31st Annual International Conference of the IEEE EMBS
Minneapolis, Minnesota, USA, September 2-6, 2009

Defibrillator Synchronization Tester

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Abstract—**A defibrillator sync output signal connector provides an ECG synchronization signal that can be used by some defibrillators for the purpose of performing synchronized cardioversion [1]. This process is used to stop an abnormally fast heart rate or cardiac arrhythmia by the delivery of a therapeutic dose of electric current to the heart during the R-wave of the cardiac cycle. Timing the shock to the R-wave prevents the delivery of the shock during the vulnerable period of the cardiac cycle, which could induce ventricular fibrillation [2]. GE patient monitors include a selectable analog output feature, which provides an analog ECG or arterial blood pressure signal. The blood pressure signal can be used to synchronize balloon pumps to provide cardiac assist to post-MI patients with poor injection fraction. Proper operation requires the defibrillator sync and analog output function to be checked. Checkouts are typically done during planned maintenance and after major part replacements such as patient monitor's main CPU board. Checking out defibrillator sync signals could be done using a GE defibrillator sync tester. The defibrillator sync tester provides a loop back path for the defibrillator sync signals to be displayed on the patient monitor screen and eliminates the need for an external oscilloscope.**

I. Introduction

Ventricular fibrillation (VF) and ventricular tachycardia (VT) are the most common causes of sudden cardiac arrest. During sudden cardiac arrest, the heart suddenly and unexpectedly stops beating normally; blood stops flowing to the vital organs including the brain and as a result the individual stops breathing and collapses into unconsciousness. Sudden cardiac arrest could happen regardless of preexisting heart diseases [3,4]. Although sudden cardiac arrest is not the same as a heart attack, which is the result of a loss of blood supply to the heart muscle, a heart attack does increase the risk for sudden cardiac arrest. The time and mode of death are unexpected. Sudden cardiac death can be defined as any cardiac death occurring out of the hospital, taking place in the emergency room or dead on arrival in the emergency room [5-7].

Sudden cardiac arrest is survivable. Defibrillation is the standard curative response to sudden cardiac arrest. The sooner defibrillation is provided after cardiac arrest, the greater the likelihood that the patient will survive a ventricular fibrillation or ventricular tachycardia event. It has been demonstrated that within the first ten minutes of a sudden cardiac arrest, a patient's survival rate improves 10 percent for every minute that is saved by getting the defibrillator to the patient [8].

The delivery of a therapeutic dose of electric current to the heart during the R-wave of the cardiac cycle is the key to the successful conversion of supraventricular tachyarrhythmias to normal sinus rhythm. It is critical to have the patient monitor and the defibrillator synchronized properly during cardioversion. To ensure the proper synchronization, the patient monitor's defibrillator sync and analog output function need to be checked. Note that the synchronization is not required in the most frequent uses of defibrillators: ventricular fibrillation and in AEDs. But whether the clinical use is frequent or infrequent is not as important to us as much as the simple fact that defibrillator sync testing is required. Checkouts are done during planned maintenance and after major part replacements such as a patient monitor's main CPU board.

The GE defibrillator sync tester can be used as an easy to use, portable and low-cost solution when checking out the defibrillator sync/analog out signals on the patient monitors.

II. Theory

The purpose of the defibrillator sync tester is to show that the ECG, arterial blood pressure, and marker input signals from the defibrillator sync out connector on the patient monitor to the defibrillator are accurate.

We do this by first providing a set of known reference ECG signals into the patient monitor. The monitor processes the ECG signals normally and sends the arterial blood pressure or ECG signal to the defibrillator sync output connector. The patient monitor also generates a marker out signal that indicates the peak of the R-wave within 35 milliseconds of each ECG QRS complex per AAMI: EC13 [9]. The test procedure then consists of comparing relevant input and output signals to ensure they are the same.

The general procedure relies on supplying reference signals using a patient simulator. Then the patient simulator ECG input and defibrillator sync output signal can be displayed and compared. Current practice is to use an oscilloscope to display both signals comparison of the signals.

The defibrillator sync tester replaces the need for an oscilloscope by selectively replacing one of the patient ECG input leads with a defibrillator sync signal. The patient monitor will then display the original ECG signal and the looped back signal sent from the defibrillator sync

tester. In effect, we are using the patient monitor as the oscilloscope.

Specifically we loop back the signal from the defibrillator sync output and connect to the ECG lead V input. The analog signal on the patient monitor's defibrillator sync output uses a scale of 1V out per millivolt of ECG signal. The defibrillator sync tester incorporates a voltage divider (Figure 1) to rescale the defibrillator sync signal back to an acceptable range before it can be sent back to the patient monitor.

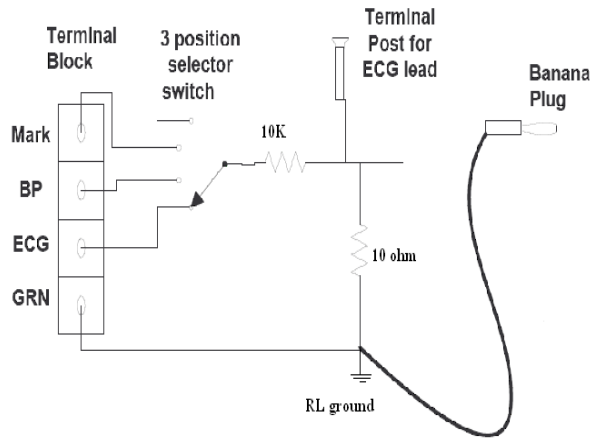

Fig. 1. Tester Circuit Diagram

The defibrillator sync tester uses a 10Ω and 10kΩ resisters in series such that the output voltage is given by:

$$V_{out} = \frac{R_1}{R_1 + R_2} V_{in}$$

$$V_{out} = \frac{10\Omega}{10000\Omega + 10\Omega} V_{in}$$

$$V_{out} \approx 0.001 \cdot V_{in}$$

The defibrillator sync tester also includes a rotary switch to allow selection of any of the defibrillator sync connector signals to substitute for the lead V signal: ECG, arterial blood pressure, or marker.

Thus if we want to compare the patient simulator generated ECG lead I, we select the lead I display on the monitor and set the rotary switch to the ECG position and display the lead I output as the lead V input signal on the patient monitor. For example in Figure 4 the patient simulator lead I is shown on top of the display and the loop backed lead 1 is displayed as lead V.

III. Method and Test Instructions

A. Required equipment

1) GE Analog Out/Defib Sync Tester (Figure 2).

Fig. 2. GE Analog Out/Defib Sync Tester

2) Appropriate analog output cable for the patient monitor under testing.
   ***Note**: It is recommended that the ends of the un-terminated analog output cable are stripped and tinned with a soldering Iron.*
3) Multiparameter patient simulator (with ECG and arterial blood pressure).
   ***Note**: The patient simulator may have to be isolated from ground or run on battery power to eliminate noise while doing this test.*
4) Arterial blood pressure patient cable.
5) Lead ECG patient cable and leadwires.

B. Setup and Test Procedure

1) The defibrillator sync tester should not be used while the monitor is connected to a patient.
   ***Note**: Before starting the test procedure, verify that pace detect is off and ECG filter is in monitoring mode. The patient monitor user manual can be referenced to turn off the pacer detect and monitoring mode.*
2) Connect the patient simulator to the 5 lead ECG cable which is connected to the monitor under test. Set the simulator to Normal Sinus Rhythm (NSR) 80 bpm.
3) On the patient monitor if the second waveform is not the V lead, set waveform 2 to the V lead.
   ***Note**: The patient monitor user manual can be referenced to set waveform 2.*
4) Connect the arterial blood pressure cable from the simulator to the patient monitor. Zero the pressure on the simulator and on the patient monitor. Set the simulator to 120/80 BP dynamic waveform output.
   ***Note**: The patient monitor and simulator user manuals can be referenced to zero the pressure.*
5) On the patient monitor set the BP ART scale to 160.

Note: *The patient monitor user manual can be referenced to set BP scale.*

6) Connect the analog output/defib sync cable to the analog output/defib sync port on the patient monitor.
7) Connect the bare wires from the analog output cable to their corresponding connections on the tester. Connect the tester ground to the analog out ground. Use the patient monitor service manual to determine the ground terminal and wire.
   Note*: "Mark out" from Analog output/ Defib sync cable connects to "MARK" on the tester.*
   Note*: The patient monitor's service manuals can be referenced for the test cable pinout and color codes.*
8) Plug the RL ground cable from the tester into the patient simulator's RL terminal. Ensure both patient lead wire and the tester ground cable are connected to the RL terminal.
9) Disconnect the V lead of the patient cable from the simulator and connect it to the "V LEAD" terminal of the tester (Figure 3).

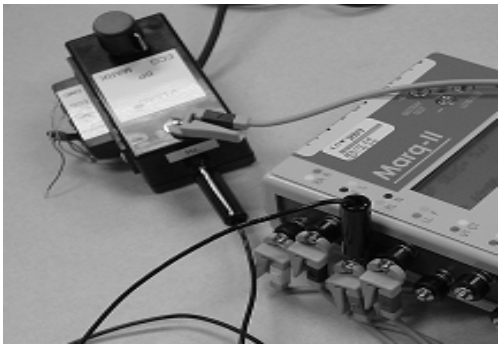

Fig. 3. Tester connectivity to the patient simulator

C. ECG Test

1) Set the selector switch of the tester to ECG.
2) On the patient monitor observe that the V lead waveform matches the primary ECG waveform (Figure 4).

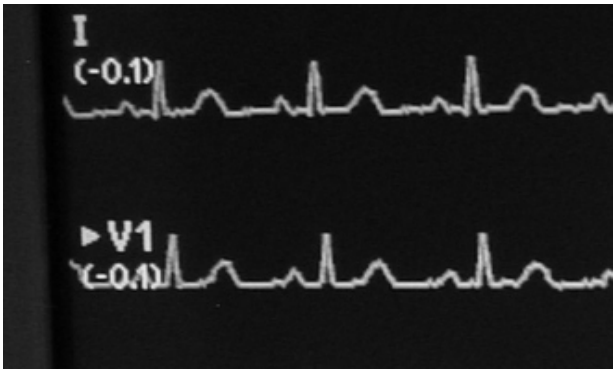

Fig. 4. ECG test results

D. BP Test

1) Set the selector switch of the tester to BP.
2) On the patient monitor observe that the V lead waveform matches the BP waveform (Figure 5).

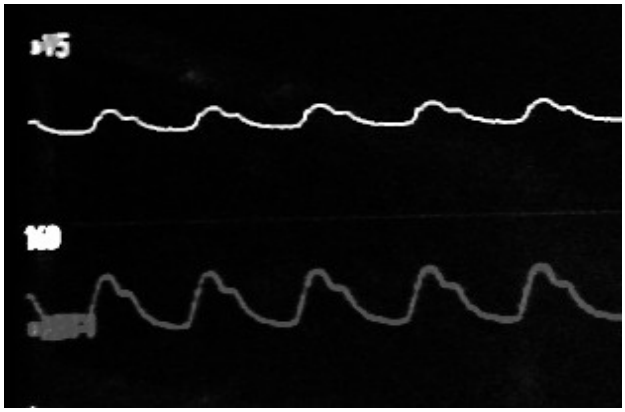

Fig. 5. BP test results

E. Marker Out Test

1) Set the selector switch of the tester to "MARK".
2) On the patient monitor observe that the V lead waveform has a marker pulse corresponding to the R wave of the primary ECG waveform (Figure 6).

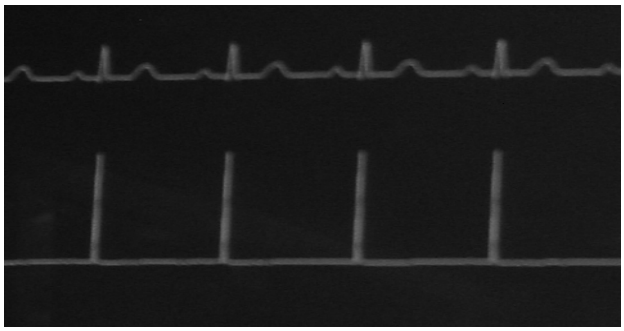

Fig. 6. Marker Out test results

F. Marker In Test

1) Set the selector switch of the tester to ECG.
2) Connect the analog output/ defib sync cable "Marker in" and "Marker out" wires together by connecting both to the "MARK" on the tester.
3) On the patient monitor verify markers are present on the ECG waveform (Figure 9).
   Note: *Markers are shown below from the GE DASH patient monitor. The marker display may vary depending on the model of the monitor.*

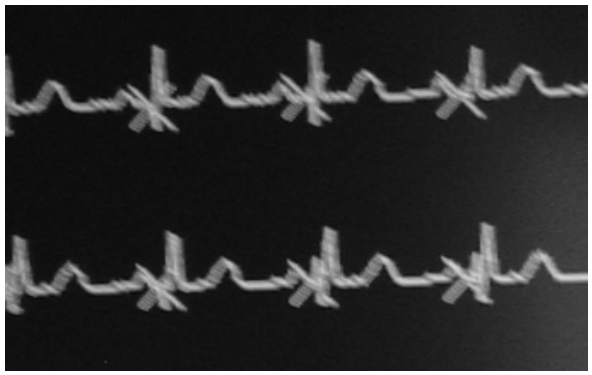

Fig. 7. Marker In test results

G. Test complete

If any of these tests fail, troubleshoot analog output or remove the patient monitor from the service.

IV. Conclusion

In general we have shown that a simple tester that leverages a patient monitor's built in display capability can be an effective and inexpensive alternative to an oscilloscope for testing the defibrillator sync output of a standard patient monitor.

There are some drawbacks to the tester. It is highly specialized to this one test. It relies on a visual comparison of the signals. At a typical ECG display time scale of 25mm/sec a difference of 35ms is slightly less then 1mm and can be difficult to detect. However, visual comparison has been judged to be sufficient for use in the previous procedures. Even in the case when an oscilloscope is used, the ability to quantify the timing difference in two channels is not used. In the case where more general purpose and/or more quantitative measurements are required an oscilloscope is still the instrument of choice. But these cases are expected to be infrequent.

As a result GE now manufactures and sells a standalone defibrillator sync tester. We expect the tester to make it easier to execute the defibrillator sync test procedure for service providers. We also hope to reduce the possibility that the procedure might be inadvertently missed. As a result signals required to operate a defibrillator are properly verified.

Acknowledgment

We would like to acknowledge Mike McLeod for design and research support.

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