Wilson's Central Terminal, the keystone to electrogram recording – What, where and why?

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Even amongst Cardiologists and Cardiac Physiologists there is considerable inconsistency in the understanding of Wilson's Central Terminal (WCT), an unusual situation considering the ubiquity with which it used both in electrocardiography and invasive electrophysiology. (1) (Figure 1) The WCT was developed, by Frank Wilson in 1934, in order to allow the possibility of straightforward and consistent unipolar recording. Eighty years later, it is still the keystone to electrogram referencing. Conceptually, the unipolar recording is that of a point source. Intra-cardiac point source or unipolar recordings may be particularly beneficial when information regarding directionality is needed, as in the ablation of accessory pathways or focal atrial and ventricular tachycardias (looking for the QS pattern of retreating activation), and when examining farfield events, such as using endocardial recordings to examine epicardial depolarization. (2) On the other hand, the more commonly used bipolar recording, which is the difference between to two closely spaced unipolar signals, is useful for assessing local events as the two 'near identical' farfield signals are effectively 'subtracted out'. Furthermore, a unipolar signal can be made to approximate a bipolar signal by increasing the high pass filter from the normal value of 0.5-1Hz to around 30Hz, when directionality information will be lost. This occurs because high pass filters effectively differentiate the signal such that the new signal becomes proportional to the rate of amplitude change rather than the amplitude itself.

Unipolar electrograms are derived from the potential difference between a point source using an exploring electrode in direct contact with the heart (positive input - anode) and a zero reference (negative input - cathode). Theoretically, in a homogenous infinite medium, the potential at infinity may be zero. In reality, there can be no zero potential recorded from the human body or even the earth, which are finite conductors. In fact, what we are really achieving with a unipolar recording is the potential difference between a variable source (the exploring electrode) and a relatively static source, such as the earth would be. The misnomer of a zero potential was eloquently explained in an article, directed at electrophysiologists, by Burger, a physicist, in 1955. (3) Traditionally and presently, the 'zero reference' used is the WCT. (4) The WCT was originally developed for use in electrocardiography as the 'zero' for the precordial leads, which are also unipolar recordings, in contrast to the limb leads that use a bipolar configuration. We now also use the WCT for most of our invasive electrophysiology recordings, including those that involve 3D mapping systems. This clever solution avoids the complexities of having to earth a subject whenever a recording is taken. Prior to Wilson developing the WCT, a limb lead was used as the 'zero reference' for precordial unipolar recordings. As the sensitivity required to record from an external precordial, versus direct epicardial electrode needs to be great, this also necessitated amplification of the limb lead recording making it noisy and ineffective as a 'zero reference'. (4)

The WCT offers a virtual ground by comprising the sum of three limb electrodes (right arm, left arm and left leg) connected to a central terminal through three large resistors (e.g. 5000 Ohms). (Figure 2) The mathematical assumption made is that the heart lies as a point source at the centre of Einthoven's triangle. The net effect is a potential difference of close to zero. The equations and their solutions can be found in Wilson's original publication. (4) The use of greater resistance subjects the system to external interference, such as 50-60Hz electrical noise, now compensated with the 'notch filter'. Furthermore, the addition of an active current via the right leg, the 'driven right leg', allows the patient to be driven to the same voltage as the common amplifier thus reducing the common mode voltage. (Figure 3) Whilst the effectiveness of the WCT is evident, via its exceptionally widespread use, questions may arise as to where does the WCT actually lie and how closely does it approximate to a grounded electrode?

Fantastic experiments were undertaken to assess how close the WCT was to zero and where in the chest it was actually located. Numerous human immersion studies were undertaken in the 1930's and 40's whereby the WCT was compared to a distant electrode with the entire experimental apparatus and patient underwater. (5-7) Wilson accomplished this by submersing individuals in Lake Michigan, although this in itself may have introduced some error due to the relative salinity and hence conductivity of the lake water. (8) In general, the potential differences obtained between the WCT and ground ranged from 0.2-0.3 mV. Because the QRS force is mainly directed inferiorly the WCT manifests a minute negative deflection during this phase and further experiments have confirmed the WCT vector is therefore directed in a Northwesterly direction. (9)

Although not perfect, the great value of Wilson's Central Terminal as a 'zero reference' is evidenced by the fact that it has stood the test of time, both as a practical and accurate solution to the problem of unipolar electrocardiography and electrophysiology. For more accurate unipolar recording in the electrophysiology lab an electrode may be placed in the inferior vena cava and used as the cathode with respect to the distal mapping catheter electrode (anode) with the recording system then programmed in a 'bipolar' configuration.

References

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Figures

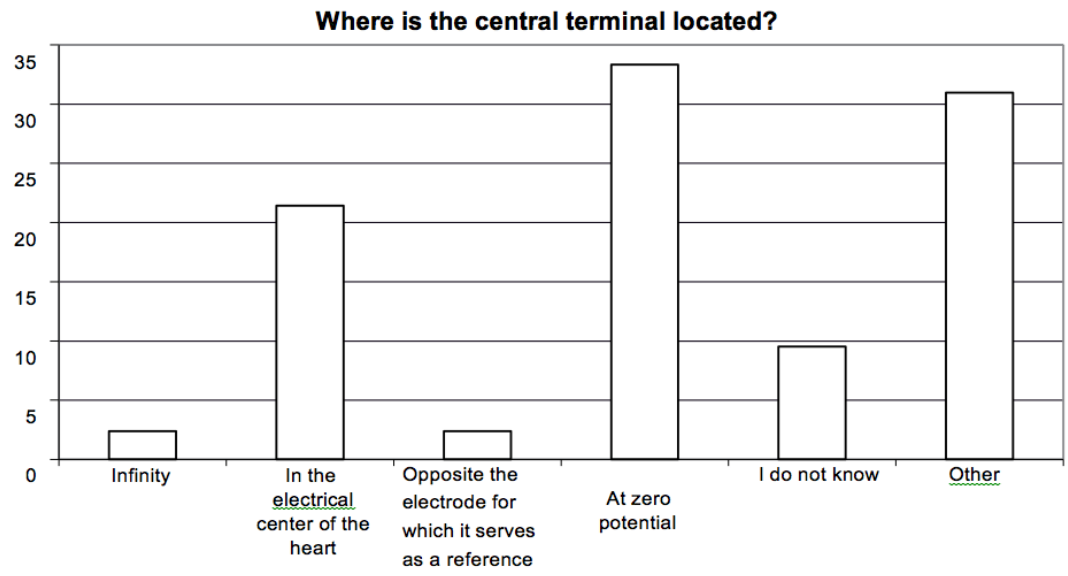

Figure 1. Survey results from 30th International Congress of Electrocardiology 2003, Helsinki, Finland. Only about half of the respondents were correct in answering that the location of the WCT is 'at zero potential' or 'in the electrical centre of the heart'. (1)

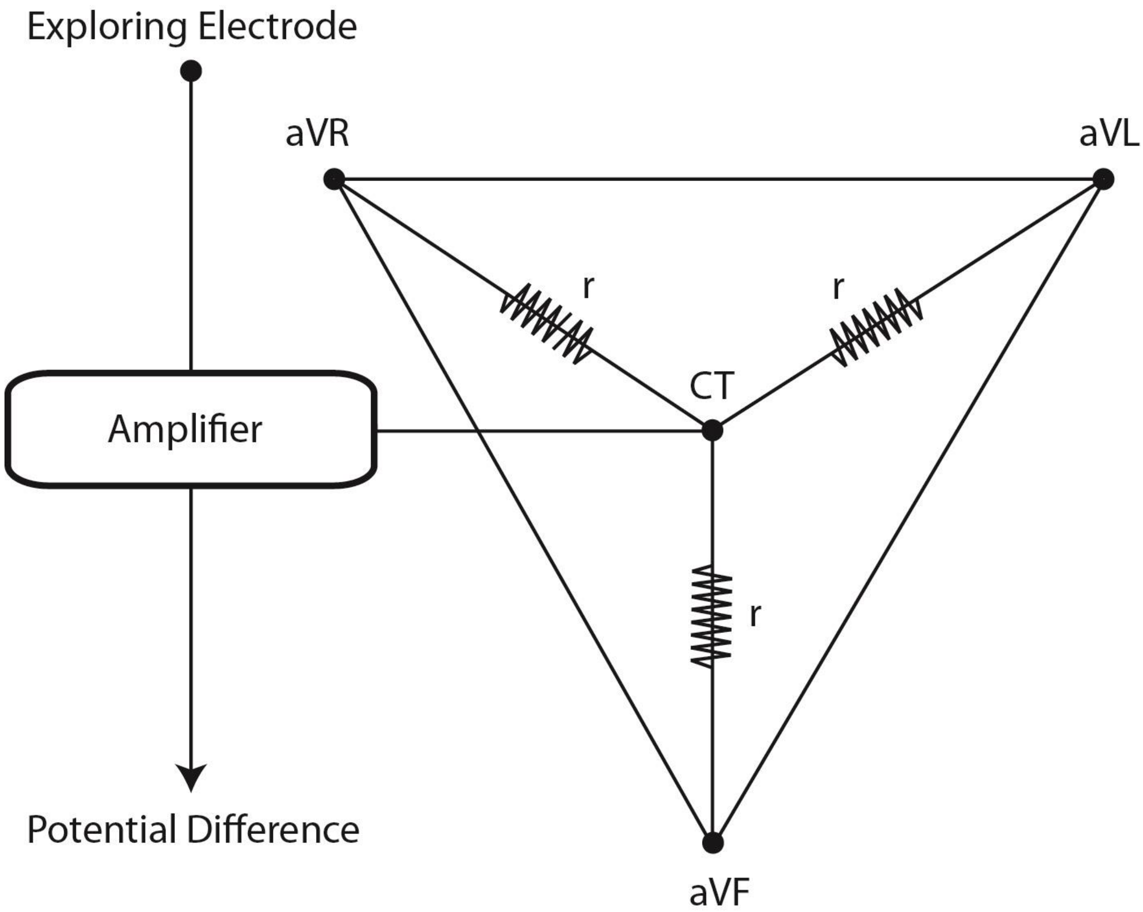

Figure 2. Diagrammatic illustration of Wilson's Central Terminal. The three limb leads (aVR, aVL and aVF) are connected to a central terminal (CT) via three 5K Ohm resistors. The central terminal has a potential difference approximate to zero and is located in space at the centre of Einthoven's triangle and is used to compare with an exploring electrode after signal amplification thus providing the unipolar electrogram or electrocardiogram

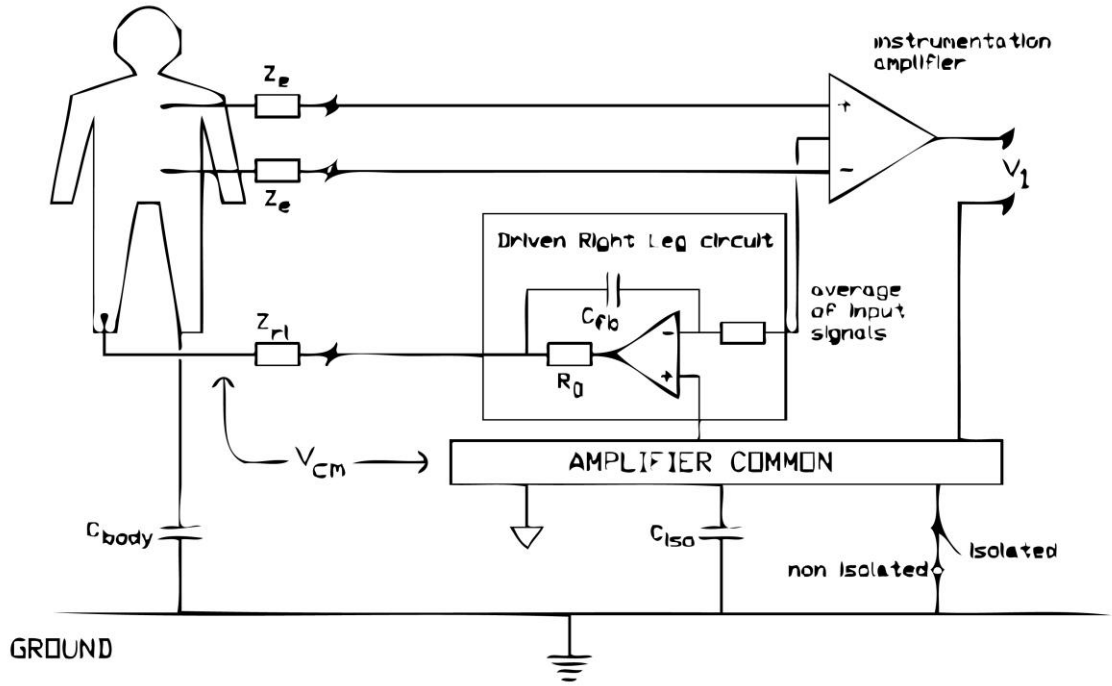

Figure 3. Modern recording systems may use a driven right leg circuit allowing the patient to be driven via a separate amplifier to the same voltage as the common amplifier, reducing electrical noise by reducing the potential difference between the common amplifier and the patient, the common mode voltage.