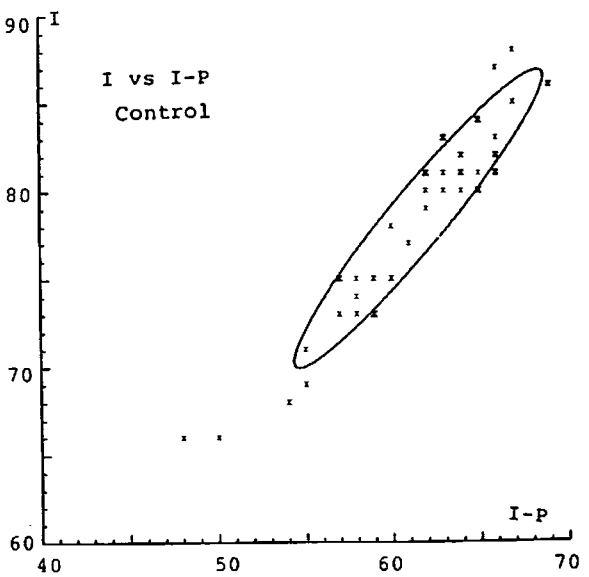

Fig. 4 Relationship between I and I-P for the control group.

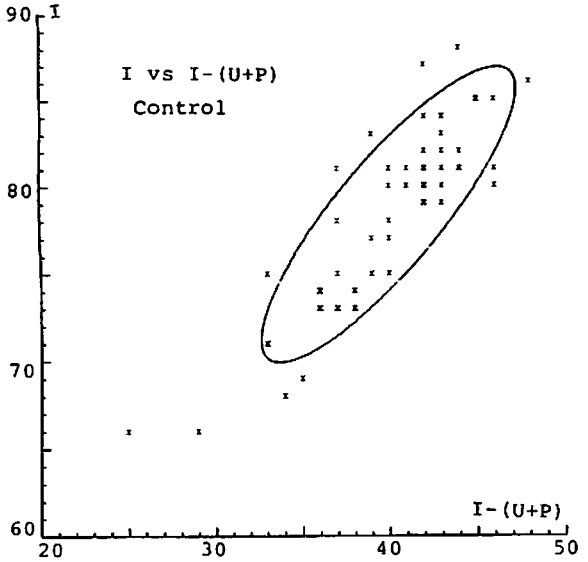

Fig. 5 Relationship between I and I-(I+U) for the control group.

3-2. Pathologic Cases

The relationship between I and I-U in the vocal cord polyp group is shown in Fig. 6. The ellipse in the figure circumscribes an area including 90 % of the data points in the control group. Several cases show an abnormal reduction in flow rate efficiency, while many of the data points are within the range of the control group. Fig. 7 shows the values of I-P in the vocal cord polyp group plotted in relation to I. Here also, there are several cases showing an abnormal reduction in expiratory lung pressure efficiency. A similar pattern

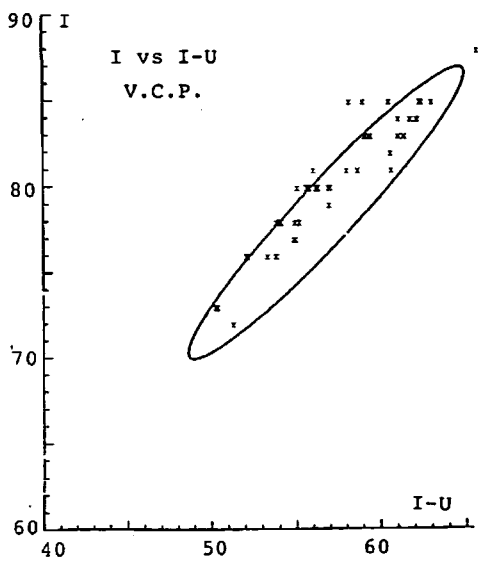

Fig. 6 Relationship between I and I-U for the vocal cord polyp group.

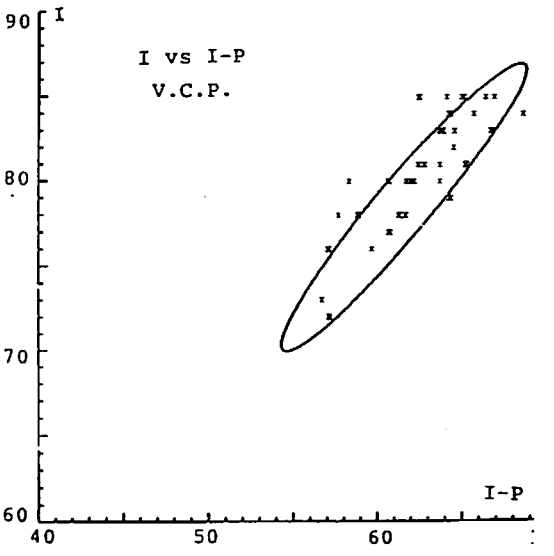

Fig. 7 Relationship between I and I-P for the vocal cord polyp group.

can be seen in Fig. 8, where the relationship between I and I-(U+P) is shown for the vocal cord polyp group. These figures indicate that several of the vocal cord polyp cases have a pathologic aerodynamic condition either in flow rate or in expiratory lung pressure, or both.

The data of the recurrent nerve paralysis group are shown in Figs. 9, 10 and 11. In Fig. 9, the values of I-U are plotted in relation to I. It should be noted that many of the cases show a large leftward shift of data points, indicating a profound reduction in flow rate efficiency compared to the control group. This finding corresponds to an excessive air flow through the glottis due to incomplete glottal closure in phonation. The relationship between I and I-P is shown in Fig. 10. More than half of the cases show an abnormal reduction in pressure efficiency, but to a lesser degree than for the flow rate. This finding may reflect an excessive expiratory force due to excessive air flow passing through the glottis. The relationship between I and I-(U+P) in Fig. 11 shows a pattern similar to Fig. 9, indicating a profound reduction in the total efficiency in many cases. These figures indicate that many cases in the recurrent nerve paralysis group suffer from a great reduction in aerodynamic efficiency, mainly due to excesssive air leakage through the glottis.

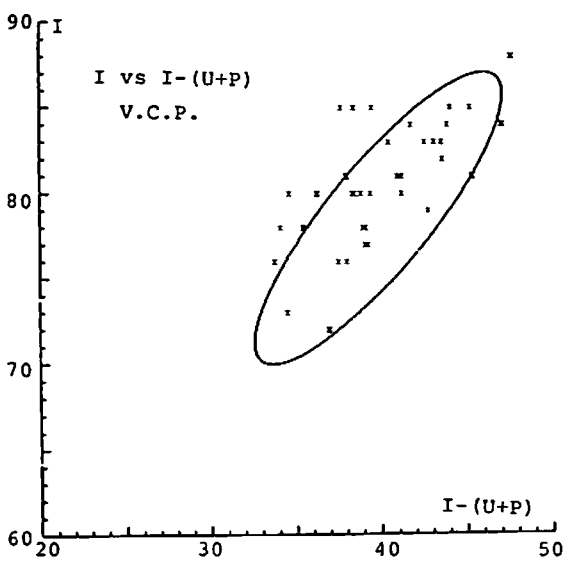

Fig. 8 Relationship between I and I-(U+P) for the vocal cord polyp group.

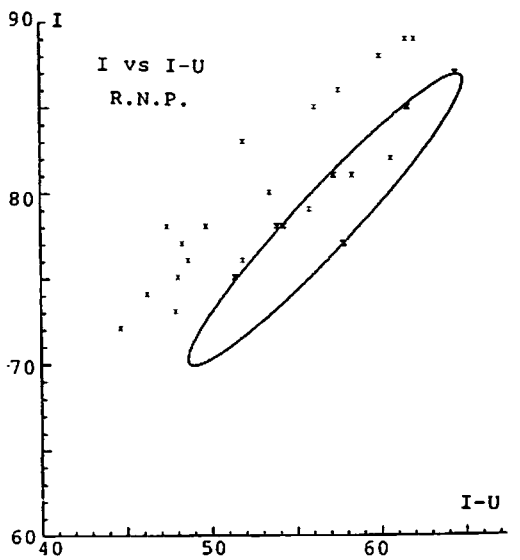

Fig. 9 Relationship between I and I-U for the recurrent nerve paralysis group.

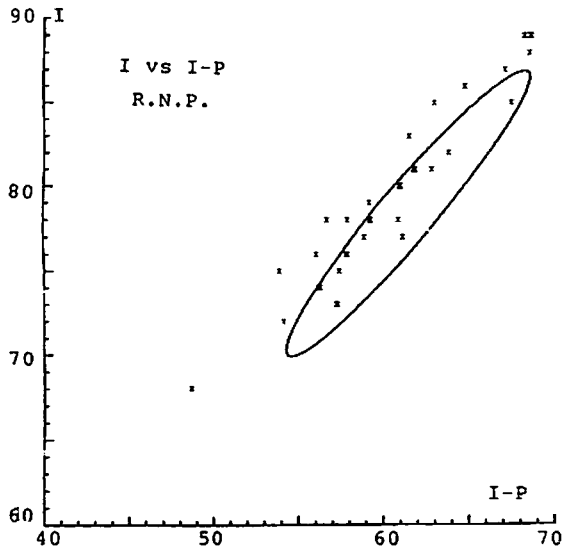

Fig. 10 Relationship between I and I-P for the recurrent nerve paralysis group.

3-3. Relationship between U and P

The values of I-P for the control group are plotted in relation to those of I-U in Fig. 12. The ellipse includes 90 % of the data points. The figure shows a linear relationship between the two values, with little individual variation. This result indicates that the lung pressure value is well estimated by the value of the air flow rate, and vice versa, as far as our experimental conditions are concerned. If the results can also be applied to pathologic cases, we may conclude that the clinical evaluation of aerodynamic conditions can be reasonably achieved by a measurement of air flow rate and vocal intensity without measuring expiratory lung pressure.

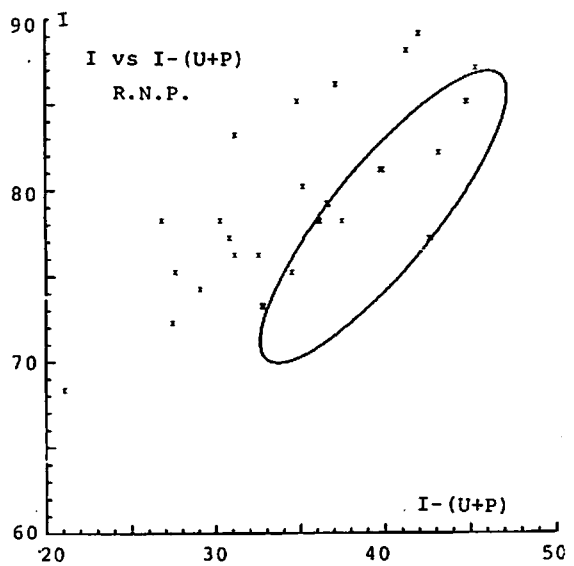

Fig. 11 Relationship between I and I-(U+P) for the recurrent nerve paralysis group.

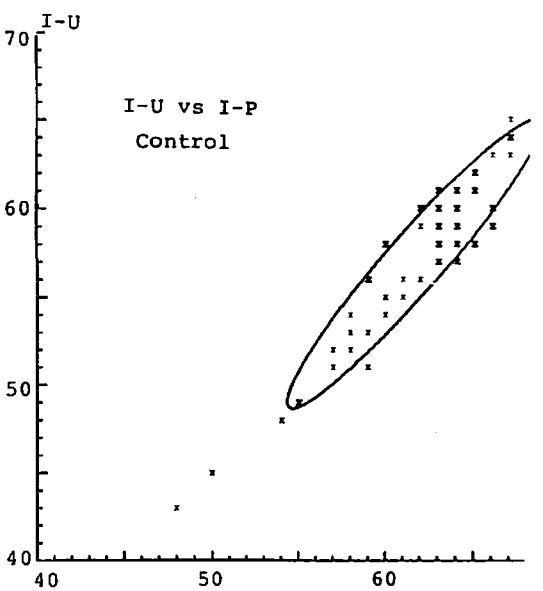

Fig. 12 Relationship between I-U and I-P for the control group.

Fig. 13 shows the relationship between I-P and I-U for the vocal cord polyp group. The distribution of the data points is not the same, but is close to that for the control group. Fig. 14 shows the same display for the recurrent nerve paralysis group. It can be seen that the distribution of the data points is different from that of the control group, showing greater individual variation. These data indicate that we need to have both flow rate and pressure data for a comprehensive evaluation of aerodynamic conditions in pathologic cases having a great reduction of the efficiency in either flow rate or expiratory lung pressure, or both.

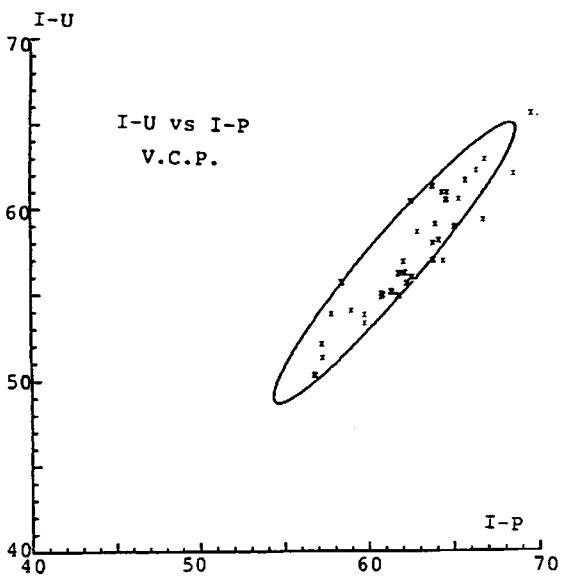

Fig. 13 Relationship between I-U and I-P for the vocal cord polyp group.

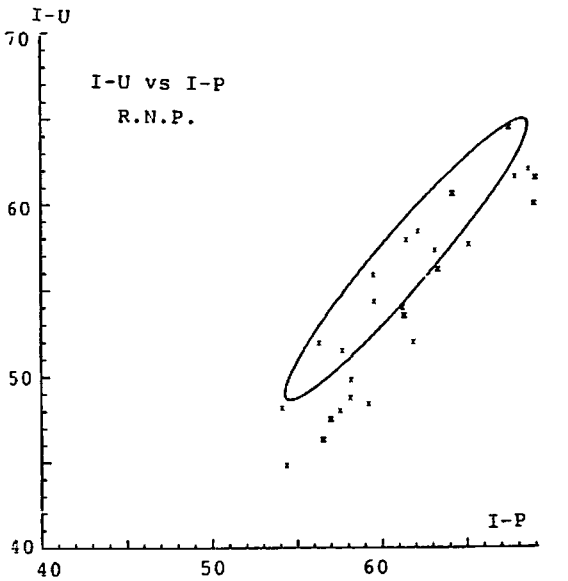

Fig. 14 Relationship between I-U and I-P for the recurrent nerve paralysis group.

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3) Sawashima, M., K. Honda, S. Kiritani, K. Shirai and N. Sakata: Airway interruption method for measuring expiratory air pressure during phonation. Transactions of the Committee on Speech Research, Acoust. Soc. Jpn., S84-108, 1985.