How to tell heart rate from an ECG?

Standard textbooks of physiology and medicine (1-4) mention that heart rate (HR) is readily calculated from the ECG as follows:

- HR = 1500 / RR in mm
- HR = 60 / RR interval in seconds.
- HR = 300 / number of large squares between successive R waves

In each of the above instances, the authors are actually referring to instantaneous heart rates, which is the number of times the heart would beat if successive RR intervals were constant. However, a few authors (5-7) have clearly mentioned that this formula should be used only if the rhythm is regular and have suggested a correct alternative. Because the above formula is almost always mentioned, students determine HR this way without looking at the ECG any further. This may deprive them of meaningful information that we seek to obtain by estimating HR. We found out that this is indeed the case by administering the following multiple-choice question to a large number of doctors (n = 150) who had graduated in the past 2 – 3 years and medical students doing internship (n = 125).

Select the single best response.

How do you determine heart rate from an ECG?

A. 1500 / RR interval in mm
B. Determine the number of RR intervals in a 10 second strip and multiply by 6
C. Counting number of QRS complexes in 5 small squares and multiplying by 60.

Eighty one percent (221 of 272) chose option A. We also asked interns (n = 40) and postgraduate students (n = 50) to determine HR from a lead II ECG strip showing

marked sinus arrhythmia. Each was questioned separately. Only 27 of 90 calculated HR by averaging RR intervals over a six or ten second period. Students who reflexively used the “1500 / RR formula” either said 60 beats per minute (BPM) or 75 BPM or 90 BPM – the result depended on the RR interval that caught their eyes first!

Let us go over the basic facts to determine what actually needs to be done.

How did this formula come about? What does the term ‘heart rate' mean? Does it have more than one meaning?

The ECG paper which moves at a speed of 25 mm per second moves 60 × 25 = 1500 mm per minute. HR (by which we mean ventricular rate or QRS rate) is the number of cardiac cycles per minute (5) or more correctly the number of times the heart beats per minute. It can be estimated by counting the number of QRS complexes in a 10 second period and multiplying that by 6 or by counting the pulse for 10 seconds and multiplying that by 6.

If one RR interval measures 20 mm, then HR is 1500 / 20 = 75 BPM. The value so obtained should be routinely called “instantaneous heart rate” (8), a term that is usually not mentioned in textbooks of medicine or physiology but frequently used in research. It is the number of times the heart would beat in one minute if the duration of successive cardiac cycles were constant. In certain instances (see ECG 3 mentioned below) the term HR is used to refer to instantaneous HR rather than an average rate. Even normally, cardiac cycle duration varies from beat to beat. For example, it fluctuates with phases of respiration. During inspiration, RR intervals become shorter and during expiration, they become longer. This is especially true if one is breathing slow and deep. This phenomenon is called respiratory sinus arrhythmia. In this instance, if one were to take a shorter RR interval into

consideration for calculating HR, then the estimated rate would be higher. If one were to take a longer RR interval instead, the estimated rate would be lower than actual.

What information are we seeking to derive from HR?

Our idea is to obtain an estimate of cardiac output and to assess the relationship between the prevailing BP and HR over variable periods of time (from as short as 2 seconds to as long as a minute).

What are the various means by which HR can be determined?

- Auscultating the heart (heart rate)
- Examining the pulse (pulse rate)
- Looking at an ECG (QRS rate or ventricular rate)

What extra information does the ECG provide that one cannot readily obtain by palpation of arterial pulse or auscultation of heart?

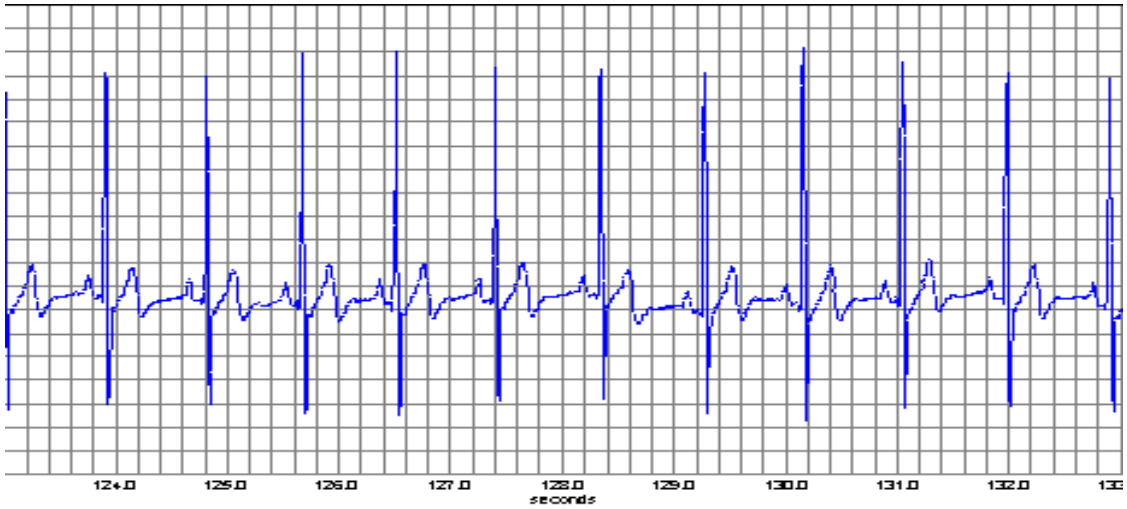
First, cardiac rhythm is best determined from an ECG and irregularities of rhythm (arrhythmias) may be readily identified and quantified. Second, one could determine where each cardiac impulse originates (i.e. the pacemaker for each beat). Normally, it originates in the SA node and the rhythm is called sinus rhythm.

How must HR be determined from an ECG?

Before calculating HR, we must assess rhythm. To do both of this, we obtain what is commonly called a rhythm strip. Generally, a lead II ECG is taken for at least 10 – 15 seconds. We must determine where each impulse is originating. Is each QRS

complex preceded by a P wave? Is PR interval normal? Three examples are mentioned below.

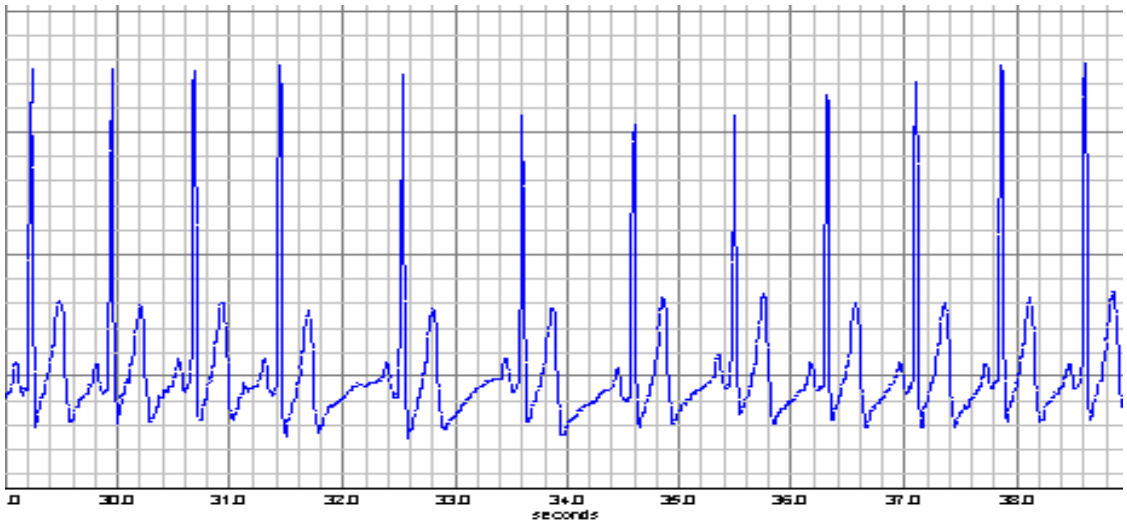
ECG 1:



If the rhythm is regular as in ECG 1, i.e. successive RR intervals are fairly constant, then 1500 / RR in mm may give a reasonably accurate value of HR. However, if RR intervals vary, it is best to determine the number of RR intervals that are contained in a 10 second strip and multiply this by six.

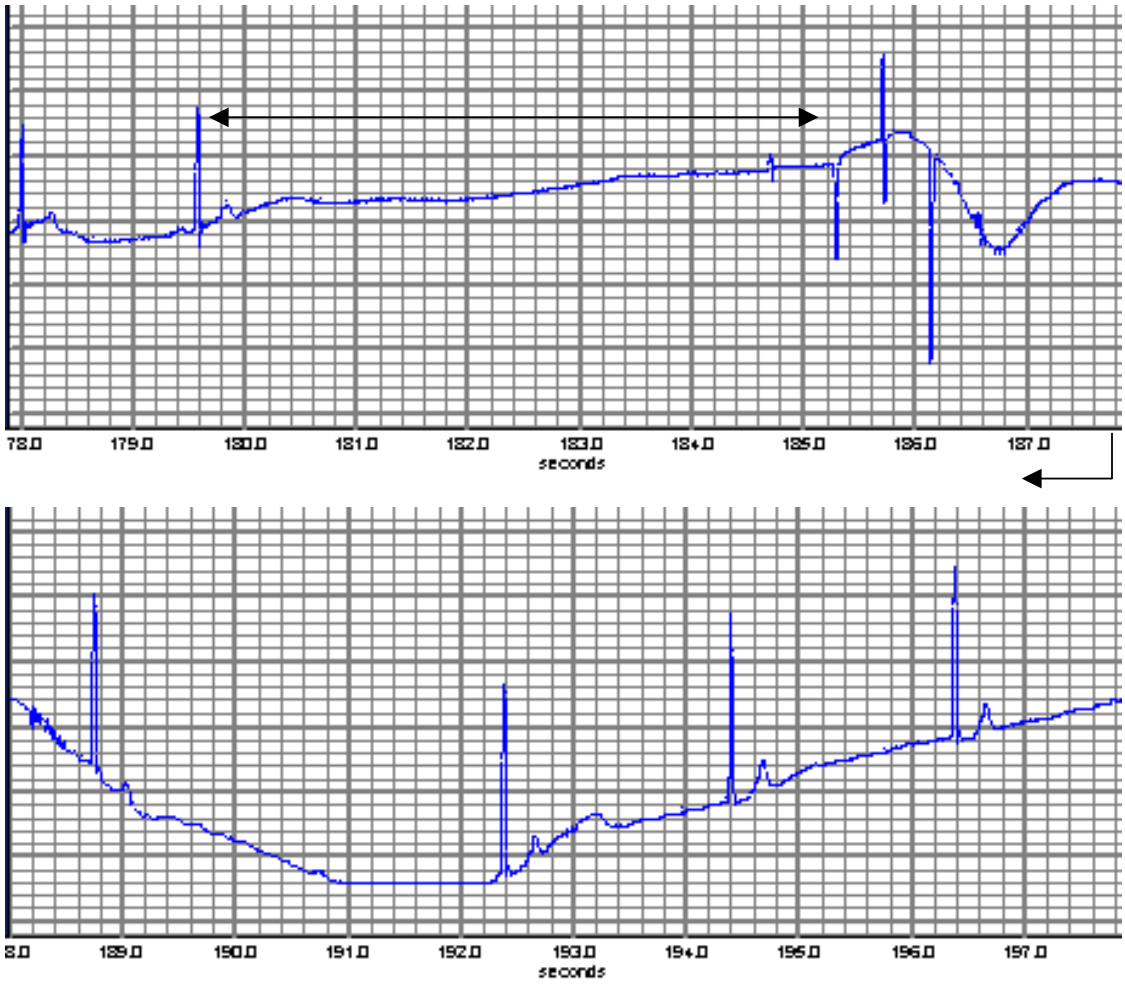
In this example, RR interval = 20 mm, HR = 1500 / 20 = 75 BPM. There are 11 RR intervals in a 10 second strip. Therefore average HR = 66 BPM. Most ECG papers have every fifth or fifteenth square marked (1 or a 3 second interval) with a vertical line on the upper border for this purpose.

ECG 2:



In this ECG, RR intervals vary considerably. However, each QRS complex is preceded by a P wave and PR interval is normal. This physiologic phenomenon is called sinus arrhythmia. The number of RR intervals in a 10 second strip must be multiplied by 6. In this example, 11 RR intervals are present in 10 seconds and HR = 11 × 6 = 66 BPM.

ECG 3:



In this example, it is not correct to simply average as we suggested above. Here, we must calculate rate over shorter durations and it may be as short as one cardiac cycle. In the upper panel of ECG 3, we may say, “at this instant (marked) the heart has stopped”, because RR interval = 6 seconds (equal to a HR of 10 BPM). This would be then easily interpreted as having occurred due to a particular physiologic mechanism (a sudden increase in cardiac vagal outflow). In the lower panel, we see a further period of asystole (3.5 seconds = a rate of 17 BPM) followed by escape beats at a rate of 30 BPM. Here we are referring to either instantaneous heart rate or heart rate calculated over very short periods of time (2 – 4 seconds) and average heart rate calculations over longer durations do not make much sense. In summary,

when the duration of cardiac cycles is changing quickly, then HR must be determined over shorter time periods during which RR intervals are fairly constant.

Key Points

1. We suggest that the term instantaneous heart rate be used regularly in textbooks and a distinction made between this and average heart rate.
2. To determine HR from an ECG, RR variability must be assessed. If successive RR intervals appear relatively constant, then average HR is approximately 1500 / RR in mm.
3. If RR intervals vary, average HR (ventricular rate) should be estimated by determining the number of RR intervals in a 10 second strip and multiplying this by 6.
4. If cardiac cycle duration changes significantly and abruptly, then HR should be calculated over shorter periods of time (it may be as short as one cardiac cycle) to correctly interpret underlying physiology.

Learning Objectives

The learner should be able to:

1. Define and calculate instantaneous heart rates
2. Identify RR variability in an ECG, define sinus arrhythmia
3. Calculate HR correctly when RR variability is considerable
4. Determine whether to calculate average HR or instantaneous HR as appropriate

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