FlowTrace® ECG, Diastolic/Systolic Ratio (D/S), & Diastolic Filling Percentage (DF%)

AureFlo's FlowTrace® software uses ECG signals to analyze and display D/S Ratio and DF%, two expressions used to represent the amount of blood flow through a bypass graft that occurs during diastole. A D/S Ratio compares diastolic flow to systolic flow, and a DF% compares diastolic flow to flow occurring during both systole and diastole.
Expressed mathematically:

$$\text{D/S Ratio} = \frac{\text{average diastolic flow}}{\text{average systolic flow}}$$

Transonic's D/S Ratio is an extension of Transonic's FlowSound® analysis. Surgeons are encouraged to listen to FlowSound® while simultaneously examining the corresponding flow waveform. FlowSound® and waveform analyses correlate with Transonic's coronary artery graft assessment where:

- o A high D/S Ratio indicates a diastolic-dominant flow profile.
- o A D/S Ratio between 1 and 2 indicates a balanced, diastolic-systolic, flow profile.
- o A D/S Ratio <1 indicates a systolic dominant flow profile.

Diastolic Filling is expressed as a percentage:

$$\text{DF\%} = \frac{\text{average diastolic flow}}{\text{total (diastolic + systolic) flow}} \times 100$$

- o A DF% >50% indicates a diastolic-dominant flow profile.
- o A DF% approximating 50% indicates a balanced, diastolic-systolic, flow profile.
- o A DF% <50% indicates a systolic dominant flow profile.

ECG Signal Specifications

Transonic® AureFlo® Flowmeters have ECG signal capability derived from a patient-connected ECG-capable device such as the anesthesia monitor. The ECG signal source is connected to a compatible HT300-Series Flowmeter via a cable provided with the AureFlo® system (see AureFlo® Operators Manual for detailed instructions). A biomedical specialist should be consulted to connect the Flowmeter to the ECG signal device. The ECG is pre-amplified to standard levels, and is often displayed on a standard grid so users may directly read it in "millivolts" and "milliseconds" (Fig. 1.)

Fig. 1: ECG signal that will be recognized by Flowtrace® software. The R-peak of the QRS complex is the highest signal peak, the point when the systolic contraction starts to affect the flow waveform. The peak of the T-wave is the point where diastolic relaxation starts to affect coronary flow, typically 200 mSec after the R-peak.

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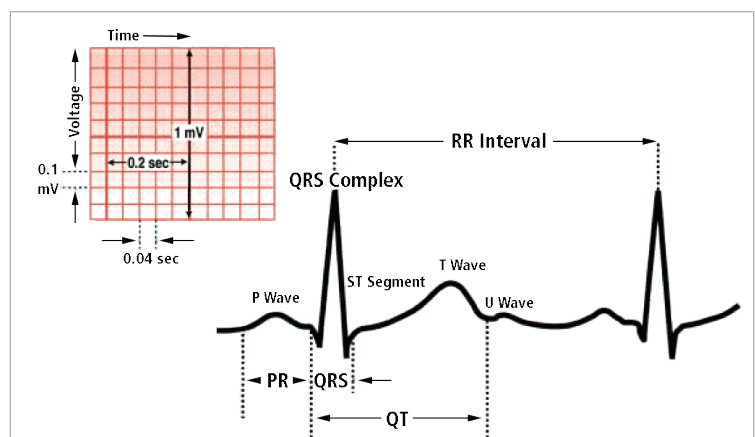
FlowTrace® ECG, Diastolic/Systolic Ratio (D/S) & Diastolic Filling Percentage (DF%) Cont.

Diastolic/Systolic Calculation Prerequisites

In order to clearly delineate systolic and diastolic phases of a flow waveform, FlowTrace® relies on a signal analysis of the ECG trace. FlowTrace® only performs the calculation of the D/S Ratio with associated flow waveform coloring when it:

- Is connected to a compatible HT300-Series Flowmeter
- Has a stable ECG signal that can be analyzed by Flowtrace® software to identify systolic and diastolic phase demarcations.

The presence of blue/red colored signals during CABG mode of FlowTrace® indicates good ECG signal connection and waveform. If an ECG appears, but doesn't colorize, a different lead should be selected.

Diastolic/Systolic Phase Colorization

Real-time Waveform Colorization

FlowTrace® colorizes both the ECG and flow waveform in real time with systolic phases colored red and diastolic phases colored blue, so that the surgeon can see, at a glance, the electrical and mechanical functions of the heart. Therefore, the D/S ratio can be defined as: "The ratio between systolic and diastolic areas in the flow waveforms, where the systolic phase and the diastolic phase coincide with the heart's contraction and relaxation as derived from the ECG signal leads connected to a compatible HT300-Series Flowmeter." These areas under the waveform are used to calculate the D/S ratio or DF%.

Snapshot Mode Waveform Colorization

FlowTrace's® Snapshot Mode will also colorize the systolic and diastolic waveform phases (in the presence of a valid ECG signal). Snapshot's colorization and D/S Ratio calculation use an algorithm derived from retrospective analysis of a larger number of ECG cycles, and flow averaging over the full retrospective snapshot.

Differences from a Chart Recorder's Visual Identification of Systole and Diastole

FlowTrace® identifies the systolic and diastolic phases of the heart's electrical activity on the ECG. HT300-Series Flowmeters utilize mean flow, Flowsound®, and a strip-chart recorder to analyze and record the effects of the heart's contraction and relaxation. Because electrical evidence of contraction and relaxation precede the mechanical effect, there is a slight time delay noted between the colorization points on the ECG and the corresponding points on an AureFlo® flow waveform. During isovolumetric contraction, there is no initial systolic effect on coronary flow. Comparably, during isovolumetric relaxation, coronary flow continues to perfuse the myocardium. These time lags result in coronary flow overlapping into the next mechanical phase of the heart's cycle, and the delays are reflected on the flow waveform.

FlowTrace® Diastolic/Systolic Identification Summary

The D/S ratio and DF% both represent comparisons of diastolic volume flow to systolic flow or total flow to determine whether a patient's graft flow has diastolic or systolic dominance.
A suggested decision tree entails, in order:

1. Assess mean flow
2. Assess flow waveform morphology
3. Assess pulsatility index (PI)
4. Assess D/S ratio or DF% in the context of the flow waveform

If any point on the above list should any of the findings be of concern, coupled with the surgeon's clinical judgment, graft revision could be considered.