Ann.Bull.RILP(1984)No.18, 19-26

FURTHER WORKS ON THE AIRWAY INTERRUPTION METHOD OF MEASURING EXPIRATORY AIR PRESSURE DURING PHONATION

Masayuki Sawashima, Kiyoshi Honda, Shigeru Kiritani, Sotaro Sekimoto, Susumu Ogawa* and Katsuhiko Shirai*

Introduction

For clinical purposes, we are developing a system of measuring expiratory air pressure during phonation using the airway interruption method, combined with measurements of the air flow rate and vocal pitch and intensity. The principles and basic instrumentation of the system with some preliminary results of measurements were reported last year[1]. Although the system was considered to be useful and practical in evaluating aerodynamic conditions at the glottis, there were several technical problems to be solved. In this paper, we report on our further work on two of these problems, the display of data and the estimation of subglottic pressure.

Data display

In order to display data in an appropriate form as a record of clinical examination, we developed a data acquisition system using a micro-computer. The output signals of the fundamental frequency and intensity of voice, the flow rate and the expiratory air pressure are sampled with an 8 bit A/D converter at a rate of 32 Hz. The CRT screen displays the time curves of the four parameters for 4 seconds (128 samples per channel) in 4 channels, as shown in Fig. 1. The time point of the measurement is marked by a cursor, and a sample value is displayed at the bottom of the CRT screen. With a hard copy of the screen, all the data displayed are recorded on a print-out sheet. The size of the print-out is designed to be approximately 10cm x 8.5cm, appropriate for attachment on to patient records. The collected data can be stored on a "mini-floppy" disk.

Estimation of subglottic pressure

The pressure value obtained by the airway interruption method is considered to be an aerodynamic representation of the so-called expiratory force. It is not the real subglottic pressure during phonation, although the difference between the two values may be minor when the flow resistance of the lower respiratory tract is negligible compared to that of the glottis.

*Department of Electrical Engineering, School of Science and Engineering, Waseda University.
This work was supported by a Grant-in-Aid for Scientific Research (No. 59870055), Ministry of Education, Science and Culture.

The relation between the two values is considered to be represented by the following equation:

$$P_{EX} - P_S = U \cdot R_S$$

where P_{EX} is the expiratory pressure obtained by the airway interruption; P_S is the real subglottic pressure during phonation immediately before the interruption; U is the flow rate immediately before the interruption; and R_S is the flow resistance at the lower respiratory tract. A schematic diagram is shown in Fig. 2a. Thus, the difference is assumed to be greater with the increase in the flow rate, which happens quite often in patients with voice disorders. It is therefore desirable to know the P_S value in order to evaluate the airodynamic conditions at the glottis of such patients. Assuming that there is little change in the flow resistance of the lower respiratory tract within a subject during expiration, the value of $U \cdot R_S$ may be reasonably estimated as a function of the flow rate. Based on this assumption, we designed the experiment shown in Fig. 2b.

In this experiment, the artificial flow resistance was provided by a thick paper-screen with a hole inserted between the mouthpiece and the shutter. In the figure, the screen is indicated as R. We prepared eight different screens with different hole sizes, each of the sizes being approximately 36, 30, 25, 20, 16, 12, 9 and 8 square millimeters. The resistance at the screen increased with a decrease in the size of the hole. An additional pressure transducer was inserted between the mouthpiece and the screen. Here, the air pressure in front of the screen (the P'_S in the figure) was measured when the shutter was open, while the expiratory air pressure (P_{EX}) was measured when the shutter was closed.

When we blow air at the screen through the mouthpiece, the relation between P_{EX} and P'_S is represented by the equation shown in the figure:

$$P_{EX} - P'_S = U \cdot R_S + U \cdot R_g$$

where R_g is the glottal resistance. The value of R_g is considered to be negligible when the glottis is open, as in normal respiration. Thus the difference between P_{EX} and P'_S is nearly equal to $U \cdot R_S$.

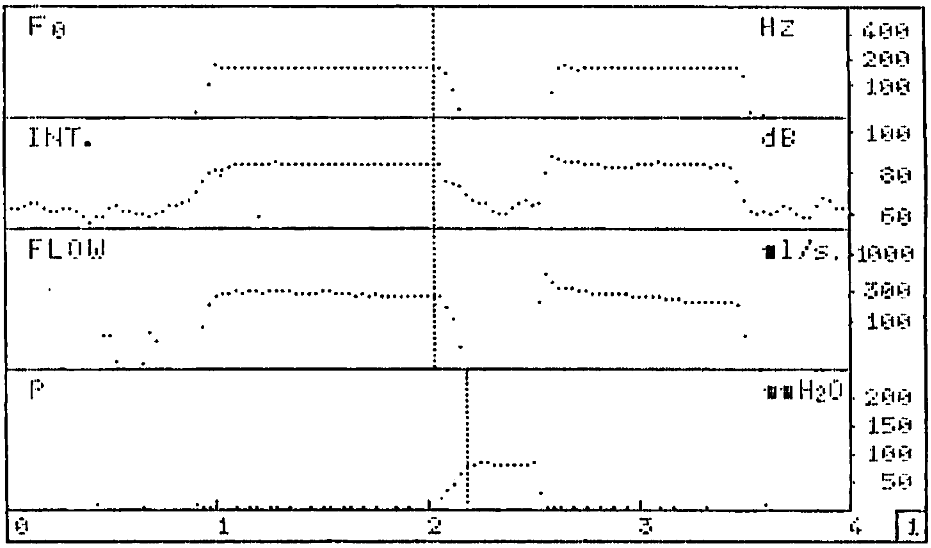
Three normal adult males served as subjects in this study. The airway interruption was made during sustained blowing at the screen with the glottis open. The expiratory air flow rate was monitored by the indicator installed with the instrument. The procedure was repeated with different screens and different air flow rates. P_{EX} and P'_S were measured for each blowing action.

The relationship between the pressure in front of the screen, P'_S, and the flow rate U obtained for one of the subjects is shown in Fig. 3. In the graphs of this figure, the ordinate indicates P'_S, and the abscissa indicates U. The graphs present the data for each of the eight different screens. It can be seen that P'_S increases with an increase of the air flow rate. At a constant rate of flow, P'_S increases with a smaller hole size for the screen. In normal phonation, subglottic pressure ranges between 50 - 100mmH_2O with a flow rate of 100 - 200ml/sec. Similar conditions were present with screens with a hole-size of 0.8mm^2 and 0.9mm^2. The data obtained from the other two subjects were nearly identical to that in Fig. 3.

The values of $U \cdot R_S$ as estimated by P_{EX} - P'_S are shown in Fig. 4a-c for the three subjects, respectively. In the figure, the pressure difference along the ordinate was plotted in relation to the flow rate on the abscissa for each of the eight different screens. It was noted that, for all three subjects the pressure difference increased with an increase in the flow rate, while it showed little difference for the different hole sizes of the screen. The actual values of the pressure difference at a flow rate of 100ml/sec were in the range of 5mmH_2O at most. The values approached 10mmH_2O at a flow rate of 200ml/sec and exceeded 10mmH_2O at 400ml/sec. Thus, the pressure difference can reasonably be expressed as a simple function of the flow rate. There may be some individual variation in the value of the pressure difference at a given flow rate, but the relationship between the two values can be considered to be well expressed by a function which is common to all the subjects. Further study is needed on this aspect.

Reference

1. Sawashima, M., S. Kiritani, S. Sekimoto, S. Horiguchi, K. Okafuji and K. Shirai (1983); The airway interruption technique for measuring expiratory air pressure during phonation. Ann. Bull. RILP, No. 17, 23-32.



FO(Hz)	INT(dB)	FLO(ml/s)	P(mmHzO)
142	84	235	77

Fig. 1 Four-channel display of time curves before and after airway interruption during sustained phonation. Vertical dotted lines indicate the time points of the measurements. Sample values are seen at the bottom.

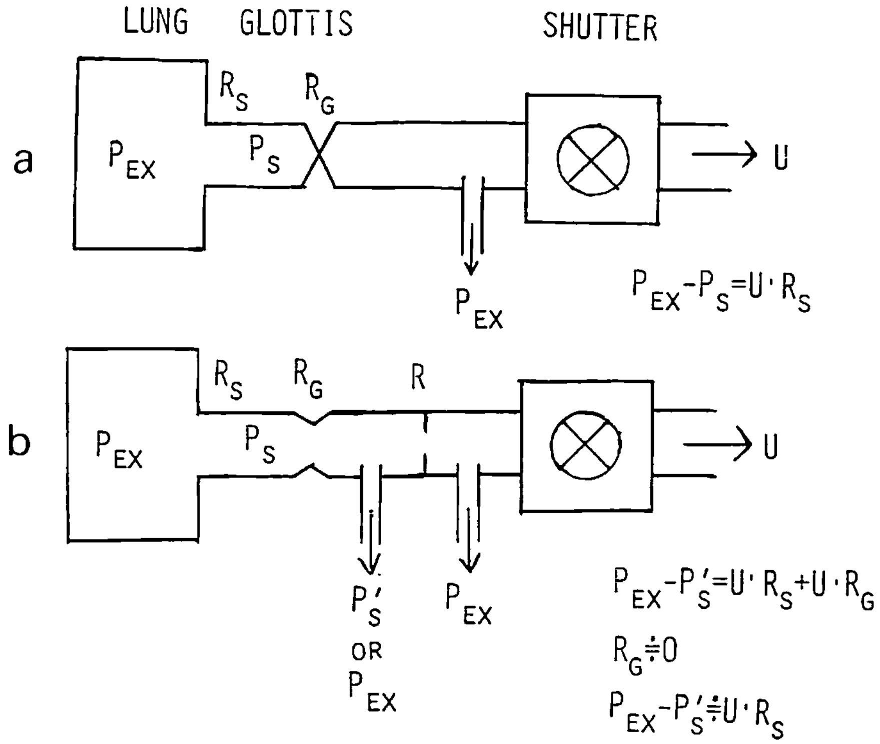


Fig. 2 Schematic representations of the relation between the subglottic pressure and the expiratory pressure(a), and of the experimental design for estimating the difference between the two pressure values(b).

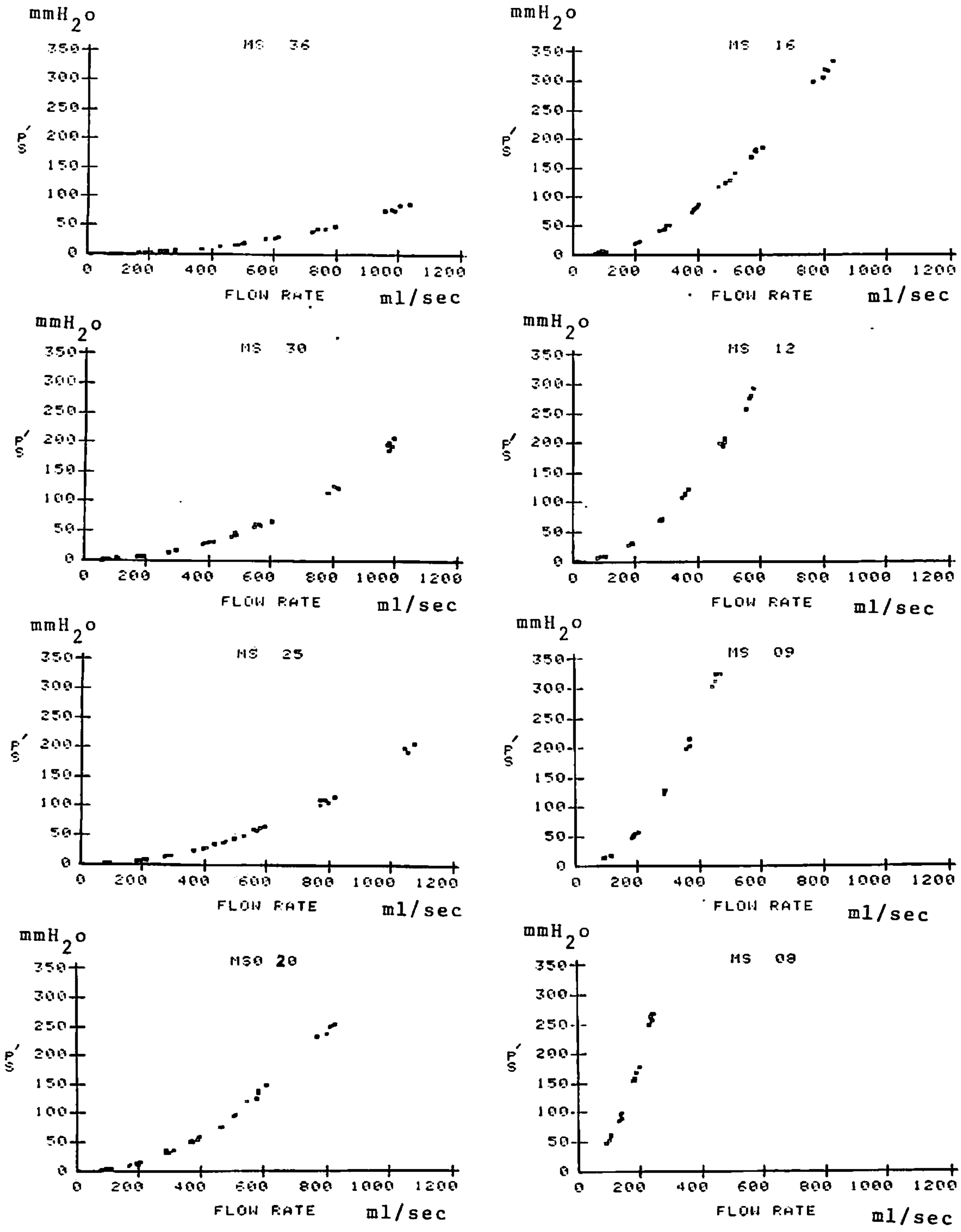


Fig. 3 Air pressure in front of the screen plotted in relation to the flow rate for each of the eight different screens.

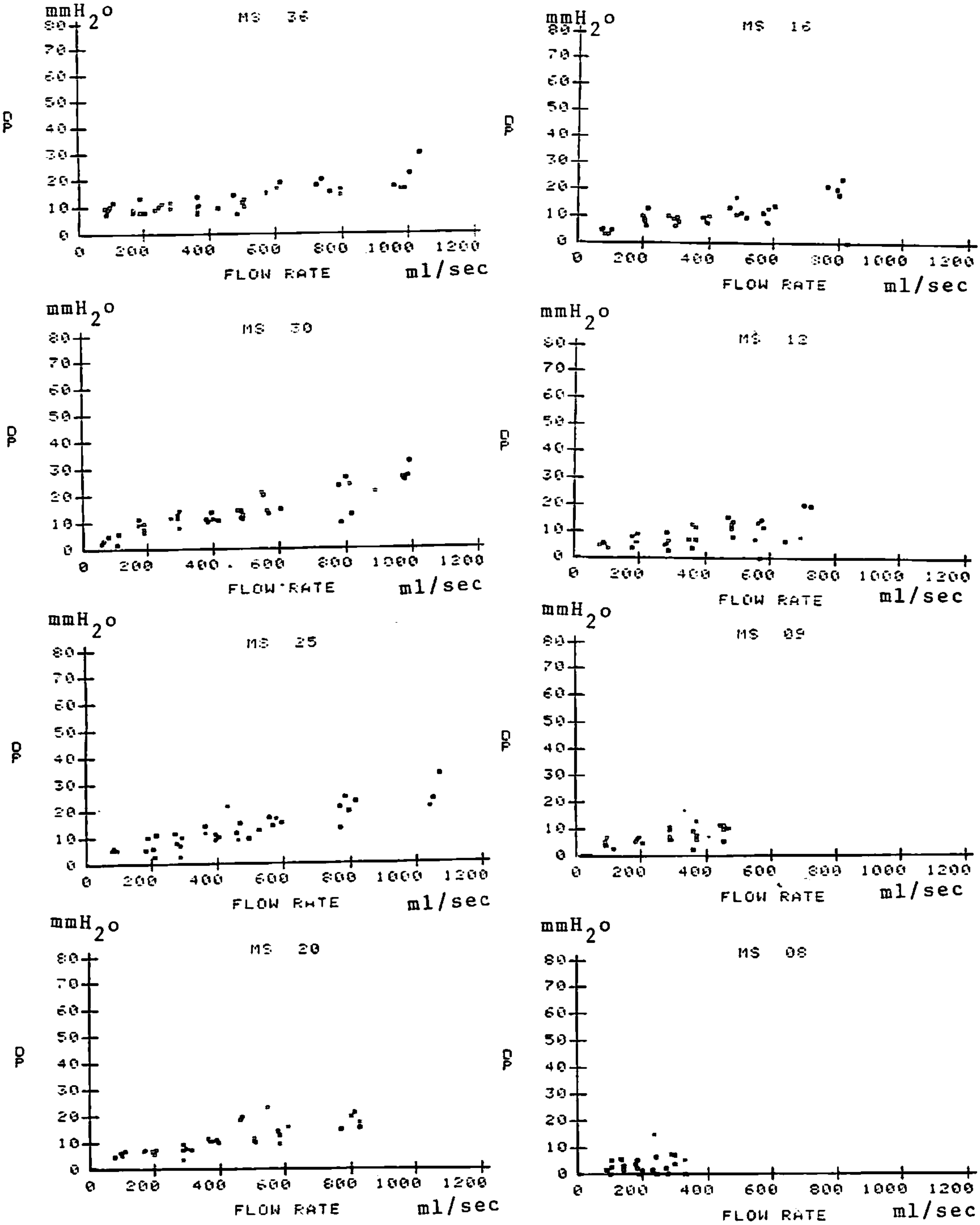


Fig. 4a Pressure difference between the expiratory air pressure and the pressure in front of the screen plotted in relation to the flow rate for each of the eight different screens for subj. MS.

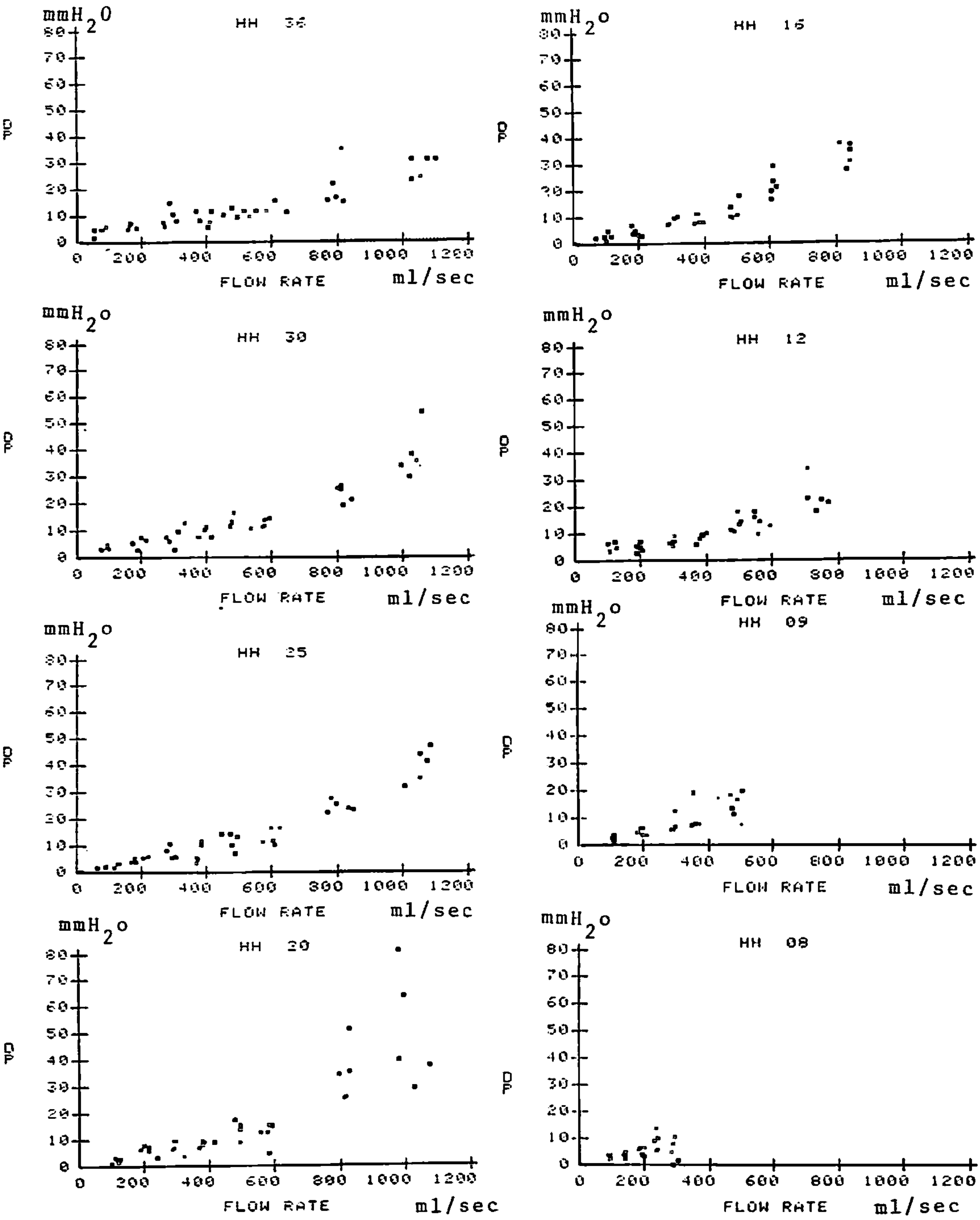


Fig. 4b Same information as in Fig. 4a, for Subj. H.H.

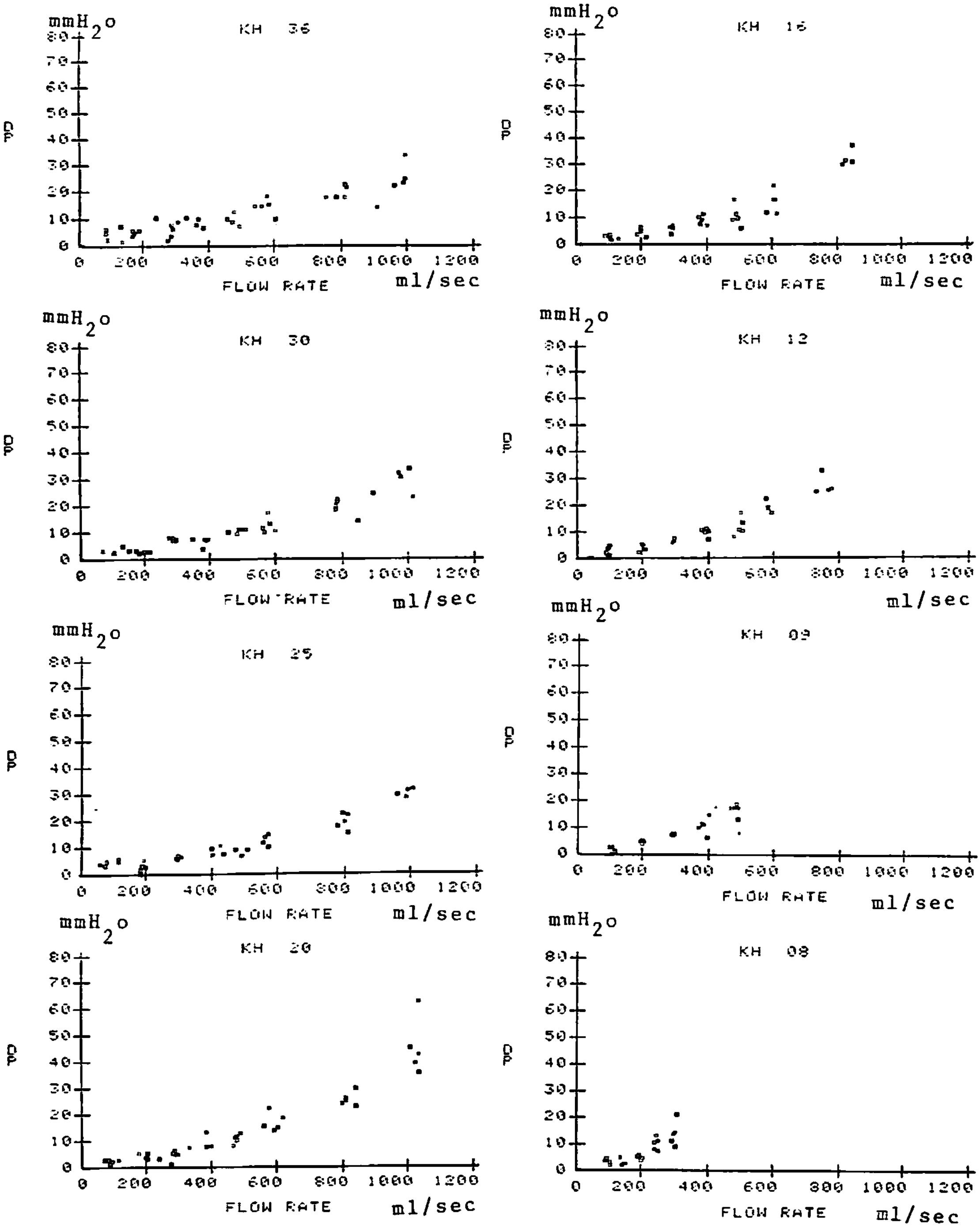


Fig. 4c Same information as in Fig. 4a, for Subj. K.H.