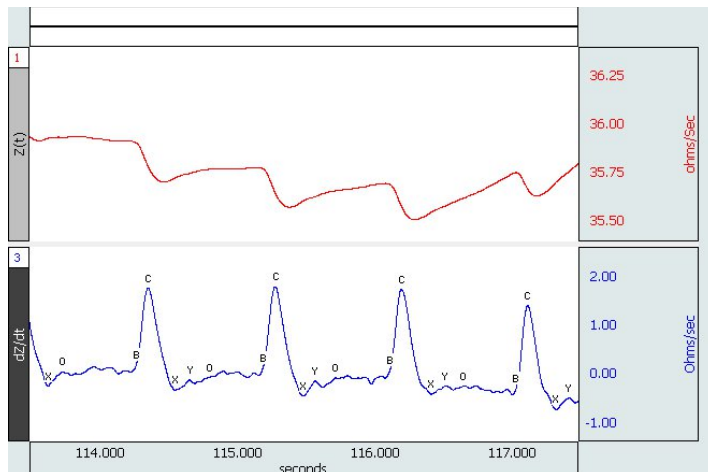


## Impedance cardiography (ICG) measurement protocol

### General information

ICG measures the electrical impedance (resistance) of the blood in the thorax (chest), specifically in the aorta. This impedance depends on the blood levels in the aorta. Every heartbeat shows a change in impedance. When blood levels are high (directly after the opening of the aorta valve in the heart) the impedance is low. The ICG signal ( $Z(t)$ ), as well as its derivative ( $dZ/dt$ ) are used to calculate various hemodynamic parameters, such as stroke volume, cardiac output and the pre-ejection period.

- ICG is measured in ohms/sec



Source figure: <https://www.biopac.com/application/icg-impedance-cardiography-cardiac-output/>

### Necessary equipment

- ICG devices;
- Disposable electrodes (Ag/AgCl) (the amount is dependent on placement method);
- Scrub gel (NuPrep);
- Cotton buds/cotton wool pads;
- Gloves;
- Alcohol wipes.



### Cleaning/preparation

**Important:** Always wear disposable gloves when cleaning the participant's skin, applying electrodes or when you disconnect the participant. After use, you should always remove them and dispose of them.

When placing the electrodes it is important to reduce the impedance (resistance) of the skin by removing oils and dead skin cells. The recommended method for doing this is with a scrub gel (NuPrep). The gel is gently rubbed on the skin with a cotton bud or a cotton pad. Then the skin is dried with a clean cotton wool pad. Place the electrodes directly after cleaning the skin.

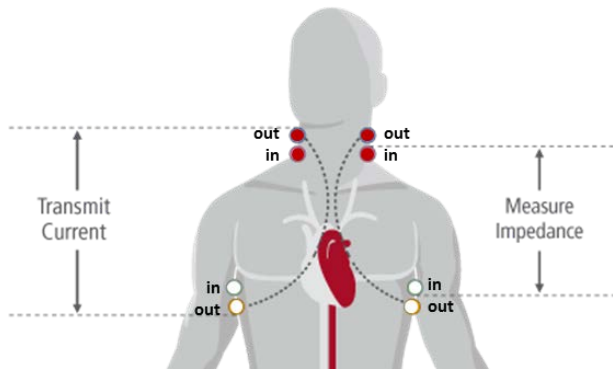
### Placing of the electrodes

**Important when using Biopac devices:** when attaching the leads, you must squeeze the plastic lock connector at the end of the lead. When disconnecting the leads, squeeze the lock connector again. Never pull on the lead itself. This material is very fragile and breaks easily. Similarly, when the leads need to be attached to or detached from the wireless module, you should use the plastic squeezable connector and refrain from pulling on the leads. Afterwards, loosely coil the leads and tuck them into the appropriate pocket. Do not knot or twist the leads, as it may damage them.

**Important:** Place the electrodes 5 to 10 minutes before you start taking measurements.

The number of electrodes used and the placing of the electrodes differ depending on the research. In general, there are two different methods for placing electrodes in ICG studies (explained below). In addition to these methods there are other ways to apply electrodes.

### Method 1 (e.g. Biopac)



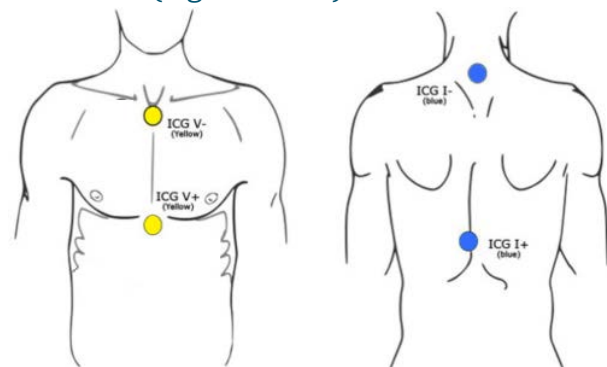
Biopac – Edited figure from source: <https://medis.company/cms/index.php?page=icg-impedance-cardiography>

For this method, eight disposable electrodes are used. Four of these electrodes are placed in the neck, two on the left hand side and two on the right hand side. These pairs are placed over the neck artery with 5 cm between the electrodes (measured from the centre of the electrodes). The other 4 electrodes are placed on the ribs, two on either side. Each pair is placed high up on the rib cage (for women just below the bra strap) and in line with the centre of the shoulder. In addition, the electrodes must be placed 5 cm apart (measured from the centre of the electrodes).

For this method, you will need 4 pairs of leads, two pairs of red leads and two pairs of white leads. The red leads need to be attached to the electrodes in the neck. The red “out” leads should be attached to the upper electrodes, the red “in” leads to the lower electrodes. The white leads are attached to the electrodes on the chest. You should attach the white “out” leads to the lower electrodes, the white “in” leads should be attached to the upper electrodes. A tip for remembering the leads is that the “in” leads always connect to the electrodes closest to the heart.

When using the wireless Biopac module, you can fasten the strap with the transmitter to the participant’s waist and then attach the leads to the electrodes. When doing this, please make sure the strap is placed between the Biopac transmitter and the skin, so the transmitter does not make contact with the skin.

### Method 2 (e.g. Vu-AMS)



VU-AMS – Edited figure from source: Nederend, ten Harkel, Blom, Bertson, & de Geus, 2017

In this method, four electrodes are used. Two electrodes are fixed to the chest, one just above the sternum and one just below the sternum. The other two electrodes are placed on the back, three centimetres above and three centimetres below the electrodes on the chest. The yellow leads are attached to the chest, the short one to the lower electrode and the long one to the higher electrode.

### Afterwards

When you are finished, remove the leads and, if using, the wireless modules. Then the participant can remove the electrodes him or herself. Removing the electrodes can be painful for some people. Depending on the sensitivity of the participant's skin, there may be red marks visible on the skin. These will normally fade within a few hours. Give the participant a tissue to remove any excess gel or allow the participant to wash the areas in question with water and soap. The disposable electrodes can be disposed of in the bin. After each participant, you should clean any equipment that has been in contact with the participant. This may apply to the leads that were attached to the electrodes and, if using the wireless Biopac module, the transmitter as well. Clean these components carefully with an alcohol wipe. The strap must be cleaned after use with Incidin Plus.

### Tips to ensure useful data

- Check whether the electrodes and leads are attached properly;
- The participant must move as little as possible to prevent artefacts in the data;
- The participant must be comfortable and sit in a natural posture with both feet on the floor;
- When the data looks irregular or shows a flat line, check whether the leads are properly attached and whether the electrodes are still properly attached.

### Literature

Nederend, I., ten Harkel, A. D. J., Blom, N. A., Berntson, G. G., & de Geus, E. J. D. (2017). Impedance cardiography in healthy children and children with congenital heart disease: Improving stroke volume assessment. *International Journal of Psychophysiology*, 120, 136-147.