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Intraesophageal Microphone for Phonocardiographic Recording

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Determination of systolic time intervals requires a simultaneous high-speed recording of the electrocardiogram (ECG), phonocardiogram (PCG), and central pulse tracing (CPT).[1] The interval from the onset of the Q wave of the ECG to the initial high-frequency vibrations of the second heart sound (S_2) of the PCG (Q–S_2 interval) is a basic measurement. Unfortunately, the site of the surgical procedure or extent of the sterile field, patient position, or noise in the room may prevent the use of a precordial microphone.

We have recorded PCG's simultaneously from the precordium and from a standard esophageal stethoscope with a second external microphone. The PCG's recorded from the two sites were not consistently equivalent. An intraesophageal microphone was fabricated and recorded time intervals were found comparable to those obtained with the precordial method.

METHODS

Microphone Construction

Comparison of the onsets of S_2 as sensed simultaneously by a precordial microphone and by a microphone attached to a standard esophageal stethoscope revealed a variable delay in transmission. To eliminate this delay, a hearing-aid microphone was threaded down a standard esophageal stethoscope (Portex 24FG). The microphone output was fed into a small amplifier (fig. 1), which was powered by a 1.5-volt battery.¶ The output of this amplifier was fed into a Hewlett Packard 8813A heart-sound amplifier. With the stethoscope intact the leakage current was 6 microamperes with an applied voltage of 110 volts. A leakage current of 40 microamperes was produced when the stethoscope wall was not intact. This larger current can be reduced to less than 10 microamperes by placing an isolation amplifier (Analog Devices, Model No. 273K) between the microphone amplifier and the heart-sound amplifier.

The frequency responses of the assembled unit were equivalent to those of tracings from the precordial microphone.

Patient Application

Lead II of the ECG was amplified by a Hewlett Packard 8811A bioelectric amplifier. The precordial PCG was detected with a Sanborn P/N 62-1500-C13 dynamic microphone. A similar microphone was attached to a standard esophageal stethoscope positioned to obtain a clear tracing of S_2. Signals from the microphones were amplified with two Hewlett Packard 8813A heart-sound amplifiers. The three tracings were recorded simultaneously on a Honeywell 1858 CRT Visicorder at a paper speed of 100 mm/sec. The standard esophageal stethoscope was then replaced with the new esophageal microphone and another recording made.

Using a Hewlett Packard 9864A digitizer interfaced with a Hewlett Packard 9830A programmable calculator, six to ten Q–S_2 intervals from each of ten patients were measured in duplicate from the precordial PCG, and from the esophageal PCG using the external microphone. The procedure was repeated for the comparison of the precordial with the intraesophageal microphone. Using this method, the limits of discrimination are 2.5 msec with a repeatability of less than 5 msec.

RESULTS

To determine the reproducibility of measurements made on the Hewlett Packard digitizer, the Q–S_2 interval was determined twice from each of 174 recordings made using the precordial microphone. The results are shown in figure 2.

Figure 3 plots the Q–S_2 interval recorded using a standard esophageal stethoscope attached to an

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¶ The total cost of the microphone and amplifier was $15.00.

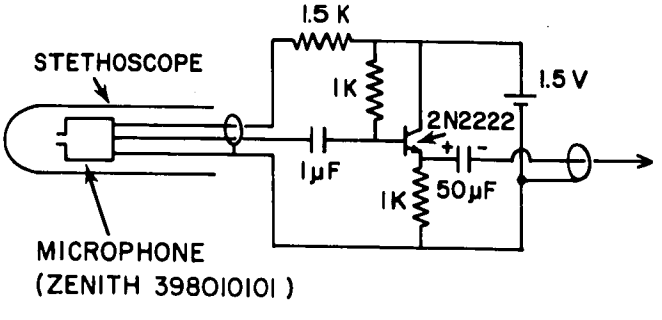

FIG. 1. Schematic diagram of the microphone amplifier.

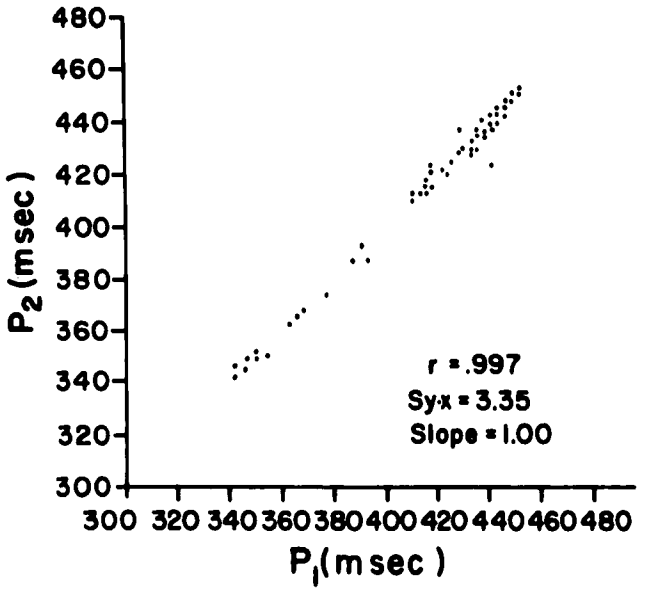

FIG. 2. P_1 represents the first reading of the $Q-S_2$ interval in milliseconds, and P_2 the duplicate reading.

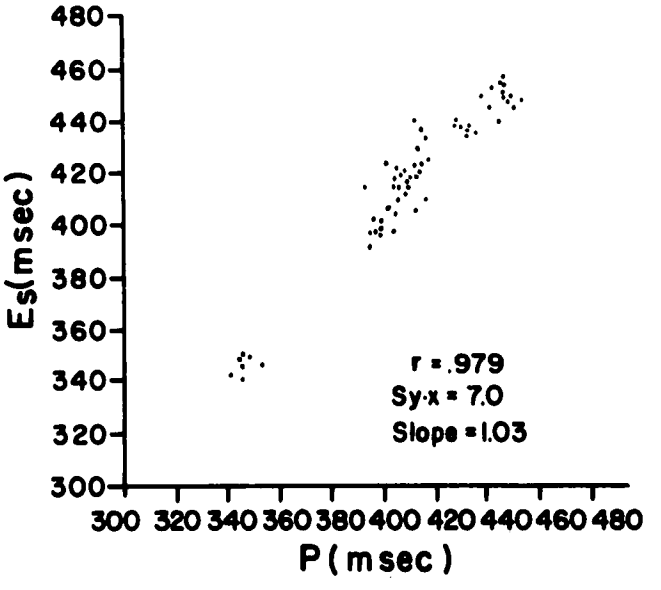

FIG. 3. The $Q-S_2$ interval as measured from the precordial microphone is plotted along the horizontal axis (P), and the $Q-S_2$ interval as measured using the standard esophageal stethoscope (E_S) along the vertical axis. ($E_S = 1.03 \times P - 17$ milliseconds.)

external microphone against the same interval measured from the precordial PCG. Overall there was a 5-msec delay in the results obtained for the esophageal stethoscope (mean precordial $Q-S_2$ = 411 msec, mean esophageal $Q - S_2 = 416$ msec), and the standard error of estimate was more than twice (7.0 msec) that for the control method ($P < .001$).

Figure 4 presents the same relationship for the PCG's recorded from the precordial and intraesophageal microphones. The standard error of estimate was 2.9 msec, which is not different from that for the precordial microphone ($P > 0.1$), but is less than that for the esophageal stethoscope ($P < .001$).

DISCUSSION

An external microphone attached to a standard esophageal stethoscope introduces a delay averaging 5 msec in the recording of S_2. This delay, if caused by sound transmission in air at 37 C, would not exceed 1.4 msec.[2] Our observations suggest that the frequency response of the system was inadequate to record the initial high-frequency vibrations. A constant delay in the onset of S_2 would have been tolerable, but the variability found precluded the use of this system in measuring the $Q-S_2$ interval.

The time intervals recorded using the intraesophageal microphone were equivalent to those obtained from the precordium.

The intraesophageal PCG was generally easy to obtain and had a better signal-to-noise ratio than the precordial PCG. We believe it represents an excellent alternative to the precordial microphone for use in anesthetized patients, and may find application in management of critically ill patients as well.

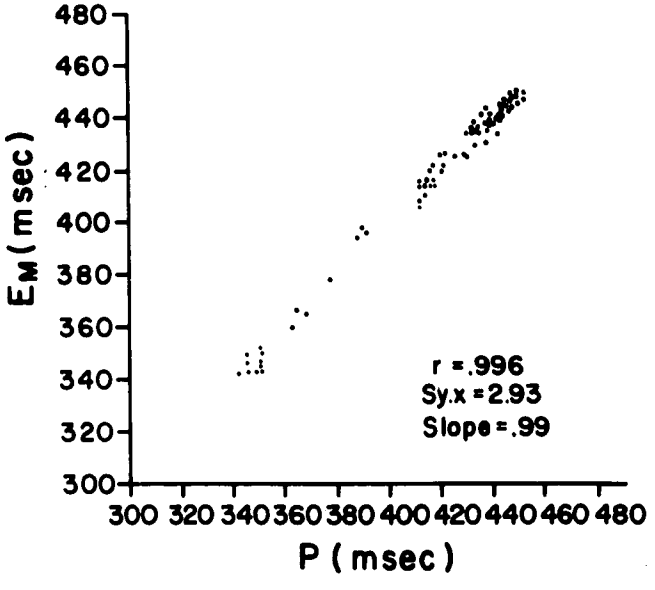

FIG. 4. The $Q-S_2$ interval as measured from the precordial microphone is plotted along the horizontal axis (P), and the $Q-S_2$ interval as measured using the intraesophageal microphone (E_M) along the vertical axis.

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