Breath-by-Breath vs. “True” Breath-by-Breath

By John Hoppe

- What does it mean when a Metabolic Measurement System offers Breath-By-Breath (BBB) measurements?
- What is so-called “true” BBB?

Traditional (meaning older) instruments calculated data in fixed time intervals only, such as 30 or 60 seconds. This was because gas analyzers were slow and unable to follow the exhaled gases breath contour. When faster gas analyzers and reasonably priced computers became available, fast on-line breath-by-breath computations promised more, or better information.

The first attempts at BBB computations are now referred to as “true BBB”. Proponents of “true BBB” would like you to believe that “true” means “correct” or “better”.
The purpose of this paper is to dispel that notion.

To understand the problems and difficulties with “true” BBB systems, one must fully comprehend how “true” BBB calculations are made.

Two factors affect gas analyzer signal output: One is “Travel” time, this is the time it takes gas to flow from its source, usually a sampling port near the mouth, until it arrives at the actual gas sensor. Travel time is a function of the inner diameter of the sampling tube, tube length, pumping speed, gas viscosity and gas humidity. The other is sensor response time; this is the time it takes the sensor to respond to a step change in gas concentration. Together they are usually just referred to as “Delay Time”.

Flow and volume measurements can be considered instantaneous; there is no time delay between the exhalation and the measured expiratory flow.

To compute VO2 and VCO2 correctly, the instantaneous flow measurement has to be multiplied by the gas measurement belonging to this same breath.
Since the gas measurement will not be known until after the “Delay Time” has passed, the system software must hold the flow profile in memory until the corresponding gas measurement is available.

Sounds simple enough, but before proliferation of computers was impractical.

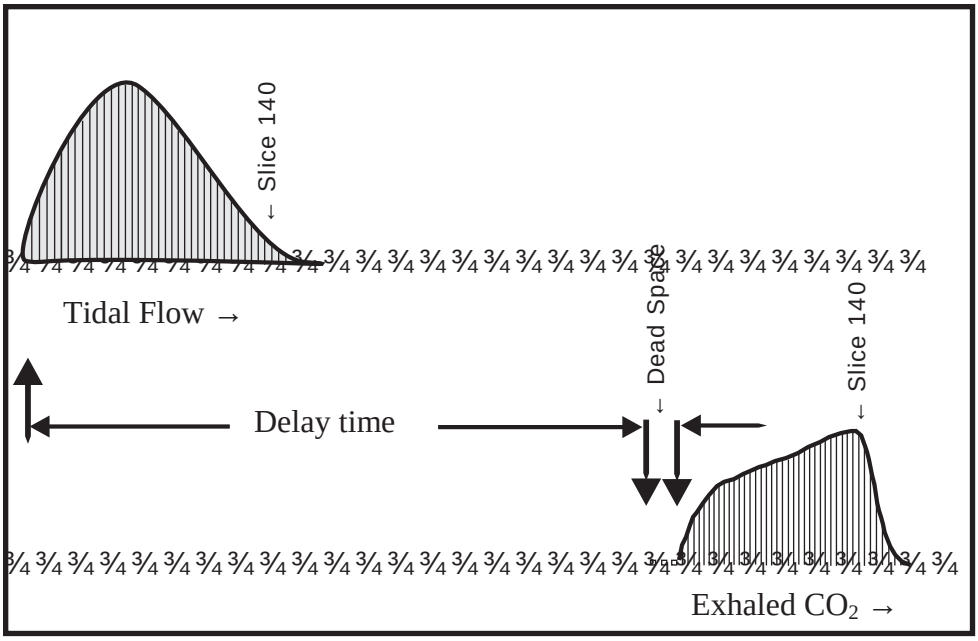

Fig 1

Enter “true” BBB. Figure 1 shows the VO2 and VCO2 calculation of true BBB systems. Both the Volume or Flow signal and the gas signals are digitized, essentially sliced into many fragments at the, typically 200 hertz, sampling rate of the data acquisition system. At a breathing rate of 40, this means that a typical exhalation breath and gas contour will be separated into 150 slices.

Now, flow slice number 1 will be multiplied by gas concentration slice number 1, which corresponds to anatomical dead space gas, thus practically air, and so on. Since several initial slices of exhaled gases are practically void of any significant metabolic content, but are being multiplied by high flow typical of the beginning of exhalation, the probability of error due to temporal misalignment is very high.

Conversely, note that at the end of the breath, CO2 is the highest (EtCO2), but flow is the lowest.

Calibration of all metabolic measurement systems is done with the flow sensor and the sampling tube at room temperature, and ambient humidity. During a test both get saturated with water and the temperature is higher. Does this affect “Delay Time”?

Now take a look at slice number 140, flow is now low, but CO2 is at its maximum. An increase in delay time of just 10 slices (equal to just 50 milliseconds) means that the maximum CO2 level is multiplied by ZERO, meaning it is not counted at all.
Of course the same happens to O2, for both early and late slices.

Therefore, the issue is that true BBB systems are extremely sensitive to minute, unforeseeable changes in delay time, producing results with unpredictable accuracy, as multiplication errors of the early and late phases of exhalation are being summed up in computation of total VO2 and VCO2 of every breath.

What physiological process is so time-sensitive that you need to know the intra-breath variation in VO2 and VCO2? Surely there are a handful of people out there who actually have an answer. But as far as we know none of the metabolic measurement systems on the market report intra-breath VO2, they only report the result for each completed breath. Even that data is unacceptably noisy, so typically, several breaths are averaged to obtain usable results.

Vacu·Med's "Vista" metabolic measurement systems offer a better, simpler BBB calculation. It has to do with proportional sampling.

Using proportional sampling we draw a small sample of the exhaled gas at the mouth. "Proportional" means that at low exhaled gas flow, our sample pump runs slow, at high exhaled gas flow, the sample pump runs proportionally faster. A mixing motor rapidly mixes the gas so that the gas analyzer only sees constant mixed exhaled values for any given breath.

Vacu·Med uses a permanently calibrated, micro-processor compensated volume transducer. Each rotation of the turbine blade produces two pulses corresponding to 10 ml each, which makes totalizing a breath volume very simple. Count the pulses then multiply by the pre-calibrated pulse volume. So we do not multiply slice by slice, but total by total. This also eliminates any conversion error of flow sensors, such as pneumotachometers, that must be calibrated for different flow ranges with multiple strokes of a calibration syringe prior to each test. Furthermore, every flow sensor except the turbine is sensitive to the chemical composition of gases.

It should be obvious here that a minor change in delay time using Vacu·Med's method has no effect on the result.

This is one of the reasons Vacu·Med can guarantee the accuracy of the VO2 and VCO2 measurement to be better than 3%, while the manufacturers of true BBB systems are suspiciously silent about the accuracy of their systems.

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