



Calibration of Conductance Signal for LV Volume Studies

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The Scisense Conductance system outputs an analog voltage that is proportional to the conductance measured in the left ventricle (LV). Since conductance measured in the LV is proportional to the volume of blood in the LV, we can use this voltage signal to make a blood volume measurement of the LV. Before we can use the analog voltage output from the conductance system, it is necessary to calibrate, or scale, the signal so that it represents conductance values. The actual calibration calculations are performed by the data acquisition system being used. The calibration signals are provided by the Scisense conductance system.

Calibration of a linear relationship assumes that the equation $Y=MX+B$ is true for the particular application. In our case, "Y" is the value of conductance measured in the LV. "X" is the raw voltage output from the Scisense Conductance system. We further assume that our graph is going to pass through the point where both $X=Y=0$, hence offset "B"=0. What we need to determine is "M", the "slope" or "scaling factor" that translates the voltage signal "X" to the required conductance value shown on a graph.

In order to determine "M", let's re-arrange the linear equation. Since "B"=0, we can rearrange as $M=Y/X$. "X" is a measured value and is known at all times. If we provide **two** known values of "Y", corresponding to the measured "X" values, we can determine the value of "M" as $M= Y/ X$

The Scisense conductance system has built in conductance signals that are used as **known** calibration values. The device that generates conductance values (measured in "Siemens") is called a "Mho Box". The Mho Box generates conductance signals in the μ Siemens range, for example 750-3745 μ Siemens in the case of the mouse scale

If we select 750 μ Siemens (Y_1) and 3745 μ Siemens (Y_2) as our two calibration points, the equation for "M" will be $(Y_2-Y_1)/(X_2-X_1)$. If our values for X_1 and X_2 are 0.47 and 4.3 Volts respectively, $M= 2995/3.83=886.1$. What this means is that for any value of X that is output by the conductance system, the calibration program will multiply the value by 886.1 to arrive at the corresponding μ Siemens value. In this case, the display will be calibrated in **μ Siemens** along the "Y" axis and time on the "X" axis.

Converting Conductance Values to Relative Volume

If we wish to convert the **μSiemens** values to volume measurement, we need to use the following equation:

$$V = 1 / (\rho \cdot L^2) \cdot (G - G_p) \quad (\text{eq 1})$$

$$V = 1 / (\rho \cdot L^2 \cdot G) - 1 / (\rho \cdot L^2 \cdot G_p) \quad (\text{eq 2})$$

In the above equations ρ = blood calibration factor, ρ = blood resistivity, L = segment length of the catheter, sized to match the long axis of the LV, G = conductance of blood. G_p = parallel conductance path, comprising any conductance path exposed to the electrical field that is not the blood volume in the LV. It will cause the volume measurement to be artificially high. Later on, we will look at a method for establishing this value, but for now we will ignore its contribution (**$G_p = 0$**) and use the following simplified equation for calculating **relative volume** of blood in the LV:

$$V = 1 / (\rho \cdot L^2 \cdot G) \quad (\text{eq 3})$$

Lets look at equation 3 and some of its variables:

- The value ρ is a volume calibration factor. It is experimentally derived. It compensates for the LV not being a perfect cylinder and the fact that the electrical field in the LV is non-homogeneous.
- The value ρ is the resistivity of blood. It is **assumed** to be 66 ohm cm at 38°C for a typical animal. This is not strictly true and will change with temperature and **any** drug administered to the subject. It will also vary between species of gene-altered mice. This value can be measured either at the conclusion of the experiment or in some cases serially as the experiment progresses.
- The value L is the segment length of the catheter, measured center to center and ideally matching the length of the LV long axis.
- G is the measured value of conductance. It will be the value on the “Y” axis of the calibrated conductance output. **This parameter is what the Scisense Conductance Catheter measures.**

Solving equation 3 for the conductance values of 750μSiemens and 3030μSiemens, will yield corresponding volumes of 10.2μ and 40.5μL. (For mice, ρ will be close to 1.) The final **relative volume** will be 40.5-10.2=30.3μL. This value is relative because it still includes the conductance measured outside the LV blood volume. However, any change in the conductance value will come from the blood volume increasing and decreasing with each heartbeat, and thus meaningful data is available to the investigator without having to determine the values of parallel conductance.

Calibration Using a Graduated Cuvete

A second method of calibration involves using **known volumes** as inputs to the calibration software. This is done by using a “Cuvete” a device with holes drilled to a precise diameter, so that when combined with the distance “L” of the ring spacing on the catheter, will give a known volume. The actual depth of the holes in the cuvette is not critical, as the conductance will be measured only for that portion that falls between the electrodes.

The cuvette is used with either heparinized blood or a saline solution. It is important that this solution have the proper conductance values, matching that of blood. **In order to measure this value, a conductance meter will be necessary.** These are commercially available. Temperature of the saline solution is also critical, as it will affect the readings. Note that heparin will not only keep the blood from clotting, but it will also affect the conductance value of the blood.

If the catheter rings are immersed in the known volume of saline, a conductance will be measured corresponding to that volume. The conductance will be converted to an analog voltage signal and sent to the data acquisition input.

Since the analog signal represents a known volume, it can be used as one of the two calibration values. A second value is found by inserting the catheter into a larger volume point in the cuvette. This will generate a second calibration point. If these two values are entered into the calibration program, then it will generate the slope for the linear equation.

Estimation of Parallel Conductance Offset Value.

As previously mentioned, equation 1, is used to convert measured LV conductance values to LV blood volume.

$$V = 1 / (L^2)(G - G_p) \quad (\text{eq 1})$$

or

$$V = 1 / (\text{LV volume} - \text{Parallel conductance volume}) \quad (\text{eq 2})$$

G=conductance of blood.

G_p=parallel conductance path, comprising any conductance path exposed to the electrical field that is not the blood volume in the LV.

The electric field generated by the catheter is not entirely restricted to the interior of the LV. Because of this, the conductance signal measured by the catheter rings represents a sum of conductance values for the LV blood pool and the surrounding tissues. In order to obtain an accurate value of LV volume, it is necessary to determine and subtract the extra-ventricular component of the

conductance signal. The saline bolus dilution method is the preferred way of performing this correction. This involves injecting a small bolus of hypersonic saline solution such that it washes into the LV without creating an actual change in pressure or volume. The image below is an excerpt from [Am J Physiol Heart Circ Physiol 279: H1411-H1420, 2000](#). It shows the procedure for a pressure volume loop that is calibrated in conductance values (micro Siemens)

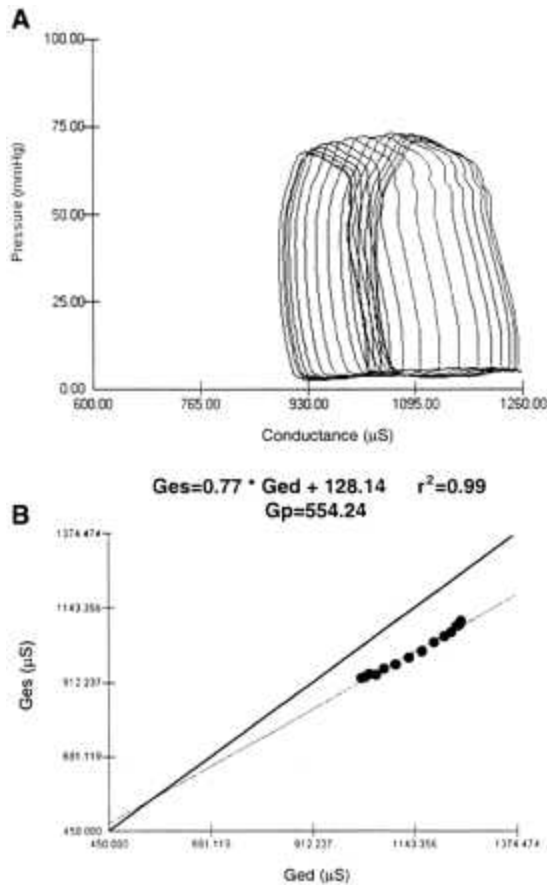


Image A shows the PV loops as the saline bolus washes in to the LV. The higher conductivity of the blood creates an increase in the conductance signal that is apparent as a shift to the right. To determine Gp the points of maximum and minimum volume from each beat during the wash-in are plotted against each other and linearly regressed. (**image B**) The point where the line of regression meets the line of identity (stroke volume would be zero at this point because end systolic conductance = end diastolic conductance).

Many of the commercially available software packages will perform the calculations required for parallel conductance measurement.

Summary

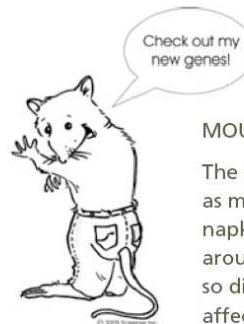
Proper calibration of conductance signals is essential for determining absolute values of blood in the LV on a beat-by-beat basis. The technology is well understood and well published. Derivation of precise volumes will depend on the researchers needs and the proper experimental method for determining all of the variables in the volume equation.



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The mouse'n genes was conceived, as many great ideas, on a restaurant napkin. As a serious discussion around transgenic mice evolved, so did Sammy Scisense, as he is affectionately known today.

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