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Tips for wireless cardiac triggering in MRI

Application Tip

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This Application Tip provides information concerning Cardiac triggering. It can be used as a guidance to optimize the quality of cardiac triggering.

During cardiac examinations, the patient's ECG signal is measured to trigger scans to the cardiac cycle. A four-lead VCG (VectorCardioGraphy) signal is measured to reduce the effects of the static magnetic field on the ECG-signal. The measured signals are displayed in the physiology display.

Systems types for which this document is applicable:

- Ingenia 1.5T and Ingenia 3.0T, SW release 4.1.1 and higher
- Achieva 1.5T and Achieva 3.0T, SW release 2.6.3 and higher, only if equipped with a wireless basic triggering unit

See also Instructions for Use:

Do not use the VCG signal for monitoring or diagnostic purposes. The VCG signal is distorted when the patient is inside the magnet. It can only be used as a trigger signal for cardiac triggered imaging.

Check system hardware

Before VCG-triggering is used, it is important to check whether the system's hardware is up-to-date. A field service engineer should check if all FCO's that are applicable to the system are installed.

Patient preparation

Proper patient preparation is essential for circumventing skin burns and for a reliable VCG signal. It is necessary to confirm that low resistance electrodes are being used.

The skin may be cleaned with a special abrasive skin prepping gel. Use a clean gauze pad to dry the skin.

See also Instructions for Use:

- Do not use alcohol since this will dry the skin and thus prevent good electrical contact. Old electrodes may cause heating of the skin.
- Never reposition or reuse electrodes. Always use new electrodes. Repositioning or reuse may result in a heating effect as a result of high skin resistance.
- Do not place the VCG battery module directly on the patient's skin as this may cause heating.
- Do not place the VCG battery module close to the imaging field of view as this may cause artifacts.

On exam level the patient's heart rate must be entered. All triggering-related parameters are derived from the entered heart rate. The patient's actual heart rate might increase during long breath-hold scans or during stress examinations. Missed triggers can be avoided in this case by entering a heart rate that is slightly higher than the patient's actual heart rate.

Effects of the main magnetic field

The ECG-signal is a measurement of an electrical differential potential on the patient's skin. An electrical current that is placed in a magnetic field will cause induced voltages. The moving electrolytes in the blood (especially in the aortic arch) will also induce voltages. These are superimposed on the measured ECG-signal.

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In summary: the ECG-signal will change in the presence of a static magnetic field. These alterations are mainly seen in the baseline of the ECG-signal and usually superimposed on the area of the T-wave. The distortion is referred to as the T-wave artifact or the magneto-hydrodynamic effect (MHD).

The strength of the induced voltages increases with increasing field strength.

Figure 1 is a graphical representation of ECG-signals in the absence of a magnetic field (0 T) and at increasing field strengths of 1.0T, 1.5T and 3.0T respectively.

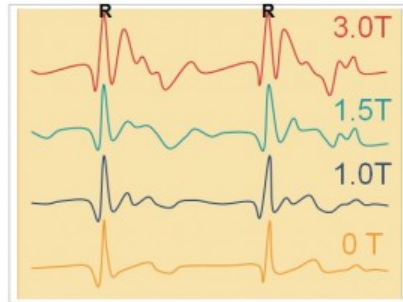


Figure 1
B0-effect on the ECG signal.

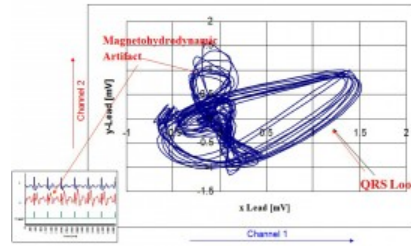


Figure 2
VCG-trace measured in two orthogonal directions.

Triggering algorithms rely on the detection of the R-top. Amplitude-based algorithms might result in incorrect triggering (detection of T-wave artifact) if the amplitude of the T-wave artifact approaches the amplitude of the R-top.

VectorCardioGram measures the ECG-signal in two orthogonal directions from which it is possible to resolve the real R-top from a possible T-wave artifact, as is shown in Figure 2.

Practical implications:

- Even if the patient's VCG signal looks normal during patient preparation, the VCG signal can become distorted once the patient is moved into the isocenter:
 - The B0-disruption causes the signal to rapidly changed shape. The VCG signal has to be re-calibrated which will require about 7 seconds
 - Patient movement also disrupts the ECG-signal. Recalibration is required after patient motion and trigger markers can disappear for a few seconds.
- Inspect the signal on the physiology display for trigger markers. If these are displayed on the R-top after the calibration is done, the system is ready for triggering
 - As a final check, ask the patient to breathe in and out a few times while in the bore to check if the trigger markers remain visible during inspiration and expiration.

See Figures 3a and 3b for examples of the effect of B0 and the trigger marker detection.



Figure 3a
VCG at 3.0T outside magnet bore.



Figure 3b
VCG at 3.0T inside magnet bore.

See also Instructions for Use:

Do not use the VCG signal for monitoring or diagnostic purposes. The VCG signal is distorted when the patient is inside the magnet. It can only be used as a trigger signal for cardiac triggered imaging.

Electrode positioning

Electrode positioning or lead placement is crucial to obtain a good VCG-trace for triggering. The recommended lead placement for **wireless triggering** is shown in Figure 4.



Figure 4
Wireless electrode positioning.

- White: at first intercostal space, just left of the sternum
- Green: at the level of the xiphoid, just left of the sternum
- Red: in horizontal line with green electrode, at similar distance as green-white
Position very much to patient's side!
- Black: as much as possible in a horizontal line with white, close to the armpit
Use the largest possible distance between white and black

The distances between green and white, and between green and red must be ~ 15 cm to obtain sufficient amplitude of the VCG-signal. A smaller distance between the electrodes might reduce the noise and artifact level in the VCG signal, but it will decrease the amplitude of the measured R-peak as well.

It is known that trigger detection can be lost during breath-hold instructions. A possible cause for this could be found in the rotation and angulation of the heart during the breath-hold (mainly seen during inspiration). The effect on the VCG-signal is described in Figure 5:

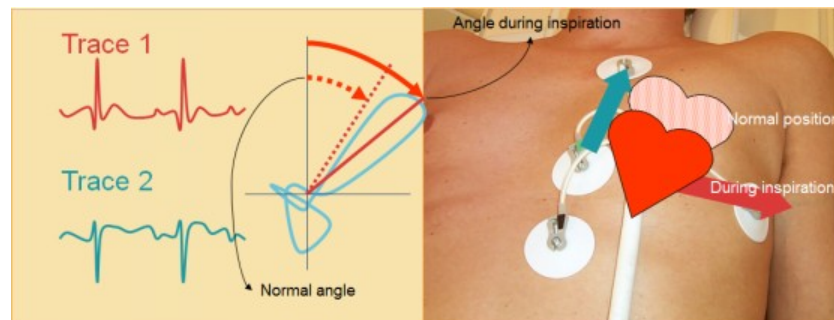


Figure 5
Rotation and angulation of the heart during inspiration may cause tilting of the VCG trace

If this effect is encountered, the recommended electrode position could be modified by inverting the green and black electrode. This is displayed in Figure 6a. The inverted electrode positioning can also be achieved by placing the green electrode just below the black electrode, as shown in figure 6b. (note that this setup requires an extra electrode to be placed).

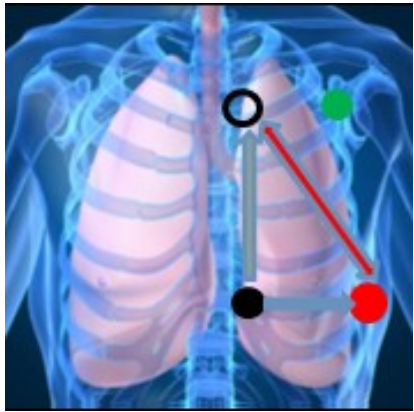


Figure 6a
Inverted electrode positioning.

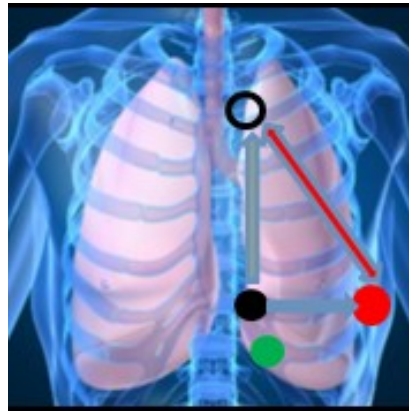


Figure 6b
Alternative inverted electrode positioning.

Alternative to VCG-triggering: PPU

In some cases, where the VCG signal is affected too much by e.g. the influence of the static magnetic field or the breathing pattern of the patient, VCG triggering might still fail. PPU (Peripheral Pulse Unit) can be used in those cases to perform cardiac triggered sequences. Please note that the detection of the PPU trigger moment is delayed when compared to the VCG R-peak detection as the blood pressure wave must propagate to the finger. And additional signal processing is required.

The delay can easily be recognized in a comparison of Q-flow scans through the ascending aorta, acquired with VCG-triggering and PPU-triggering respectively.

- In the VCG-triggered scan (Figure 7a), peak velocity in the AAO is measured shortly after the detection of the R-peak in the heart, which marks the start of the flow curve. The flow curve represents one full cardiac cycle, and as such, the end of the flow curve indicates the detection of the next R-peak.
- In the PPU-triggered scan (Figure 7b), peak velocity in the AAO is measured already before the detection of the R-peak in the finger, which marks the end of the flow curve.

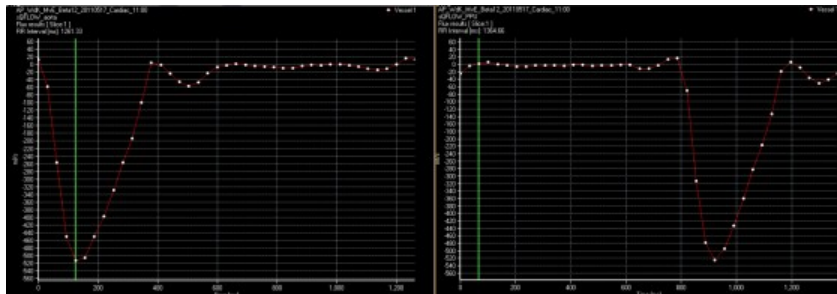


Figure 7a and 7b
VCG triggered Qflow scan (left) and PPU-triggered Qflow scan (right).

For retrospective triggered scans, the first image in a PPU-triggered scan is acquired once the R-peak is detected in the finger, and it will be delayed in comparison to VCG-triggering. Full coverage of the cardiac cycle is however preserved and all required functional information will be available.

Figures 8a and 8b show first image of a retrospective cine scan acquired with VCG and PPU-triggering respectively on Ingenia 1.5T. The PPU-triggered cine scan starts in mid-systole instead of at end-diastole.

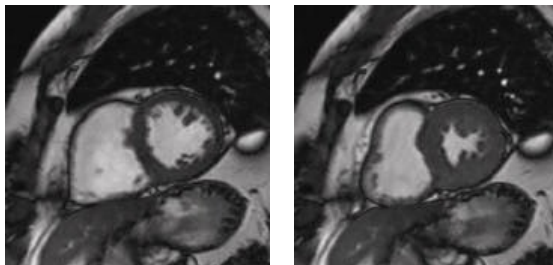


Figure 8a

First phase of a VCG-triggered cine scan.

Figure 8b

First phase of a PPU-triggered cine scan.

The delay will also affect trigger delay timing in prospective triggered scans: As an example, trigger delay "mid diastole" will be measured with a delay and will result in images that are triggered towards systole in the next cardiac cycle.

Practical implications

- Change the setting of the parameter "trigger device" on the motion page from ECG to PPU
 - Note that the displayed value for patient's heart rate in the physiology display is taken from the VCG-module as long as the leads are connected:
 - Either disconnect the VCG-leads or remove the battery from the VCG-module to display the patient's heart rate as measured by the PPU-module
- For retrospective triggered scans, the first image of the cine loop will be acquired in systole
- For retrospective triggered scans, trigger delay "mid-diastole" will result in images in systole
 - Change trigger delay time to shortest or to user defined (enter a value that is shorter than the calculated value as displayed on the info page) to correct for the delay in R-peak detection

Related information:

This document is an update to the Application Tip "Tips for Cardiac Triggering" that was previously published in 2011. This 2011 Application Tip is still available on NetForum and provides additional information with respect to wired physiology.

Please click on the link below to view the Application Tip from 2011:

[Tips for cardiac triggering, previous version](#)

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