

FIGURE 1. Dr. William Hrushesky administers a Sine-O-Graph test to a patient. The earlobe clip senses heart beat, the mouthpiece senses respiration, and the computer performs analyses to determine RSA (Respiratory Sinus Arrhythmia).

RSA — RESPIRATORY SINUS ARRHYTHMIA

A New Measure of Cardiac Health

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Cardiologists, oncologists, gerontologists and sports physicians are among those who often need to know how well a person's heart is performing. Although an ECG can describe the heart's ability to generate and distribute electrical impulses, less available and more expensive procedures such as echocardiography are required to gain information about the heart's ability to pump blood efficiently. One indicator of this pumping ability—*cardiac filling pattern* (i.e., heart muscle compliance)—can now be examined with a noninvasive and

inexpensive computerized medical instrument called the Sine-O-Graph (Figure 1).

The Sine-O-Graph measures respiratory sinus arrhythmia (RSA), the variation in heart rate due to breathing. A healthy person's heart does not beat at a steady rate—the heart rate quickens during inspiration and slows during expiration. For many years, doctors have noticed that the amount of this breathing-related pulse variation, or RSA, decreases with age. RSA is prominent in children, and can usually

be noticed. As a person's diaphragm contracts, the chest cavity expands, and the drops. (In some cases, they were tau... appears after

Figure 1 shows the amplitude of the signal. In Figure 2, the amplitude is only 7 BPM.

RSA HISTORY

Although the Sine-O-Graph was first used in 1973 by Dr. Hrushesky, it was not until now that it has become a standard tool for analyzing heart rate variability. "guess" since cardiac arrhythmias are independent of respiration, Schmitt and his colleagues have shown that the amount of RSA is related to the amount of breathing. In a study of 100 patients, Schmitt found that the amount of RSA was significantly lower in patients with heart disease than in healthy patients. This finding suggests that RSA may be a useful indicator of cardiac health. In a study of 100 patients, Schmitt found that the amount of RSA was significantly lower in patients with heart disease than in healthy patients. This finding suggests that RSA may be a useful indicator of cardiac health.

In 1973, Dr. Hrushesky and his colleagues developed the Sine-O-Graph as a noninvasive method for measuring RSA. The Sine-O-Graph consists of an earlobe clip, a mouthpiece, and a computer. The earlobe clip senses heart rate, the mouthpiece senses respiration, and the computer performs analyses to determine RSA. The Sine-O-Graph is a simple, easy-to-use device that can be used in a variety of settings, including the doctor's office, the hospital, and the home.

SINE-O-GRAPH

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be noticed simply by taking a wrist pulse. As a person ages, however, his or her cardiac muscle becomes less responsive to chest-cavity pressure changes, so the RSA drops. (In fact, medical-school students once were taught that the RSA actually disappears after middle age.)

Figure 2 shows how heart rate varies during several respiration cycles. The RSA amplitude is one half of the peak-to-trough value of a fitted sinusoidal curve. In Figure 2, the RSA amplitude is approximately 7 BPM.

RSA HISTORY

Although the RSA was first observed in 1733 by Stephen Hales (1), attempts to accurately quantify the RSA have been, until now, less than adequate. Early methods usually relied on complex statistical analyses which tried, mathematically, to "guess" when the subject was breathing, since cardiac and pulmonary cycles occur independent of each other. In 1964, Otto Schmitt circumvented this difficulty by having subjects follow a visual prompt, which told them when to inhale and exhale (2). Using this method, Schmitt found that subjects could easily "synchronize" their respiratory and cardiac cycles by inhaling during a period of two heartbeats and exhaling over the next three heartbeats. Schmitt found that the instantaneous heart rate during this "voluntary cardiorespiratory synchronization" (VCRS) oscillated in a predictable pattern. However, because the results of a single VCRS test could take over two hours to compute, and the clinical relevance of the RSA had yet to be determined, the idea sat idle for almost two decades.

In 1982, Dr. William Hrushesky, an oncologist anxious to quantify the heart damage induced by cardiotoxic drugs such as adriamycin, came across Schmitt's attempts to measure the RSA. Hrushesky saw that if the instantaneous heart-rate data were fit to a sinusoidal curve (using a least-squares fit), the amplitude of the fitted curve could reproducibly describe the average extent of a patient's RSA. Noting that most of the earlier problems with Schmitt's VCRS method could be corrected using microprocessors and sophisticated (yet inexpensive) sensors, he created the Sine-O-Graph, a modern RSA evaluator.

SINE-O-GRAPH OPERATION

The Sine-O-Graph consists of specialized circuitry made to interface with the Apple

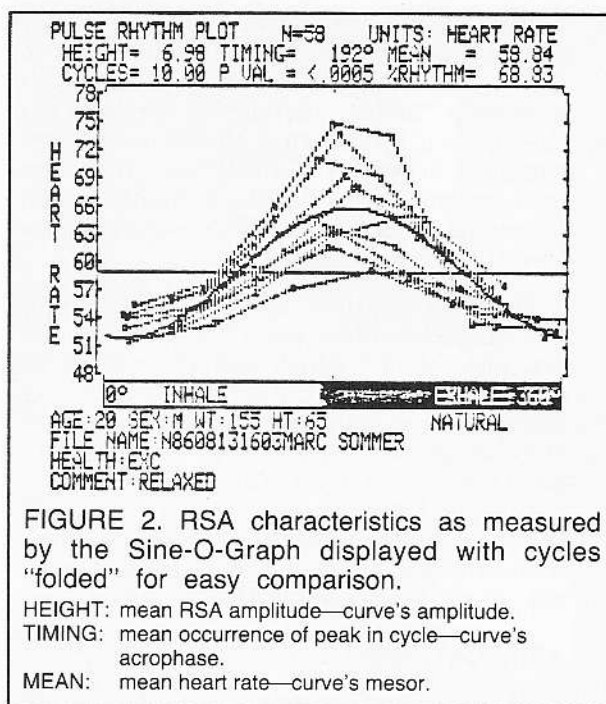


FIGURE 2. RSA characteristics as measured by the Sine-O-Graph displayed with cycles "folded" for easy comparison.

The personal computer, and Sine-O-Graph software on a floppy disk. To take a test, one loads the Apple's dual-disk drive with a Sine-O-Graph program disk and a data-storage disk (single drives may be used instead, but are sometimes less convenient). A unique file is created for the subject, and after the input of appropriate medical information and history, the program starts its actual data-collection process.

To collect data, two remote sensors are used: a painless photoelectric earlobe clip to detect heart beats and a mouthpiece to detect respiration and distinguish inhales from exhales (Fig. 1). These sensors transmit signals to the interface board, which immediately processes the information and stores it in memory. After a programmable number of breathing cycles has been completed, the computer stops collecting data and performs a detailed analysis.

DATA ANALYSIS

The Sine-O-Graph uses the methods of *cosinor analysis* (3); the data is plotted as heart rate vs point in breathing cycle and then fit with the best cosine curve (Fig. 2). This curve reveals several characteristics of the subject's RSA: the curve's "height" represents the *average RSA amplitude*, the "mean" shows *mean heart rate*, and the "timing" during a single breathing cycle reveals when the *RSA peak* occurs. These results, along with the statistical probability of the fit's validity, then can be displayed numerically or graphically.

The Sine-O-Graph can simultaneously graph the raw data and its fitted curve either continually over the entire test, either in a "folded" manner to compare cycles or in a format that shows means and standard errors. An entire test, from the moment one turns on the computer until he or she is shown the RSA results, takes less than five minutes.

The first versions of the Sine-O-Graph had subjects follow visual prompts on the computer screen which told them when to inhale or exhale. This form of VCRS was essentially a fully automated adaptation of Schmitt's method. Now, however, a subject may be tested by either VCRS or by a natural breathing method. The "natural" option records pulse and breathing data while the subject breathes at a pace he or she finds most comfortable.

APPLICATIONS

Because of its simple, noninvasive use and low cost, the Sine-O-Graph is ideal for RSA measurement in both research and clinical settings. Many studies suggest that RSA amplitude is an accurate indicator of cardiac health; the Sine-O-Graph is being recognized as an instrument with exciting practical significance.

Using the Sine-O-Graph, Hrushesky has collected data on over 1000 subjects. His findings show that the RSA amplitude decreases markedly as a person ages (4). For example, the RSA amplitude in twenty-year-old subjects averages 10 beats per minute but, for eighty year olds, this decreases to less than 1 beat per minute.

Using these data, Hrushesky has compiled tables of "normal" ranges for RSA amplitudes in specific age groups. These tables have been stored in the Sine-O-Graph's software and can be overlaid onto a subject's RSA graphs for comparison.

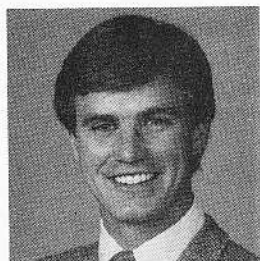
In addition to determining a subject's biological cardiac age, the Sine-O-Graph has also been used to quantify the amount of heart damage caused by cardiotoxic cancer drugs such as adriamycin. Hrushesky has found that the RSA amplitude drops significantly with progressive exposure to the drug in patients destined to develop clinically important levels of heart damage. Using the device, medical staff can be alerted to those particular patients' risk of developing congestive heart failure. If abnormal or progressively abnormal values are discovered, more expensive invasive testing may be indicated before proceeding with further treatments.

Other researchers are using the Sine-O-Graph to answer theoretical questions pertaining to the heart, and the basic mechanisms involved in RSA. The effects of high blood pressure, alcohol consumption and certain drugs are also currently being studied with the Sine-O-Graph.

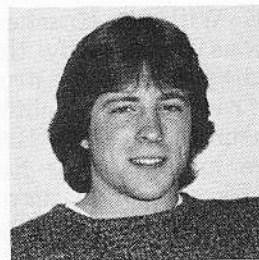
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The Sine-O-Graph is manufactured by the Sine-O-Graph Corporation, 3123 James Avenue South, Minneapolis, MN 55408, 612/825-3224.

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