The Automated Pulmonary Function Laboratory: Clinical Use In Determining Respiratory Variations in Apraxia

Mary Ann Keatley
Patricia Pike

Saint Joseph's Hospital
Denver, Colorado

Five male subjects with varying degrees of apraxia and aphasia were evaluated on thirteen measures of spirometric function using the Automated Pulmonary Function Laboratory (APFL). Results indicate that (1) The APFL may have valuable potential in determining respiratory variations in apraxia of speech; and (2) peak expiratory flow values are potentially the most significant of the thirteen variables for citing respiratory variations in the apraxic versus the normal population.

The relationship between respiratory function and prosodic disturbance in the expressive aphasic is not yet fully understood. Disturbed prosody is a prominent characteristic in the apraxic population (Monrad-Krohn, 1947; Critchley, 1962; Goodglass, 1967; Darley, 1969; and Luria, 1970). Numerous researchers, including Darley (1969), postulate that prosodic alterations may be in compensation for the articulatory problems in apraxia of speech. With the new investigations of neural regulation of respiration as studied by Mitchell and Berger (1975), it becomes increasingly more apparent that central nervous system lesions in man may indicate anatomic separation of the voluntary and automatic respiratory control systems. Mitchell and Berger note that this in turn may pose the question of a "respiratory apraxia." If this is the case, we may find that "respiratory apraxia" affects speech on the production level, manifesting itself in a prosodic disturbance.

Indirect evidence of respiratory problems in the expressive aphasic are noted by many researchers. Goodglass, et al. (1967) report that the "Broca's aphasic initiates speech with effort, and speaks in short word groupings with poor intonational patterns." Luria (1970) also notes that the "unit of innervated action is no longer the sentence or phrase, ... the patient no longer utters a whole meaningful complex 'in a single breath'", but instead uses the word or syllable as the primary unit, and speaks both haltingly and in a monotone. Benson (1967) studied a set of variables--including rate of speech, pronunciation, prosody, phrase length, effort, pauses, paraphasias, etc.--and concludes that prosody may be the most discriminating variable between the fluent and nonfluent aphasic. Kerchensteiner, in 1971, stated that prosody along with phrase length may be the most discriminating variable. Blumstein (1973) did a systematic analysis of phonological errors in Broca's, Wernicke's and Conduction Aphasia and discovered that phonological analysis alone was not sufficient to make a differential diagnosis. She concludes that the presence or absence of disturbed prosody is what qualitatively distinguishes these syndromes.

The various parts of the vocal mechanism are intimately connected, with the "respiratory organ" serving as the activator of voice production (Luchsinger and Arnold, 1965). The expressive manifestations of this vocal production are partially displayed through the prosodic aspects of speech, specifically the suprasegmental features of pitch, stress, and duration. A change in one of these features will generally cause an alteration in the other two; and a modification in the primary driving force of respiration may alter one or all three of these variables.

In light of Benson's, Kerchensteiner's and Blumstein's studies on prosody, and the significance of respiratory performance on prosodic features as noted by Lehiste (1970), it would seem that further analysis on a primary respiratory level would be a productive starting point.

The purpose of this pilot study was to determine the usefulness of the Automated Pulmonary Function Laboratory (APFL) machine in determining variations in respiration in patients with apraxia of speech. The thirteen measures of pulmonary function which were evaluated for each subject are as follows: Forced vital capacity (FVC), Forced Expired Volume (FEV) at 0.5 and 1.0 seconds, and the ratio of the Forced Expired Volume to the Total Forced Vital Capacity expressed as a percentage at 0.5, 1.0, and 3.0 seconds, Forced Expired Flow (FEF) from 25% to 75% of Forced Vital Capacity, Mid-Expiratory Time (MET), Vital Capacity Time (VC-T), Forced Expired Flow from 75% to 85% of FVC, FEF at 50% of FVC, FEF at 75% of FVC, and Peak Flow. (See Glossary for a description of all measures.)

The questions at issue in this study are: (1) What variations, if any, exist between thirteen measures of respiratory function evaluated by APFL in apraxics and their normal controls; and (2) What intra-group respiratory differences exist in the apraxic population?

The advantages of pulmonary function testing are discussed by Luchsinger and Arnold (1965). They note that not only have internal medicine and respiratory physiology come together to confirm through objective experimentation that breathing and phonation are intimately connected; but also that latent states of insufficiency are frequently associated with vocal disorders because the "respiratory driving mechanism of phonation is organically deficient." Deviations in APFL results of apraxic patients may suggest deficiencies in the respiratory driving mechanism.

METHOD

Subjects

Five brain-damaged adults demonstrating apraxia of speech with a mild to moderate aphasic involvement served as subjects. The five subjects ranged in age from thirty-nine (39) to sixty-nine (69), with a mean age of fifty-two (52) years. The etiology for all five subjects was cerebral vascular accident. Spontaneous speech samples were obtained for each subject and were evaluated on the 7-point rating scale of *The Boston Diagnostic Aphasia Examination* (Goodglass and Kaplan, 1972). All subjects fell within the assigned profile range for Broca's aphasia with varying degrees of paraphasias, word-finding and auditory comprehension problems.

A clinical evaluation of verbal apraxia was made on a 0 to 8 scale (0 indicating no apraxia of speech and 8 indicating no phonation upon command). The five subjects ranged from moderate to severe in involvement (scores 4 to 8) when initially evaluated; however Subject #1 showed no indication of apraxia one month post-onset at the time of APFL testing. All subjects were also given the Porch Index of Communicative Abilities (Porch, 1967), and revealed aphasia with verbal formulation or expressive problems, "oral apraxias".

Subject #1: Spirometry evaluations were made at one month post CVA onset. The initial speech and language evaluation indicated moderate apraxia and mild to moderate apraxia and mild to moderate aphasia. Re-evaluation of apraxia five days pre-spirometry indicated no residual apraxic problems. The fact that there were no overt signs of apraxia at the time of spirometric testing may be significant in view of the patient's test performance.

Subject #2: This subject was twenty-one months post-onset, and minimal changes in verbal apraxia had occurred. This patient is the oldest subject in the study, and general pulmonary function had been in question prior to CVA onset. These variations may account for the negative performance on spirometry measures. This subject raises the question, "Could pre-existing pulmonary dysfunction contribute to negative prognostications as they relate to apraxia of speech?"

Subject #3: Spirometry was completed two days post-onset on this 47-year-old male. A moderate to severe verbal apraxia was present at the time.

Subject #4: This subject was fifteen months post-CVA onset. General physical health shows significant improvement, and a moderate verbal apraxia lingers.

Subject #5: This 39-year-old gentleman was eight days post-CVA onset at the time of spirometry, and revealed a moderate to severe verbal apraxia.

All subjects have a history of smoking. Since pulmonary function is influenced by smoking habits, perhaps the variable of smoking should be accounted for in future pulmonary function studies of apraxia of speech.

Table I presents descriptive data for each subject, including age, sex, height, weight, and time post-onset.

TABLE I

Descriptive Data for Each Subject

Subject	Age	Sex	Height	Weight	Time Post Onset
1	52	M	6'¼"	179	1 month
2	69	M	5'5"	119	21 months
3	47	M	5'9"	182	2 days
4	55	M	5'8"	184	15 months
5	39	M	5'5"	176	8 days
Mean	52				
Range	39 to 69				

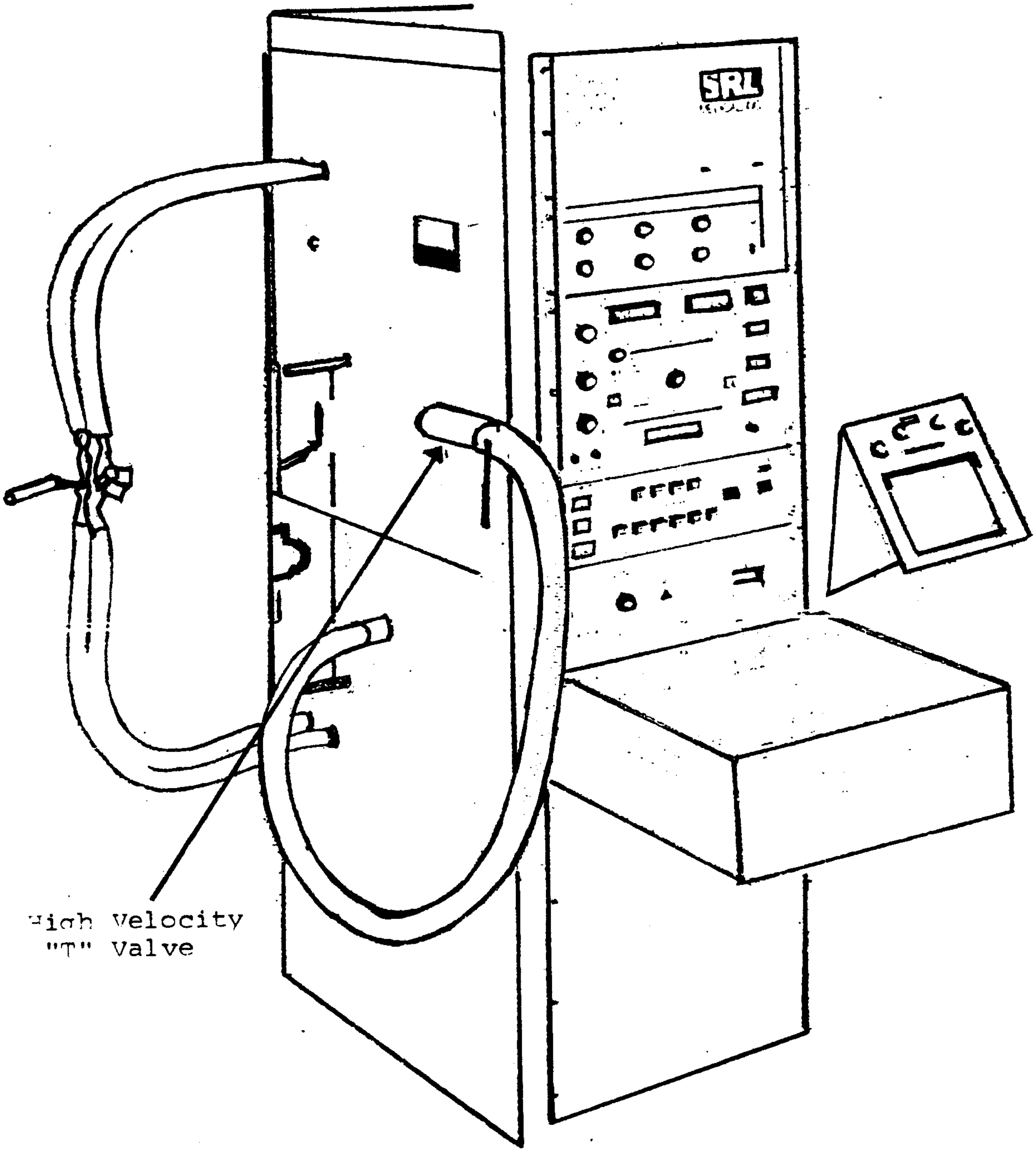

Figure 1
Model M100B Automated Pulmonary Function Lab

Instrumentation

The Automated Pulmonary Function Laboratory (APFL) "Mark III" model M100B was used to measure respiratory function in all subjects. (See Figure 1) The APFL is a precision electronic instrumentation system with a built-in mini-computer which is self-calibrating. Predicted equations or norms for adult males and females between the ages of 18 and 72 years, and children below 17 years of age, are programmed into the computer. These respiratory values were determined in relation to specific parameters with reference to the most reliable data per measurement units, i.e., forced vital capacity, peak expiratory flow, etc. Permanent records are provided in the form of a digital printout of computed results which include actual, predicted, and percentage of predicted values.

Procedures

Tests were administered with the subjects seated adjacent to the Automated Pulmonary Function Machine. A nose clip was worn to prevent air leakage through the nasal passageways. The patient was instructed first to breathe normally through the High Velocity "T" Valve. At the appropriate time, the subject was told to breathe deeply until his lungs were completely full, then to expel the air forcibly until his lungs were completely empty. Visual and gestural stimulation were used to urge the patient to exhale to the maximum extent possible. Each procedure was completed twice to insure a valid result. All tests were completed by a trained pulmonary function technician. Results were read and analyzed by a physician, Director of Respiratory Therapy, Pulmonary Diagnostic Laboratory, Saint Joseph's Hospital.

RESULTS AND DISCUSSION

This study was designed to determine the potential usefulness of APFL instrumentation as it may relate to problems in apraxia of speech. Inter-group variations are charted in Table 2.

Intra-group comparisons indicate a wide variation in performance on spirometry measurements. Subjects 1, 4 and 5 revealed better than normal performance of FEF 75-85%. Subjects 1 and 5 showed above normal performance of FEF 25-75%; and subjects 2 and 5 displayed poorer than normal performance on MET. Subject 1 performed better than the other four subjects on FEV 0.5. One subject, 4, had better than normal scores on MET.

Negative peak expiratory flow scores were demonstrated by subjects 2 through 5. Subject 1 revealed normal PF scores on the first trial. Subject 3 had negative PF scores on the initial trial; but six weeks later, when apraxia had dissipated, showed normal values on peak expiratory flow. (See subject 3, Trial 2, Table 2.)

The four subjects who scored below normal on variable 13 (PF) ranged from 25% to 75% of normal performance. It is interesting to note that the subject who displayed the most severe apraxia had the lowest PF score of 25%. The ranked relationship of PF scores appears to have a parallel relationship (see Table 3).

TABLE 2. Positive and Negative Spirometric Results

MEASUREMENT, units	SYMBOL	CODE	SUBJECT NUMBER Trial 1-2				
			1	2	3	4	5
Forced Vital Capacity liters	FVC	01		-			
0.5 Second Forced Expired Volume, liters	$FEV_{0.5}$	02	+	-			
% of FVC in 0.5 sec.	$\%FEV_{0.5}$	03		-			
1.0 Second Forced Expired Volume, liters	$FEV_{1.0}$	04		-			
% of FVC in 1 second	$\%FEV_{1.0}$	05		-			
% of FVC in 3 seconds	$\%FEV_{3.0}$	06		-			
Forced Mid-Expiratory Flow, liters/min.	FEF 25-75%	07	+	-			+
Mid-Expiratory Time, seconds	MET	08		-	+	+	-
Forced Vital Capacity Time, seconds	VC-T	09					
Mean Flow Between 75% and 85% of FVC, liters/min.	FEF 75-85%	10	+	-		+	+
Flow at 50% of FVC, liters/min.	FEF 50%	11					
Flow at 75% of FVC, liters/min	FEF 75%	12					
Peak Expiratory Flow, liters/min.	PF	13		-	-	-	-

Variations below norms (below 80% of normal standards) are indicated by a minus and those falling above average standards (120% of normal) are indicated by a plus. All categories without plus or minus notations indicate scores within normal range.

TABLE 3. Apraxia ratings (0-no apraxia present to 8-severe apraxia), and Peak Expiratory Flow Measures expressed in percentages.

Subject	Apraxia Rating at Test Time	PF-Score Percent of Normal
1	0	103%
2	6.5	25%
3		
Trial 1	5	70%
Trial 2	0	113%
4	4	78%
5	5	72%

Peak expiratory flow is the single variable noted which may be related to symptoms of verbal apraxia. The one subject who no longer displayed verbal apraxia showed normal scores on PF. All other subjects had moderate to severe apraxia, and showed negative deviations on PF measures. It is of interest that of the four subjects with negative PF scores, one subject showed nine additional respiratory deviations, one showed normal scores on all other parameters, one revealed two positive deviations, and one had one additional negative and two positive deviations.

The above findings may indicate that PF may not be correlated to other spirometric measures in the apraxic, but related to symptoms of verbal apraxia.

Peak flow normally occurs within the first half second of the expiratory cycle. The apraxic subject generally reaches peak flow between the first and third seconds of exhalation, thus raising the questions of difficulty attaining voluntary control over the initiator of respiration. Although peak expiratory flow is a measure of respiratory function on a primary level, it may be postulated that reduced PF in apraxia of speech could be potentially related to problems on the level of speech production, including prosodic disturbances which affect the features of pitch, stress, and duration. Research in this area with a larger group of apraxics as well as other neurologically impaired populations is necessary before firm conclusions can be drawn. By performing a systematic analysis of slowed vital capacity with and without phonation; as well as studying the effects of varied pitch and intensity, causal and/or other descriptive relationships between respiratory function and verbal apraxia may be determined.

A follow-up study is now in progress. To date, six additional subjects, four with mild aphasia and more pronounced apraxic symptoms, and two with primary aphasia, have been tested. Results are consistent. Those subjects with more prominent apraxic symptoms reveal abnormally low peak expiratory flow values; whereas the two aphasic subjects achieved normal scores on this measure.

DISCUSSION

The importance of abdominal breathing techniques in respiratory therapy with apraxics was discussed. The severity of apraxia may affect the severity of respiratory involvement, and may also determine to what degree the abdominal musculature must be strengthened or brought into coordination with vocal fold movement. Visual, auditory, or tactual input (or various combinations thereof) are beneficial for the apraxic individual. By using biofeedback, this type of patient may more easily monitor abdominal muscle movements.

The composition of the control group was questioned. As was previously noted, the original study compared apraxics to normals; and the follow-up study analyzes apraxic, aphasic, and normal intra- and inter-group variations and similarities.

The Automated Pulmonary Function Laboratory has multiple and varied uses. Mentioned were those with the dysarthric and cerebral palsied populations. The need for further investigations into both the diagnostic and therapeutic implications of this piece of equipment were stressed.

GLOSSARY OF OPERATIONAL DEFINITIONS

Apraxia:	An articulatory disorder resulting from impairment, as a result of brain damage, of the capacity to program the positioning of speech musculature and the sequencing of muscle movements for the volitional production of phonemes. The speech musculature does not show significant signs of weakness, slowness, or incoordination when used for reflex and automatic acts. (Darley, 1969)
Respiratory Apraxia:	Patient is unable to take a deep breath or hold his breath, although he may be able to perform other voluntary motor acts. (Mitchell and Berger, 1975)
Pulmonary-Function Testing:	A diagnostic procedure used to confirm or discount respiratory disease. This includes the study of lung volumes, flow rates, ventilation studies, etc. (Ayers, Whipp, and Ziment, 1974)
FVC	Forced Vital Capacity: The maximum amount of air that a patient can forcefully expire after a maximal inspiration. The units are liters and are expressed as: FVC=X.XX liters.
FEV	Forced Expired Volume: The volume of forcefully expired air measured at discrete time intervals from a reference point after the beginning of exhalation. The reference point in the M100 is 100 ml. All timed intervals are measured from the point that the expired volume exceeds 100 ml. The intervals for the M100 are one-half second, one second and three seconds designated $FEV_{0.5}$, $FEV_{1.0}$ and $FEV_{3.0}$ respectively.
%FEV	Normalized FEV: The ratio of the measured FEV to the total FVC expressed as a percentage. In the M100 these are $\%FEV_{0.5}$, $\%FEV_{1.0}$ and $\%FEV_{3.0}$.
$FEF_{25-75\%}$	Forced Expired Flow from 25% to 75% of FVC: The average flow over the middle half of the volume by the time interval from a point equal to 25% of the FVC to a point equal to 75% of the FVC. Average Flow: $\frac{\Delta V}{\Delta t} = \frac{\frac{1}{2} FVC}{\Delta t}$ liters/min. In the M100 the units are in liters/min. but can be converted to liters/sec on special request. The standard units are LPM and are expressed as: $FEF_{25-75\%}$ = XXX liters/minute.
MET	Mid Expiratory Time: The Δt required to calculate $FEF_{25-75\%}$ is really the mid expiratory time or MET. It is the time required to expire the middle half of the FVC. The units are seconds and are expressed as: MET = X.XX seconds.
VC-T	Vital Capacity Time: The total time interval of the FVC. The time is measured from a point equal to the reference level (100 ml) until 99.6% of the expiration is completed. The units are seconds and are expressed as: VC-T = XX.X seconds.

$FEF_{75-85\%}$ Forced Expired Flow from 75% to 85% of FVC. The same basic definition as $FEF_{25-75\%}$ except the time is measured from a point equal to 75% of FVC to a point equal to 85% of FVC.

$$\text{Average Flow} = \frac{\Delta V}{\Delta t} = \frac{1/10\ FVC}{\Delta t} \text{ liters/min.}$$

The standard units are LPM and are expressed as: $FEF_{75-85\%}$ = XXX liters per minute.

$FEF_{50\%}$ Forced Expired Flow at 50% of FVC: The instantaneous flow at 50% of the FVC. At a point equal to 50% of the FVC the flow is measured. The standard units are LPM and are expressed as: $FEF_{50\%}$ = XXX liters per minute.

$FEF_{75\%}$ Forced Expired Flow at 75% of FVC: The instantaneous flow at 75% of the FVC. At a point equal to 75% of the FVC the flow is measured. The standard units are LPM and are expressed as: $FEF_{75\%}$ = XXX liters per minute.

PF Peak Flow: The largest flow achieved during a forced expiration. The units are LPM and are expressed as: PF = XXX liters per minute.

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