Manual 6C

Ultrasound Assessment: Arterial Distensibility Tracking Procedures

The National Heart, Lung, and Blood Institute
of the National Institutes of Health

ATHEROSCLEROSIS RISK IN COMMUNITIES STUDY PROTOCOL

Manual 6C

ULTRASOUND ASSESSMENT: ARTERIAL DISTENSIBILITY TRACKING PROCEDURES

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1. INTRODUCTION

Arterial distensibility is a measure of the artery's ability to expand and contract as the heart beats. This stretching of the artery implies that the artery has some degree of flexibility or elasticity. It is this arterial property that is being studied in the distensibility component of the ARIC study.

The distensibility data is gathered at the four Field Centers by the sonographer at the completion of the ultrasound scanning protocol. The distensibility portion of the ultrasound study takes no more than five minutes, but much information concerning the dynamics of the artery wall is gathered during this time.

In acquiring the data, the sonographer uses the Biosound 2000 II sa, an arterial wall tracker, an oscilloscope, a strip chart recorder, and a personal computer. The transducer is held steady by a special transducer holder while a section of the left common carotid artery is imaged with the Biosound. The electronic signals are sent from the Biosound instrument to the arterial wall tracker where the tracker electronically locks onto the arterial wall echoes, following and recording their motion.

The data from the tracker pass through a device which converts the signals into a digitized form that the computer can store in its memory. It is this digitized information of the artery's changing diameter that constitutes the distensibility data which is gathered at the Field Center and which ultimately reaches the Ultrasound Reading Center for analysis.

2. EQUIPMENT SETUP

The goal of the equipment set-up procedure is to provide the sonographer with instructions for making cable connections to each piece of tracking equipment. This procedure is usually performed only once when the equipment is installed. However, if the cables are ever disconnected (i.e., the tracking equipment is moved from its original placement), the sonographer follows the procedure outlined here to properly reconnect the cables. Before cabling is started, the sonographer makes sure all power is disconnected. Upon completion of cabling, units are plugged in and turned on.

2.1 Work Station Equipment

(1) Arterial Wall Tracker, model number 4881
(1) Tektronix Oscilloscope, model number 2215 or 2215a
(1) Strip Chart Recorder
(4) Sets of Cables
(1) Analog to Digital Converter (ADC) Hardware Board for the PC
(3) Power Supply Outlets

The presence of all of the above equipment is verified. The tracking equipment is arranged so that the sonographer can reach the various controls of each piece of equipment with ease. It is important when placing the tracking equipment at the work station that each unit is at least 6 inches from any wall (or other unit). This is necessary to allow for adequate air flow from the fans inside the units. Note that the oscilloscope has a handle that can be positioned for viewing ease. This is done by pulling out on the knobs on each side and rotating the handle to the desired position. The teeth on the knob allow the handle to be locked into position to prevent slipping.

2.2 Cable Hookup and Installation of PC Board

After the equipment has been placed conveniently for the sonographer, the four sets of cables are connected to each piece of equipment. None of the equipment is plugged into the power outlet until all cable connections have been made.

It is suggested that the wire ties that are wrapped around the cables be kept in a convenient place. They may be needed to tie together excess cable once the entire system is set up.

When making the cable connections, the cable is inserted into the proper input or output lead and the lead turned clockwise until it snaps into place. Figure 1 shows the four sets of cables that are connected to the tracking equipment.

2.2.1 Biosound to Arterial Wall Tracker

The two cables which connect the Biosound to the 4881 arterial wall tracker are identified. The first cable is labeled TRACKER SYNC IN on one end and BIOSOUND R.F. TRIGGER on the other end. The second cable is labeled TRACKER R.F. IN on one end and BIOSOUND R.F. OUT on the other end.

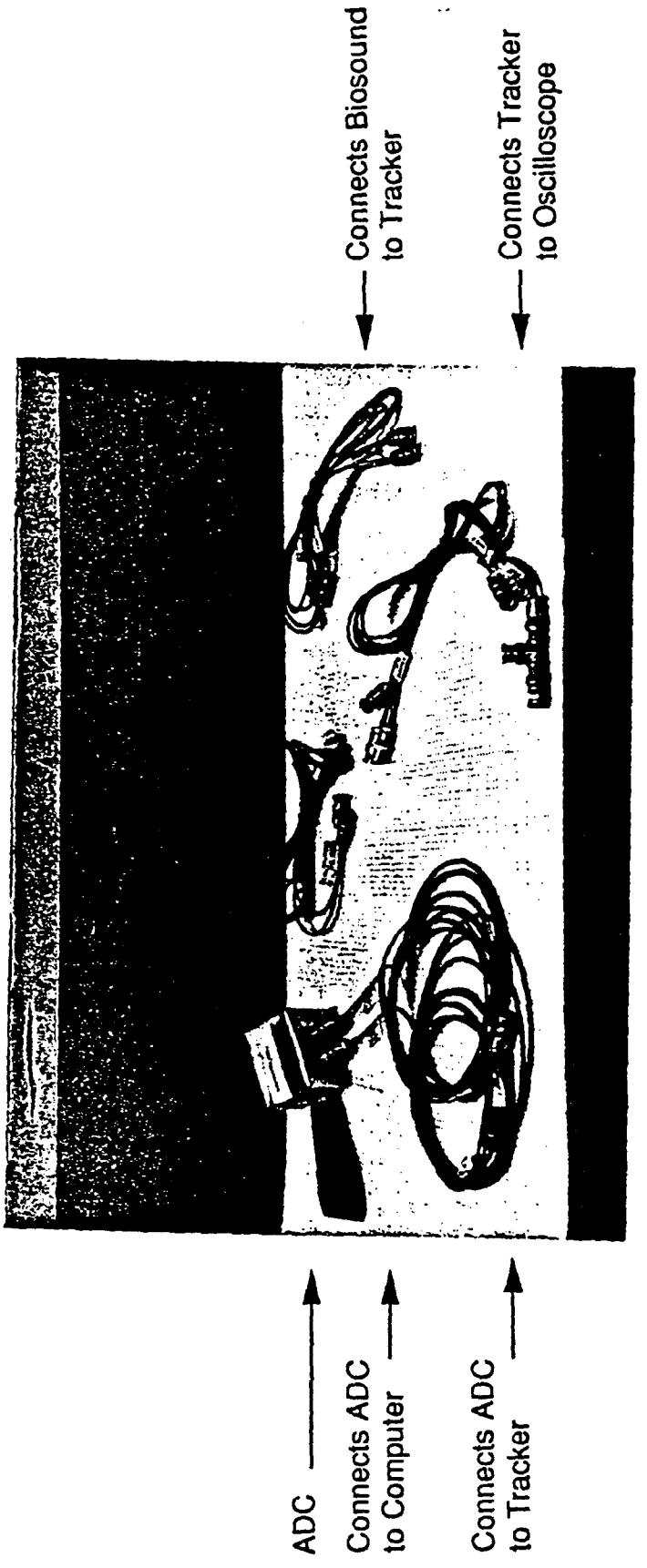


Figure 1. Cables for Tracking Equipment

The Biosound end of each cable is connected to the appropriate Biosound output lead located on the rear panel of the Biosound. These output leads are noted with an "X" in Figure 2. The tracker end of these two cables is connected to the appropriate tracker input leads which are located on the rear panel of the arterial wall tracker. These input leads on the rear panel of the tracker are labelled INPUTS FROM BIOSOUND in Figure 3.

2.2.2 Arterial Wall Tracker to Strip Chart

The sonographer identifies the two cables which connect the arterial wall tracker to the strip chart. One of the cables is labeled RECORDER CH-1 on each end and the other cable is labeled RECORDER CH-2 on each end. One end of each cable is connected to the corresponding output lead on the rear panel of the arterial wall tracker. These output leads are labeled OUTPUTS TO STRIP CHART in Figure 3. The other end of each cable is connected to the corresponding input lead on the rear panel of the strip chart recorder (Figure 4). The arterial wall tracker must be turned on for a minimum of 30 minutes before data can be collected.

2.2.3 Arterial Wall Tracker to Oscilloscope

The three cables which connect the arterial wall tracker to the oscilloscope are identified. One end of each of these cables connects to the oscilloscope output leads on the rear panel of the arterial wall tracker. The other end of these cables connects to the oscilloscope input leads which are located on the front of the oscilloscope unit.

The sonographer identifies the cable marked O'SCOPE GATES at each end. One end of this cable is connected to the input labeled CHANNEL 1 on the front of the oscilloscope. This channel 1 input is control number 13a in Figure 5.

The sonographer identifies the cable marked O'SCOPE R.F. at each end. The end with the largest lead is connected to the input labeled CHANNEL 2 on the front of the oscilloscope. This channel 2 input is control number 13b in Figure 5.

The cable marked O'SCOPE SYNC at each end is identified. One end of this cable is connected to the input labeled SYNC on the front of the oscilloscope. This SYNC input is control number 32 in Figure 5.

After the connections to the front of the oscilloscope have been made, the other ends of these three cables are connected to the corresponding output leads on the rear panel of the arterial wall tracker. These output leads are labeled OUTPUTS TO OSCILLOSCOPE in Figure 3.

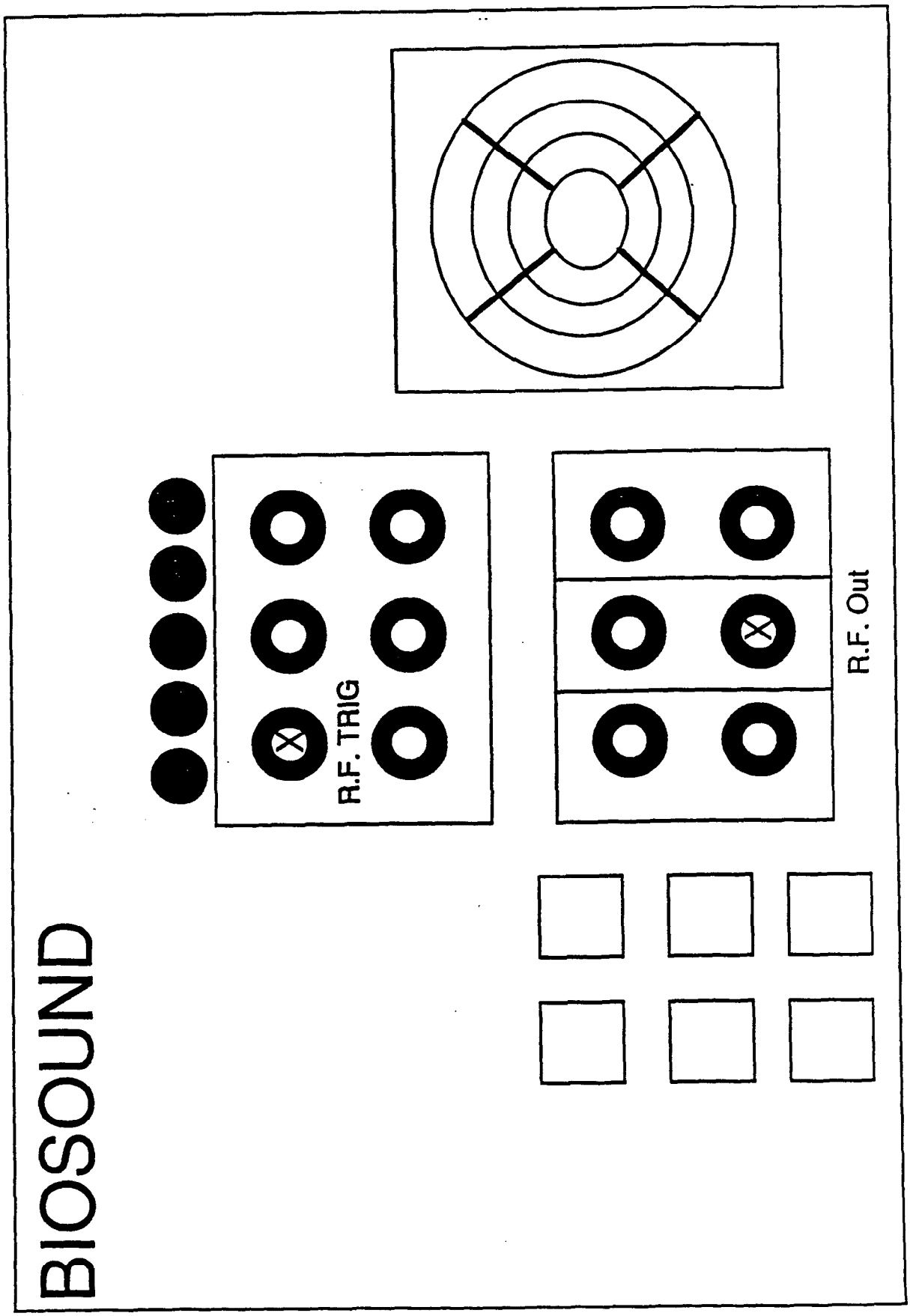


Figure 2. Rear Panel of Biosound

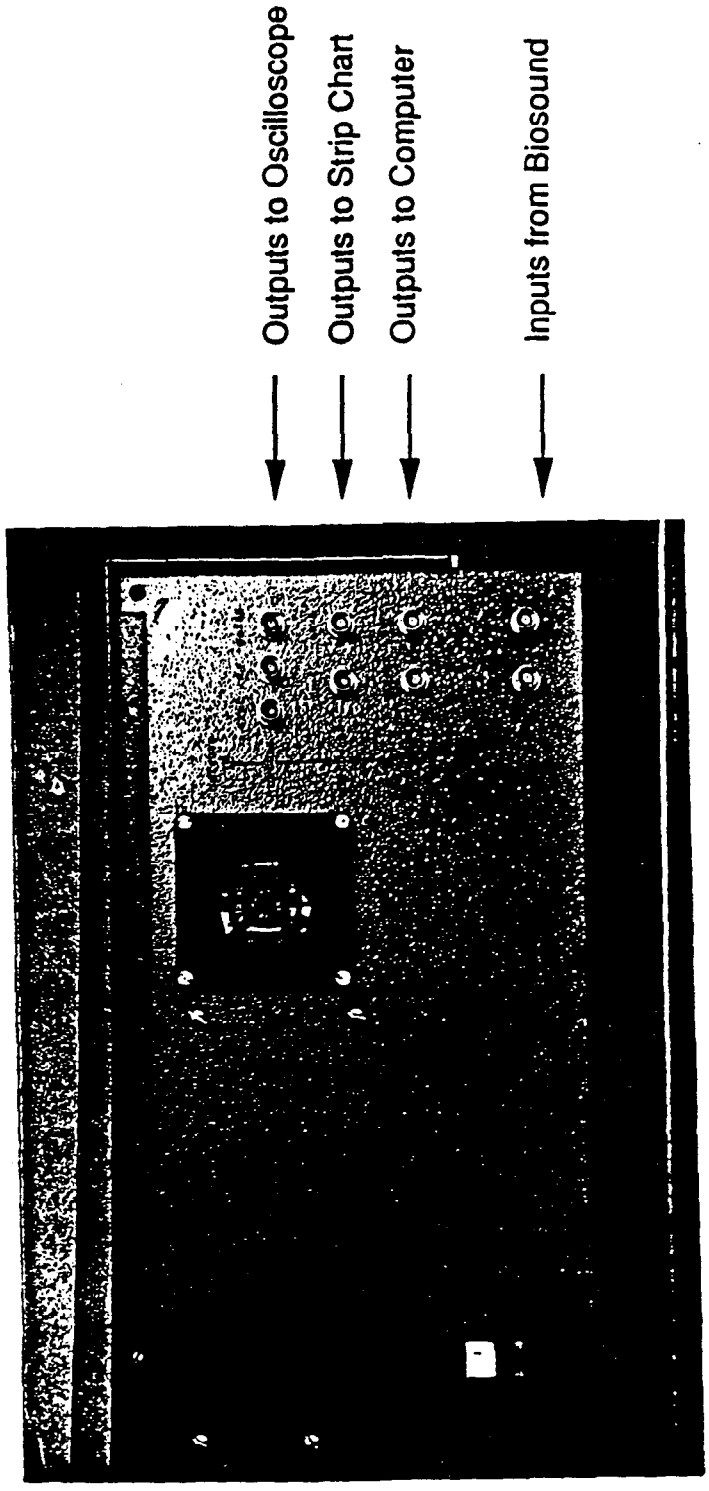


Figure 3. Rear Panel of Arterial Wall Tracker

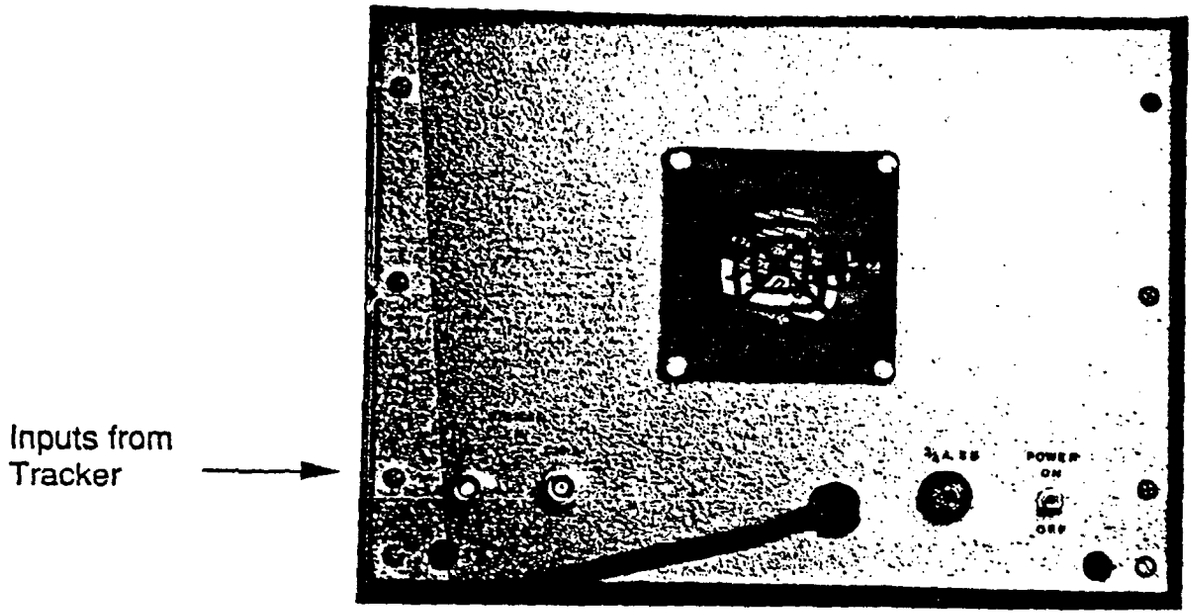


Figure 4. Rear Panel of Strip Chart Recorder

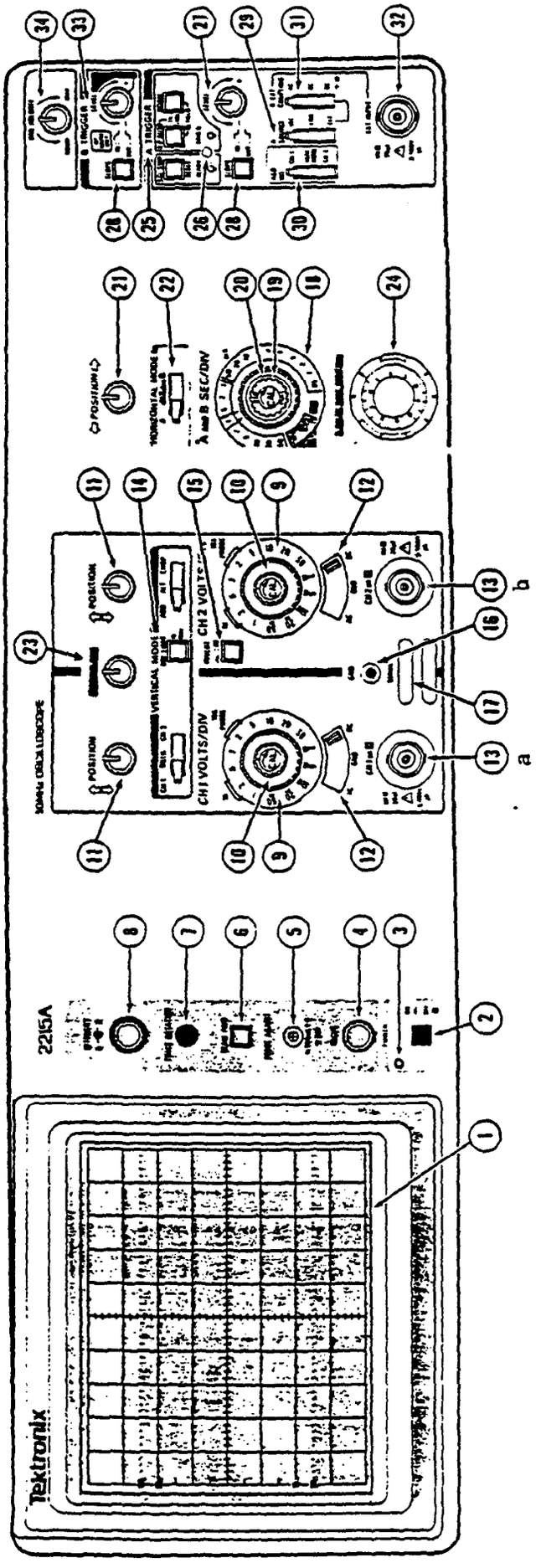


Figure 5. Oscilloscope Controls

2.3 Installation of Analog to Digital Converter

Before the fourth set of cables is connected, the ADC (analog to digital converter) board is installed into the computer. To install the ADC board, the following steps are performed:

1. Turn the personal computer OFF and unplug it from the wall outlet.

2. Remove the cover of the personal computer by unfastening the five screws in the rear and sliding the cover off from the front.

3. Remove metal bracket from any unused slot by unscrewing the top screw on the bracket.

4. Place ADC hardware board in any unused slot by lining up the connector end of board with the empty slot and firmly pressing down until it snaps into place.

5. Line the board bracket up with the screw hole and fasten with a screwdriver.

6. Insert the ribbon cable from the ADC box into the end of the board.

7. Slide the cover back on the computer and fasten with screws in the rear.

2.3.1 Analog to Digital Converter Cabling

The two cables which connect the ADC to the arterial wall tracker are identified. One end of each of the two cables is already attached to the ADC device. The other ends of these cables are labeled ADC CH-1 and ADC CH-2. The ends of these cables are connected to the corresponding output leads on the rear panel of the arterial wall tracker. These output leads are labeled OUTPUTS TO COMPUTER in Figure 3.

2.4 Oscilloscope Adjustments

The controls on the oscilloscope have been preset and do not need to be changed by the tracker operator. (There is an exception to this; the B time delay control will at times need to be adjusted. This control is discussed in section 4.3.2 of the tracking procedure.) Two oscilloscopes are used in the ARIC study, Model 2215 and Model 2215A. The front panel of Model 2215A is reproduced in Figure 5; Table 1 serves as the legend. Table 1 lists the correct control settings for both models. Using Table 1 and Figure 5, the proper control settings for each oscilloscope are verified. The Biosound MUST be turned on while setting the oscilloscope controls.

2.5 Calibration of Strip Chart

The procedure for calibrating the strip chart is performed EACH DAY before tracking begins. The strip chart is calibrated using the following instructions:

1. Turn the power ON, (located in the rear of the strip chart) and let the machine warm up for at least 15 minutes.

TABLE 1
Distensibility Table
for Setting Oscilloscope Controls
(Models 2215 and 2215A)

1.	Viewing Screen	N/A
2.	Power Switch	On
3.	Power Indicator	N/A
4.	Focus Control	Adjust for Optimum Display
5.	Probe Adjust Control	N/A
6.	Beam Find Switch	N/A
7.	Trace Rotation Control	N/A
8.	Intensity A-B Controls	Adjust to Optimum Display
9.	Ch. 1 volts/div	Set .1 volt on the xl position
	Ch. 2 volts/div	Set .2 volt on the xl position
10.	Cal Control (Calibrate)	Turned completely clockwise
11.	Vertical Position Control	Adjust to Optimum Display
12.	AC/GND/DC	Set to "DC"
13.	Ch 1 or x (Input connector)	Connect Cable labeled "Gates"
	Ch 2 or y	Connect Cable labeled "RF"
14.	Vertical Mode Switches	
	a. Ch 1 / Both / Ch 2	Set to "Both"
	b. BW Limit (Band Width)	(on 2215 only) Button pushed "Out"
	c. Add / Alt / Chop	Set to "Alt"
15.	Invert Switch for Channel 2	Button pushed "Out"
16.	GND (Ground Connector)	N/A
17.	Serial / Model Slots	N/A
18.	A and B Sec / Div Switches	
	a. A swp	Set to 5us/div
	b. B delayed swp	Set to 2us/div (pull control out to set)
19.	Cal (Sec / Div Var Control	Set fully clockwise
20.	X 10 Magnifier Switch	Pushed "In"
21.	Horizontal Position Control	Adjust to Optimum Display
22.	Horizontal Mode Switch	Set to "B"
23.	A / B Swp Sep Control	Not Used
24.	B-Delay Time Position Control	Set to Display the Arterial Wall Complex in the center of the RF Signal Screen
25.	A-Trigger Mode Switch	
	a. Sgl Swp	Not Used
	b. P-P Auto	Set to "Auto" (Auto pushed out on 2215A)
	c. Norm	Not Used
26.	Ready / Trig D Indicator	N/A
27.	(A-Trigger) Level Control	Set fully clockwise
28.	Slope	Set switch in the "Up" position
29.	A-Source	Set to "Ext"
30.	A and B Int	N/A
31.	A-Ext Coupling	Set to "DC"
32.	Ext Input Connector	Connect the cable labeled "SYNC"
33.	(B-Trigger) Level Control	Set fully clockwise
34.	Var Hold Off	Set fully counter clockwise

2. Set the RECORD MODE SWITCH on the arterial wall tracker to the CALIBRATE (CAL) position.

3. Turn the output control on the arterial wall tracker to the ZERO (0) position.

4. Turn the strip chart speed on low using the chart speed dial on the front of the strip chart.

5. Turning the strip chart knobs labeled ZERO, position the pens to the zero mark which is the bottom or right most line of the strip chart paper. Do this with channel 1 and channel 2.

6. Turn the output control on the arterial wall tracker to 10.

7. Turning the gain controls on the strip chart (below the Zero controls), position the pens to the 10 mark which is the top or left most line on the strip chart paper. Do this with channel 1 and channel 2.

8. Turn the output control on the arterial wall tracker down to 5, then down to 2.5, and verify that the strip chart pens move to those same positions on both channels. DO NOT ADJUST the GAIN or the ZERO controls when the output control is at 5 or 2.5. If the pens have been set at 0 and 10 correctly (see steps 5-7), they will not need to be adjusted at this time. If the pens do not move to the 5 and 2.5 settings, the Ultrasound Reading Center should be contacted to arrange for a recalibration of the unit.

9. Turn the output control on the arterial wall tracker back to the 0 position.

10. The pens on both channels should now be at the right most line, or zero position. Turn the zero control for Channel 2 and position the pen in the middle of the strip. This will be the new zero for this channel. NOTE: <u>If the gain or zero controls of the strip chart recorder</u> (See Figure 9) <u>are accidentally moved, the calibration procedure must be repeated</u>.

11. Turn the chart speed dial off.

12. Set the RECORD MODE SWITCH on the arterial wall tracker to the RUN position.

3. OVERVIEW OF TRACKING PROCEDURES

At the completion of the ultrasound scan and before the measurement of postural change, the participant's distensibility data are collected. The tracking procedures are those steps which are followed in the collection of this data. The sonographer should read through this entire procedure before attempting to track. An understanding of the complete tracking process is necessary in order to accurately record the distensibility data.

3.1 The Biosound Image

The tracking process begins with the Biosound (see Figure 6). The function of the Biosound in the tracking process is to acquire the B- mode image of the left common carotid artery from which the distensibility data are gathered.

The image of the arterial wall interfaces must be of a high quality. The arterial wall echoes must be strong with as little interference as possible. There are four main arterial wall interfaces, as described in the scanning protocol, but the arterial wall tracker (this tracking device is discussed later) is used to follow the motion of only two of them. These are interfaces 2 and 5 on the near arterial wall and far arterial wall, respectively. Therefore, the sonographer primarily uses these two interfaces while attempting to record a high quality image of the left common carotid artery.

To obtain a good quality image, the sonographer need only concentrate on the vertical center of the Biosound screen. Only one horizontal line of the B-mode image is analyzed by the wall tracking device. This horizontal line is the one that is in the vertical center of the screen. Therefore, the quality of interfaces 2 and 5 should be optimal in the vertical center of the Biosound monitor.

3.1.1 Biosound Controls

There are three controls on the Biosound control panel that are adjusted in this first step of the tracking procedure. The cursor is placed in the DOPPLER position so that it can be moved to the vertical center of the screen. The length of the cursor is set to 15 mm. Positioning the cursor in this manner serves as a reminder that this is the line of information used for tracking.

Other controls that are adjusted on the Biosound are the VIDEO GAIN and the TGC. The sonographer may turn these controls up as needed to facilitate tracking. This not only increases the apparent brightness of the interfaces on the Biosound monitor, but also causes the electronic signals, which are sent to the tracking device, to be strong. It is recommended that the sonographer NOT turn the gain controls all the way up to 10.

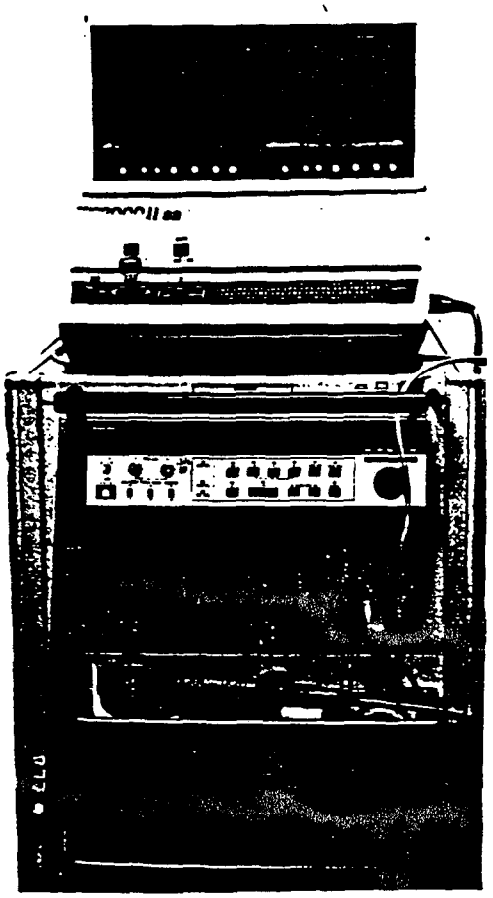


Figure 6. Biosound 2000 II sa

3.2 Oscilloscope and Arterial Wall Tracker

After obtaining the image of the left common carotid (optimal angle) on the Biosound, attention is turned to the oscilloscope (see Figure 7) and the arterial wall tracker (see Figure 8). In the tracking process, the oscilloscope displays the electronic "rf" (radio frequency) signals which are output from the Biosound. The sonographer uses this display to identify the arterial wall echoes on the oscilloscope monitor. The arterial wall tracker captures and follows (tracks) the motion of the artery walls.

The oscilloscope screen is overlaid with a grid. The horizontal scale of this grid measures time with each major division representing a time interval which is dependent on the time setting control on the oscilloscope. The vertical scale measures voltage with each major division representing a voltage interval which is dependent on the voltage setting control on the oscilloscope.

When the oscilloscope is turned on, two horizontal lines (channels) appear on the monitor. The top line is channel 1 and the bottom line is channel 2. On channel 1 there are two rectangular shaped boxes (gates). Each of these gates is used in tracking the motion of a particular arterial wall echo.

The rf signals from the Biosound are displayed on channel 2. These signals represent rf echoes received by the transducer just as the bright lines on a B-mode image represent echoes received by the transducer. Each echo complex represents a different interface. The stronger or brighter the B-mode image of the interface, the greater the amplitude of the rf echo complex on the oscilloscope.

In identifying the artery on the oscilloscope monitor, look for three main features that are characteristic of the arterial rf signals: (1) an area where there are no rf signals, (2) motion of the arterial rf signals, and (3) strong rf signals.

Once the artery on the oscilloscope is located, the gates and spikes for tracking are positioned.

3.2.1 Gates and Spikes

On channel 1, a large and small spike ride on each gate. The purpose of the large spike is to electronically capture the strongest rf signal that it can find and follow its motion. The purpose of the small spike is to reposition the large spike, if necessary. The gates are centered above the walls using controls on the arterial wall tracker. Use other controls on the arterial wall tracker to position the spikes above the portion of the near and far arterial wall that represent interfaces 2 and 5.

Once the gates and spikes are correctly positioned, observe the oscilloscope to determine whether the walls are being tracked. The motion of the arterial walls is being properly tracked when (1) the large spikes are correctly positioned above interfaces 2 and 5 of the artery walls, and (2) the large spikes remain fixed above these arterial interfaces and consistently move right to left to right etc., at the same rate as the artery walls.

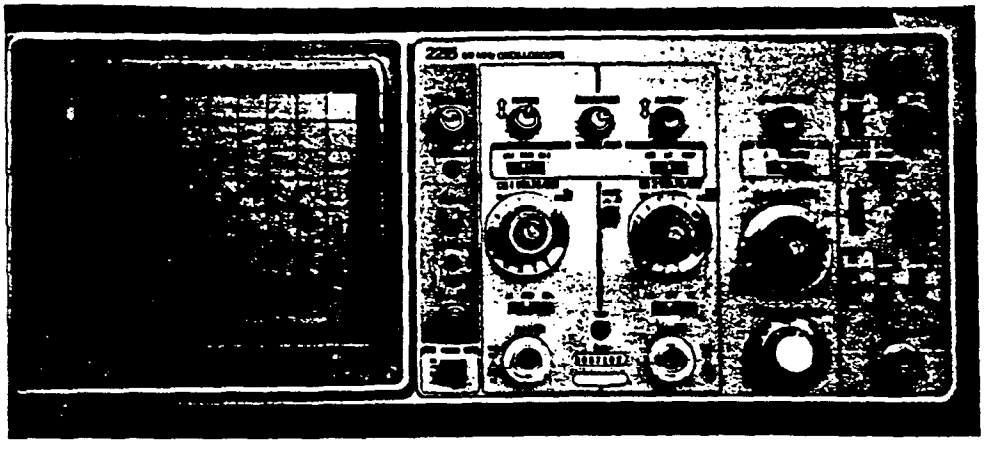


Figure 7. Tektronix Oscilloscope

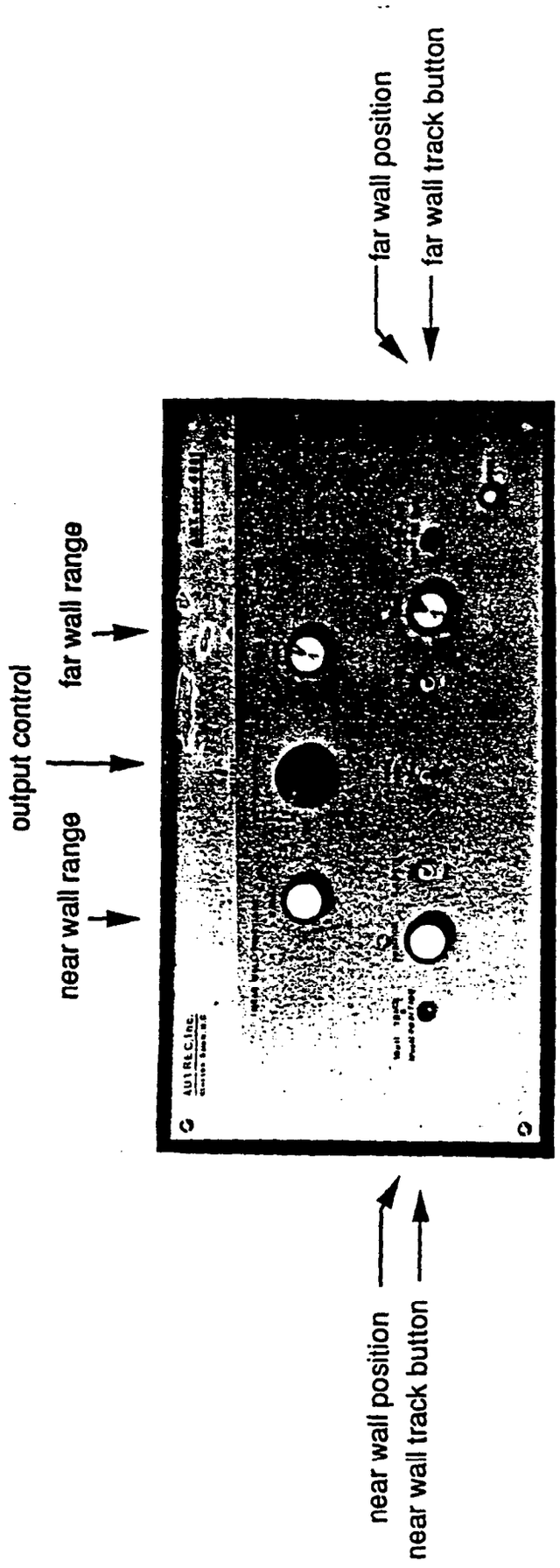


Figure 8. Arterial Wall Tracker

3.3 Strip Chart Operation

The output of the arterial wall tracker is sent to the strip chart recorder (see Figure 9), which graphically records a diameter vs. time display of the artery's pulsating walls. The arterial waveforms displayed on the strip chart allow the sonographer to assess the validity of the data which the arterial wall tracker is acquiring.

The strip chart displays two waveforms, each on a different channel. The left half of the paper, channel 1, displays a graph of the arterial diameter as a function of time. The maximum diameter which can be measured on this channel is 10 mm. The right half of the paper, channel 2, displays a magnified (10x) graph of the changing waveform shown on channel 1. Channel 2 shows the artery's changing diameter in greater detail; therefore, the sonographer focuses on channel 2 to determine if the arterial walls are being properly tracked.

When using the strip chart, the sonographer notes two things: (1) the SOUND the strip chart makes as it is displaying the graphical waveforms, and (2) the APPEARANCE of the waveforms. The validity of the distensibility data can be determined by listening to the sound the strip chart makes and by studying the shape of the waveforms.

The distensibility data is ready to be stored in the computer on the participant's floppy disk when the sonographer is confident that the data being recorded is valid and when approximately 10-15 consecutive cardiac cycles have been displayed on the strip chart.

3.4 Storing The Distensibility Data

The computer records and stores the distensibility data. After determining that good quality data are being obtained, the AUDIO RECORD FOOTSWITCH is pressed, which signals to the computer to stop recording the distensibility data. At this time, the most recent data from approximately ten consecutive cardiac cycles are temporarily stored on the hard disk of the personal computer.

4. DETAILED TRACKING PROCEDURE

This section assumes:

1. the B-mode ultrasound scan has been completed;

2. all tracking equipment is turned on;

3. the arterial wall tracker has been on for <u>at least</u> 30 minutes.

Approximately 5 minutes are spent in recording the distensibility data. If unable to record satisfactory data within this time limit, the postural change examination is initiated by pressing F1 on the keyboard to exit the distensibility study. Both the Sony and Panasonic video cassette tape recorders are turned ON and the AUDIO RECORD FOOTSWITCH is pressed. This records the stop code on the tapes. The video cassette tape recorders are then turned OFF, and the sonographer proceeds to the postural change examination as described in Manual 11.

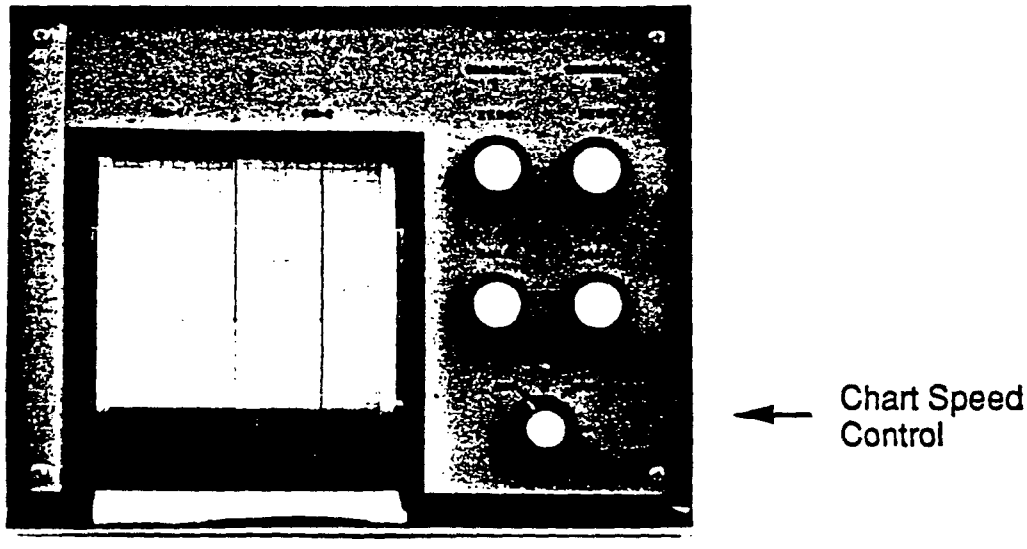


Figure 9. Strip Chart Recorder

4.1 Tracking Preliminaries

The following steps are performed prior to the actual collection of distensibility data.

1. Put both Sony and Panasonic tape recorders on PAUSE. These recorders will stay on pause until distensibility data is acquired (See Section 4.5 Step 3).

2. Verify that there is an adequate supply of paper in the strip chart recorder.

3. Instruct the participant to lie still and that during the next few minutes you will be gathering data which provides information about the walls of the arteries which you have been scanning.

4. Press the AUDIO RECORD FOOTSWITCH to signal the computer that you are beginning the distensibility study. At this point, LIGHT NUMBER 12 will be illuminated on the study flow panel.

5. Flip the cursor switch on the Biosound to the DOPPLER position (see Figure 10).

6. Using the cursor knob on the Biosound, position the cursor in the <u>vertical center</u> of the screen and rotate the control until the length of the cursor is 15 mm.

7. <u>Keeping</u> the cursor line in the vertical center of the screen, push the cursor knob to the left to position it on the left half of the monitor. This serves as a reminder that it is along this line where B-mode image quality must be optimal.

8. The <u>vertical</u> position of the cursor determines the exact part of the image which, when the "mirror" is turned off, will be sent to the tracker. The cursor <u>must</u> remain in the <u>vertical</u> center throughout the tracking procedure.

4.2 Acquiring a B-Mode Image

For tracking purposes the arterial wall interfaces must be clearly identified, with as little interference as possible, in the center of the screen. The sonographer concentrates on the boundaries of interfaces 2 and 5 while acquiring the image.

1. Place the transducer in the transducer holder (see Figure 11) and acquire a B-mode image of the left common carotid artery at or near optimal angle. Put the site located 1.5 cm below the origin of the carotid bulb in the center of the screen by placing the origin of the bulb at the bottom of the image screen.

2. Manipulate the transducer so that interfaces 2 and 5 are as clear as possible and so that the arterial wall boundaries are vertical on the screen.

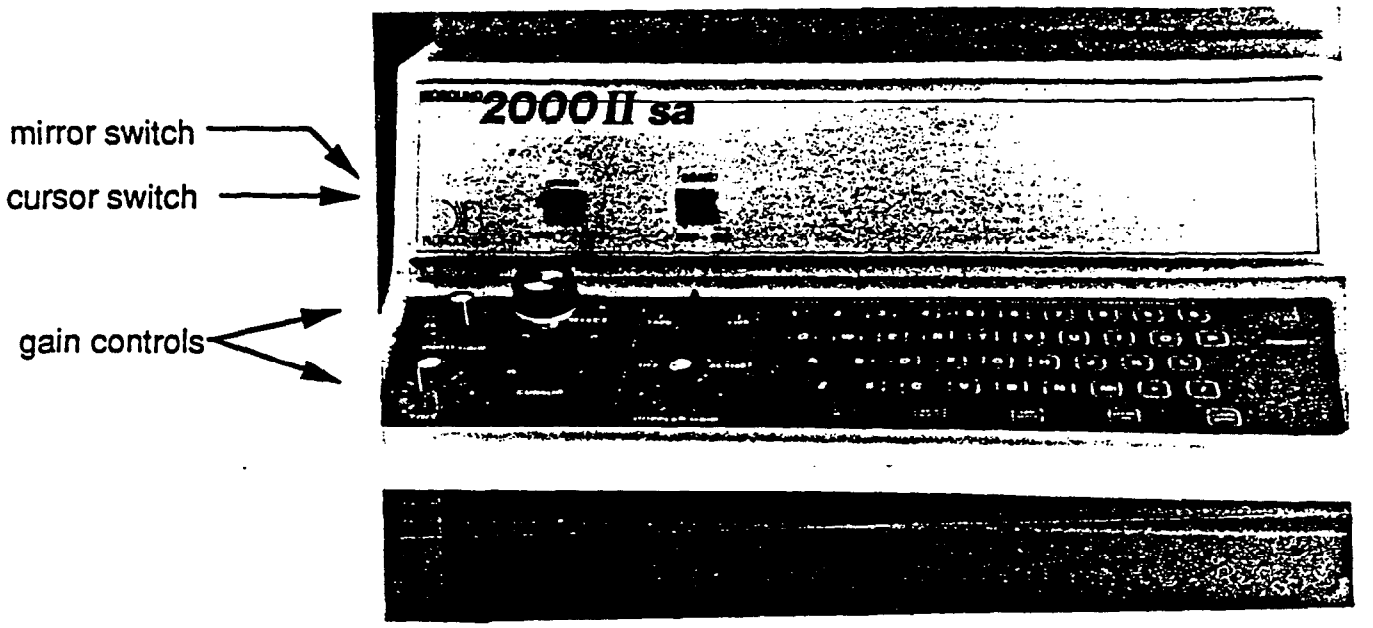


Figure 10. Biosound Control Panel

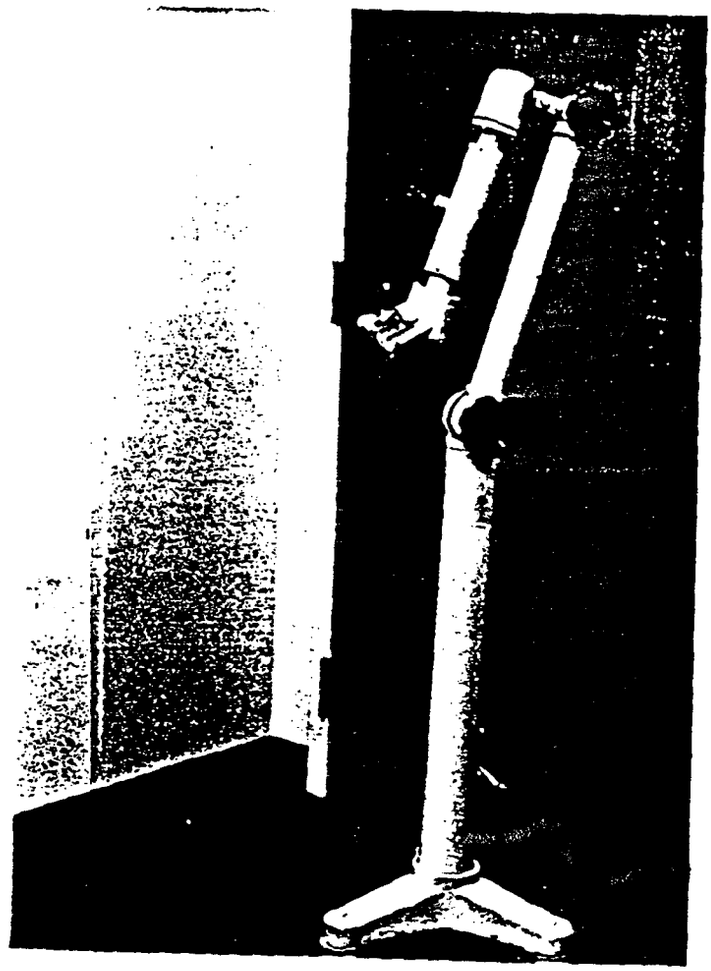


Figure 11. Transducer Holder

3. Tighten the knobs on the transducer holder so that the transducer is firmly in position and immobile.

4. Leave the transducer in the transducer holder, and check the B-mode image to verify that the transducer is steady and the image is still satisfactory for tracking purposes.

5. Flip the MIRROR SWITCH on the Biosound (see Figure 10) to the OFF position and observe that the image is replaced by a series of vertical lines.

6. The Biosound VIDEO and TGC gain controls (See Figure 10) which were used to obtain the B-mode image, should allow satisfactory tracking. If difficulty is encountered, the VIDEO and TGC gains may be increased to facilitate tracking.

7. Note the message on the computer screen instructing the sonographer to PRESS ANY KEY on the computer keyboard to begin data acquisition. Before pressing this key, make sure your data will be adequate by using the oscilloscope. (See Section 4.3).

4.3 The Oscilloscope

The sonographer turns attention to the oscilloscope and verifies that channel 1 and channel 2 appear as two bright horizontal lines on the monitor (see Figure 12). If either of these channels does not appear, Section 2.4-Oscilloscope Adjustments is consulted to verify that the oscilloscope controls are properly set.

Once ascertaining that the two gates appear on channel 1 (see Figure 12), the gate appearing above the line is used to track the near arterial wall. The gate appearing below the line is used to track the far arterial wall. If the two gates do not appear on the screen, the RANGE controls (see Figure 8) are adjusted on the arterial wall tracker.

The NEAR WALL RANGE control is turned to position the near wall gate on the left half of the screen. The FAR WALL RANGE control is turned to position the far wall gate on the right half of the screen.

4.3.1 Artery Identification

Using the rf signals on channel 2, the sonographer follows the guidelines below to identify the artery on this channel. Figure 13 illustrates an ideal image of an artery on channel 2.

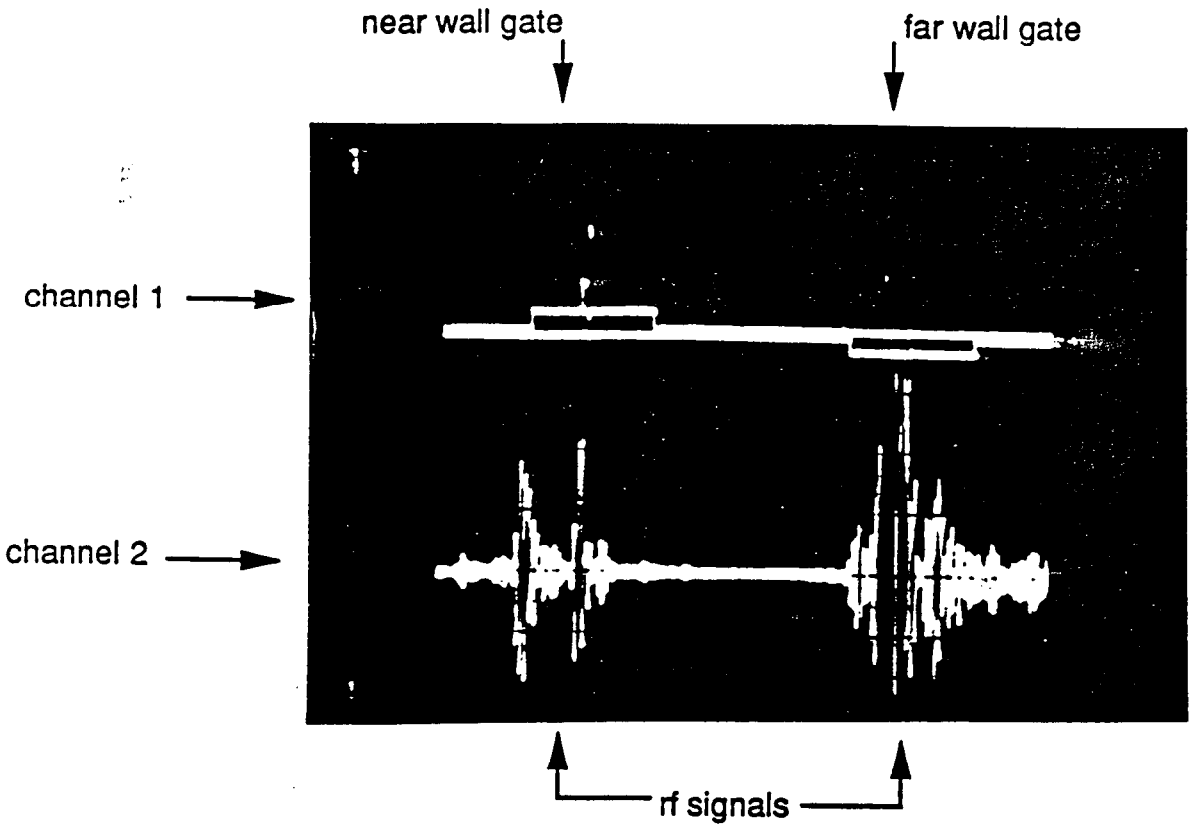


Figure 12. Oscilloscope Screen

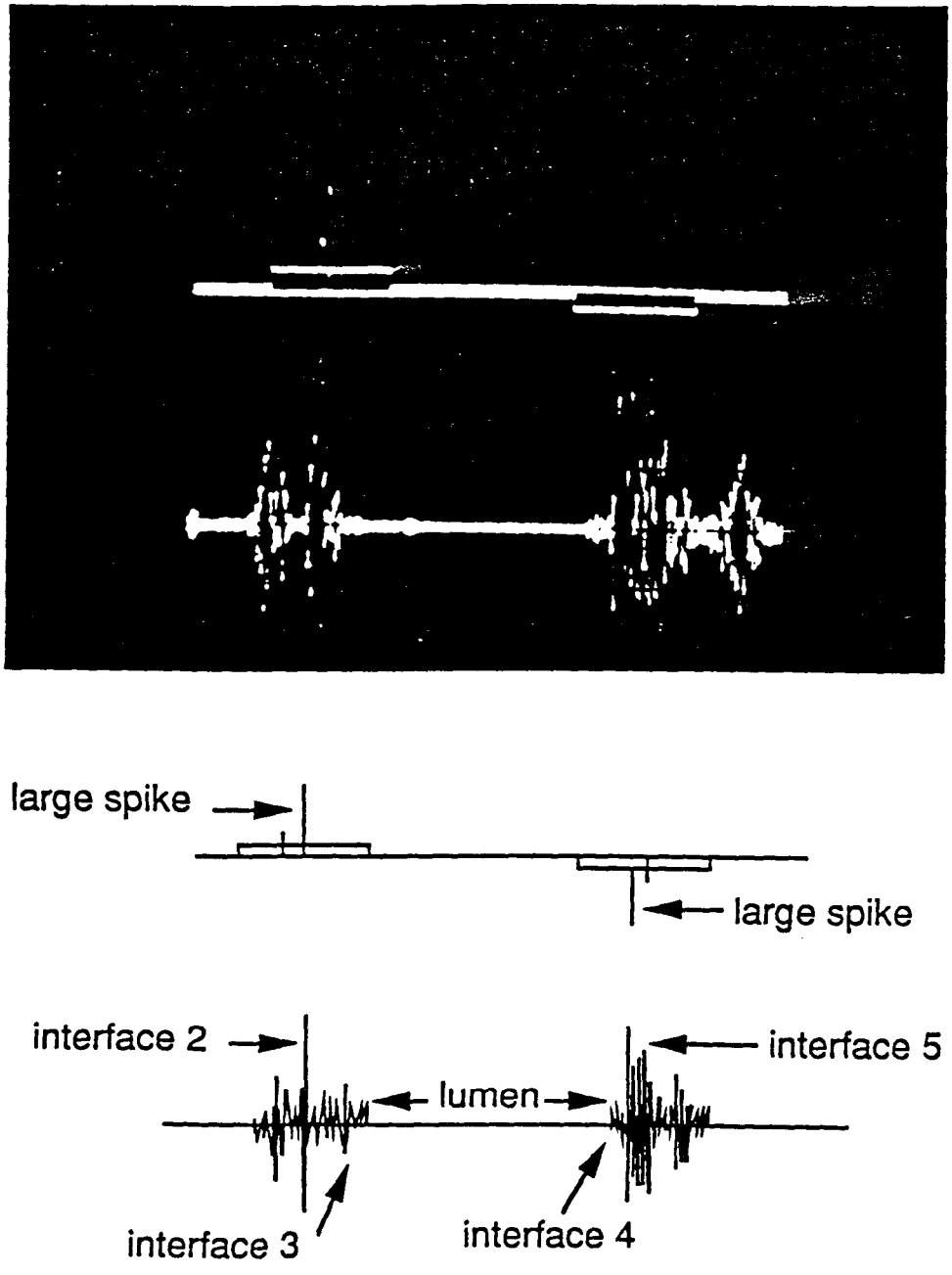


Figure 13. Ideal Image of Artery on Channel 2 of Oscilloscope Screen

1. Arterial signals are stronger (the peaks have more amplitude) than the signals from surrounding tissues.

2. The signals from arterial walls move left to right to left etc., as the artery walls pulsate. This pulsating motion often causes the surrounding tissue to move as well, so care must be taken not to confuse the motion of tissue or a vein with motion of the artery.

3. The lumen of the artery is seen on the oscilloscope as an area where there are little or no rf signals. This relatively signal-free area corresponds to the arterial lumen width.

By observing the position of the artery on the Biosound monitor, the location of the artery on the oscilloscope can be predicted. The signals appearing on the oscilloscope screen do not represent the whole Biosound screen but only a portion of it. The portion which first appears on the oscilloscope monitor may not be the portion where the artery is located. The full range of the Biosound screen can only be seen on the oscilloscope by rotating the B TIME DELAY CONTROL.

4.3.2 The B Time Delay Control

The sonographer notes the location of the artery on the Biosound monitor, i.e., on the left half of the monitor, in the middle of the monitor, or more to the right. Using the B TIME DELAY CONTROL on the oscilloscope (see Figure 5 and Table 1), this control is rotated back and forth to observe the rf signals move across the oscilloscope screen.

If the artery is located on the left side of the Biosound monitor, the B time delay control is turned fully counter clockwise. Then, while slowly turning this control back the other way (clockwise, this time), the sonographer looks for the artery using the above mentioned features.

If the artery is located on the right side of the Biosound monitor, the B time delay control is turned fully clockwise. Then, while slowly turning this control back the other way (counter clockwise, this time), the sonographer looks for the artery using the above mentioned features.

If the artery is located approximately in the center of the Biosound monitor, the B time delay control is turned fully clockwise OR fully counter clockwise. The control is then turned back the other way, while looking for the arterial features mentioned above.

After identifying the artery on the oscilloscope screen using the above mentioned guidelines, the sonographer positions the artery in the center of the screen by rotating the B TIME DELAY CONTROL.

Figure 13 serves as a reference, demonstrating an ideal image of the artery, the gates, interfaces 2, 3, 4 and 5 and the exact position of the large spikes above interfaces 2 and 5 as they would appear on the oscilloscope screen at this point.

4.3.3 Positioning Gates and Spikes for Tracking

Using the RANGE controls on the arterial wall tracker, the sonographer centers the near and far wall gate above the corresponding arterial wall. The gates are positioned so that the width of the gate encompasses the full range of arterial wall movement. The position of the near and far wall gates can not be reversed. Each gate must be centered above the correct arterial wall or the tracking operation will fail.

Steps (1) and (2) below are repeated until the large spikes are positioned above the stronger rf signals that are closest to the lumen of both the near and far wall. Occasionally, interfaces 3 and 4 may be seen on the oscilloscope. These interfaces are usually too weak to track; therefore, tracking is only done on interfaces 2 and 5. Interfaces 3 and 4 are not tracked, regardless of whether or not they can be seen. Note in Figure 13 that interfaces 3 and 4 are visualized, but the large spikes are still positioned above interfaces 2 and 5 even though, in this case, 2 and 5 are not the signals which are closest to the lumen.

To position the gates and spikes for tracking,

1. Slowly rotate the RANGE control on the arterial wall tracker toward the lumen until the large spike is on the edge of the gate. Continue to move the gate toward the lumen and observe that the large spike can be pulled along with the gate.

2. Move the gate back and forth, "kicking" the large spike with the edge of the gate, until the large spike locks onto the portion of the rf signals representing interfaces 2 and 5.

Sections 4.6.2 and 4.6.3 can be referred to if problems occur with positioning spikes on interfaces.

4.4 Data Acquisition/ADC Loop

When the large spikes are exactly positioned above interfaces 2 and 5 and are moving left to right, etc., following the motion of the arterial walls, ANY KEY on the keyboard (except F1) can be pressed to signal to the computer that the sonographer is ready to begin data acquisition. (A message appears on the screen indicating that the computer is now "IN THE ADC LOOP".) The following three steps initiate the collection of distensibility data.

1. Flip the CALIBRATE/RUN switch on the arterial wall tracker (see Figure 8) to the RUN position.

2. Turn the OUTPUT control on the arterial wall tracker (see Figure 8) to the RUN position.

3. Turn the strip chart on the high speed setting (see Figure 9).

4.4.1 Correct Strip Chart Display

As the strip chart begins to display a diameter vs. time graph of each cardiac cycle, the sonographer checks that the data being output by the arterial wall tracker is valid and that the waveform resembles an arterial waveform. Figure 14(a-d) illustrates the following characteristic features of arterial waveforms:

1. relatively fast systolic upstrokes;

2. dicrotic notches (may not be seen in some cases);

3. relatively slow diastolic downstrokes;

4. typical diastolic diameters (on channel 1) of 6-8 mm.

Corrective procedures are listed in Section 4.6.1 if the waveform does not display the above characteristics.

Before the data are stored on the computer, the strip chart should display approximately 10-15 consecutive cardiac cycles. The sonographer looks for consistency in the appearance of the cycles. When 10-15 consecutive, valid cardiac cycles have been displayed by the strip chart, the distensibility data are ready to be temporarily stored on the hard disk of the computer and later transferred to a floppy disk. NOTE: If 10-15 consecutive valid cycles cannot be acquired, the sonographer attempts to obtain as many consecutive cycles as possible.

4.5 Storing the Data and Completing the Exam

The AUDIO RECORD FOOTSWITCH is pressed to signal to the computer to stop acquiring data and at the same time reach over and turn the strip chart off. When the foot switch is pressed, the computer stores the last cardiac cycles (approximately 10) that were recorded on the strip chart. The sonographer looks at the strip to verify what was sent to the computer.

It is important that there be at least 12 seconds between the time the keyboard is pressed to begin data acquisition (see section 4.4) and the time the footswitch is pressed to end data acquisition.

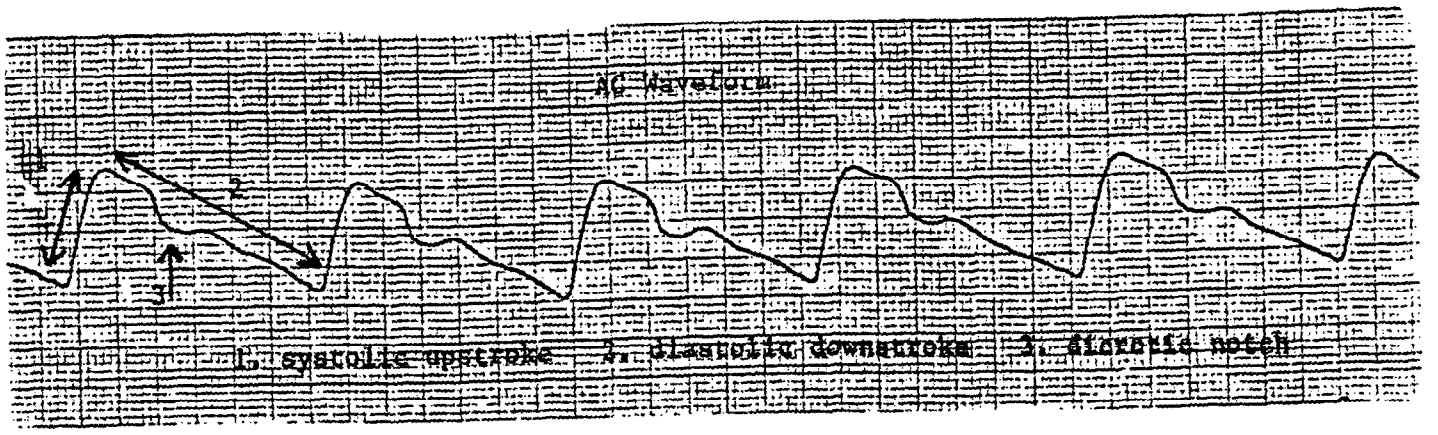
When the quality of the acquired data are satisfactory, the sonographer performs the following procedure:

1. Press <ENTER> on the keyboard to signal the computer that you are ready to continue with the postural change examination.

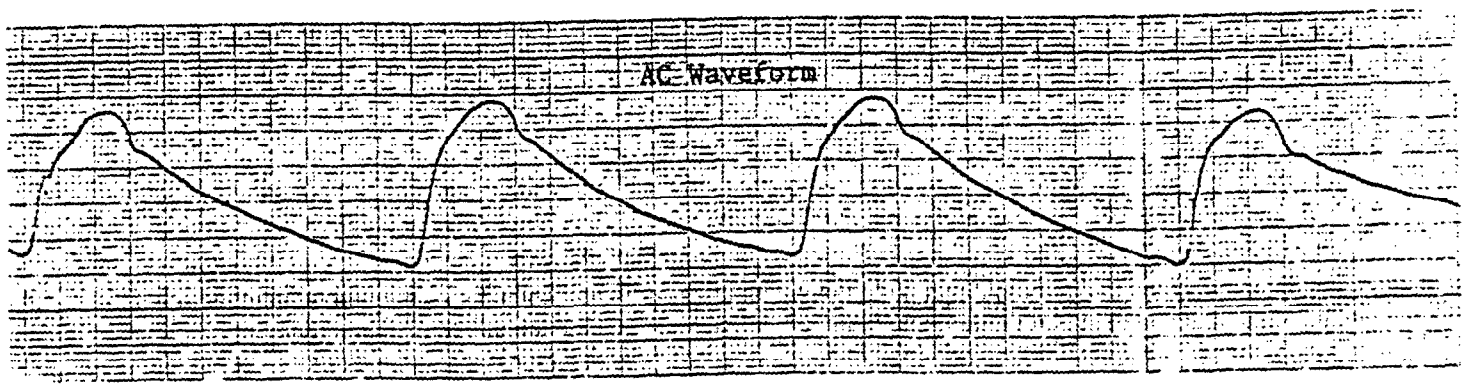
2. Turn the OUTPUT control on the arterial wall tracker to the ZERO (0) position.

3. Turn both video cassette recorders back on, wait 20 seconds, and press the AUDIO RECORD FOOTSWITCH to record the STOP CODE on the tapes.

4. Turn the cassette tape recorders off.

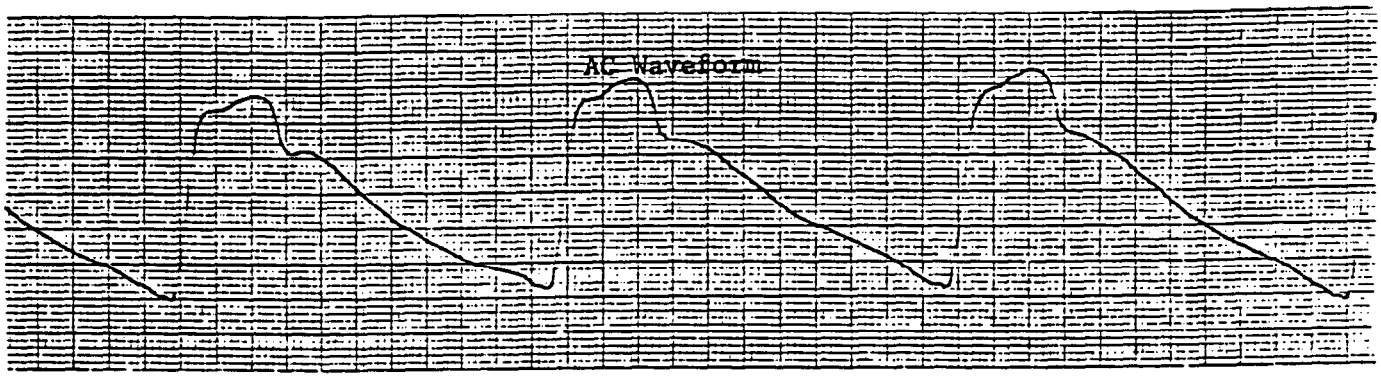


14a. AC Waveform: (1) systolic stroke; (2) diastolic downstroke; (3) diastolic notch

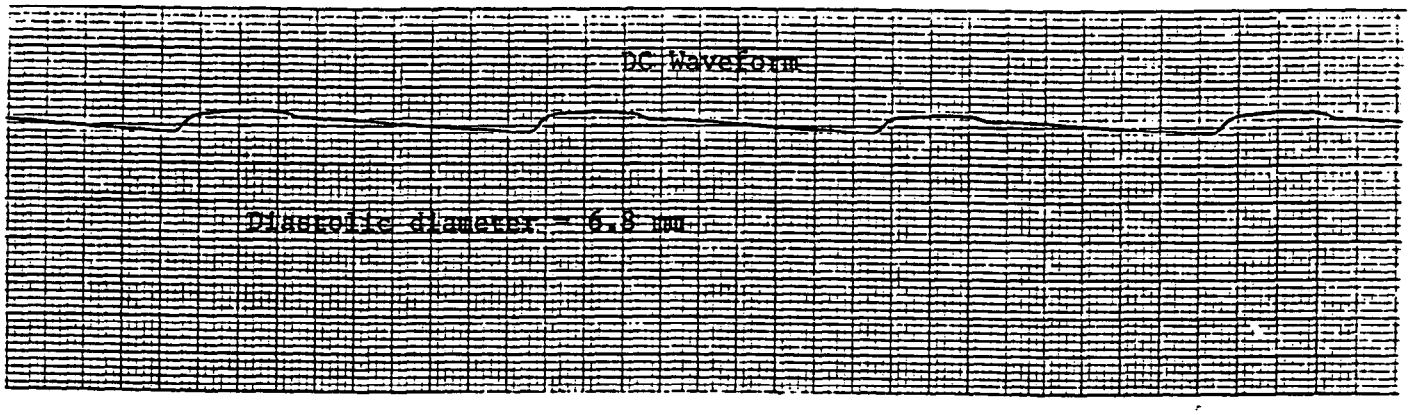


14b. AC Waveform

Figure 14. Valid Arterial Waveforms



14c. AC Waveform



14d. DC Waveform: Diastolic diameter = 6.8 mm

Figure 14. Valid Arterial Waveforms, continued

5. Flip the RECORD MODE SWITCH on the tracker to the CALIBRATE (CAL) position.

6. With the strip chart on low speed, turn the output control on the tracker from 0 to 2.5 to 5.0 to 10, letting the strip run at each setting for about three seconds. Verify that the pens on both channels move to the appropriate position on the paper. NOTE: If the calibration is off, repeat the entire strip chart calibration procedure (Section 2.5) before tracking the next participant.

7. Turn the strip chart speed control on HIGH to roll out remaining chart paper displaying the last portion of the arterial waveform and the calibration display.

8. Remove transducer and gel from participant's neck.

9. Proceed to the postural change examination as described in Manual 11.

10. While waiting to begin the postural change exam, remove the portion of strip chart paper that displays the cardiac cycles sent to the computer and the calibration display. Label the strip with the participant's ID, the sonographer's ID code and the scan date. Fold it and place it in a manila file folder. Label the file folder tab with the Field Center letter (F, W, J or M) and date, and send it to the Reading Center along with the tapes.

11. Record on the weekly Log sheet and on the note log on the computer monitor a comment about the distensibility portion of the ultrasound study, i.e., "unable to track", "tracked well", etc.

Section 4.6.4 outlines alternative procedures if the quality of acquired data is unsatisfactory.

If a distensibility exam is not performed on a particular participant or, after attempting the exam the sonographer is unable to acquire satisfactory data, record one of the following "No Tracking" codes is recorded on the Log Sheet.

0 - Equipment down - Not operational

1 - Equipment Related Problem
Use for such reasons as bubbles in transducer, problem with Biosound, flow panel, computer, etc.

- Interference
Use for such reasons as visible interference in B-mode image, excessive artifact in B-mode image, outside line interference.

2 - Anatomy Related Problem
Use for such reasons as obesity, lateral motion due to respiration, thick muscular neck, vessel too curved, etc.

- Participant Related Problem
Use for such reasons as participant kept coughing, snoring etc.

3 - Unknown Reason
Use when you feel the artery should be tracing, but for some reason, which you are unable to determine, it is not.

- Other
Use when your reason does not fall into any of the above categories. Provide an added explanation.

If distensibility data are satisfactorily acquired, one of the following tracking codes is recorded on the Log Sheet.

4 - Fair Tracking
Use when there are a few acceptable cycles in the tracking, but when most cycles are not acceptable.

5 - Good Tracking
Use when almost all cycles are acceptable.

4.6 Corrective Action/Problems

4.6.1 Incorrect Strip Chart Display

Occasionally, the strip chart waveform appearance signals the sonographer that data being acquired are unsatisfactory.

4.6.1.1 Tracker Jumps

Tracker jumps are caused by interference in the B-mode image. Figure 15(a-c) illustrates instances (indicated by the arrows) where the tracker jumped off the selected interface.

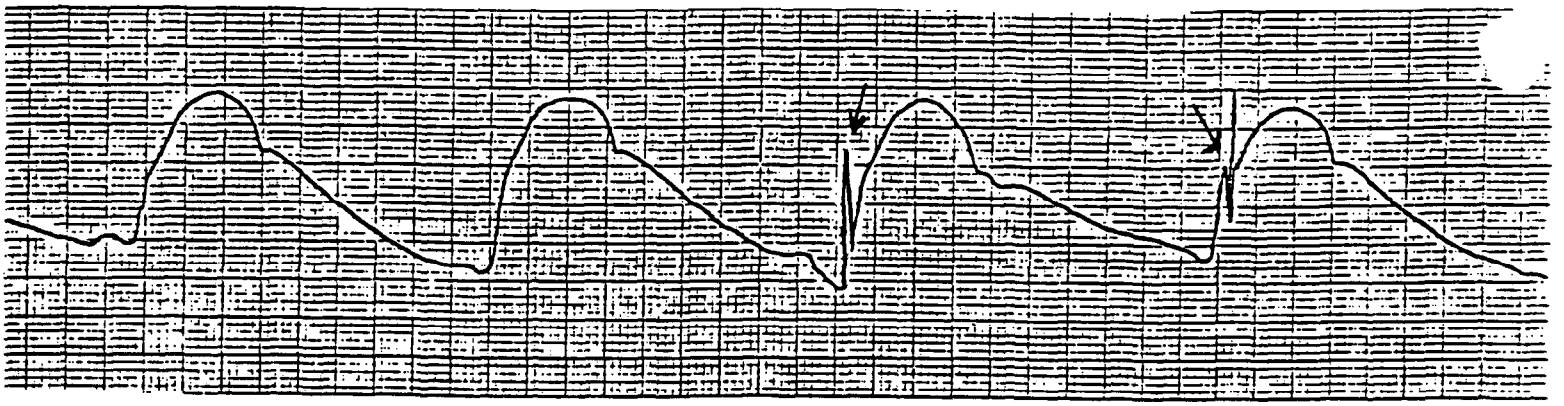
4.6.1.2 Vein Tracking

Sometimes, by mistake, a vein wall may be tracked instead of the artery wall. This yields invalid data. When the waveform looks suspicious, the Mirror Switch on the Biosound is flipped back to the Scan position. The transducer is repositioned to an image where the artery wall echoes are stronger than vein wall echoes and the distensibility tracking is repeated (See Section 4.6.4). Figure 16(a-c) illustrates the following characteristics of vein wall tracking:

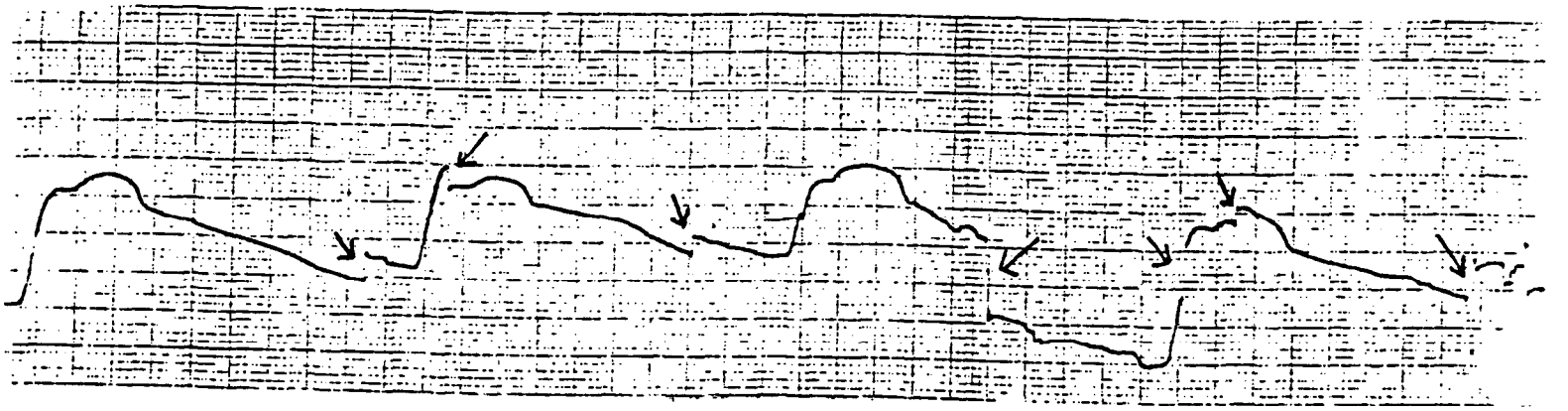
Fig. 16a. There is a slower systolic upstroke (Compare with Figure 14 a).

Fig. 16b. The diastolic downstroke is wavier (Compare with Figure 14 a).

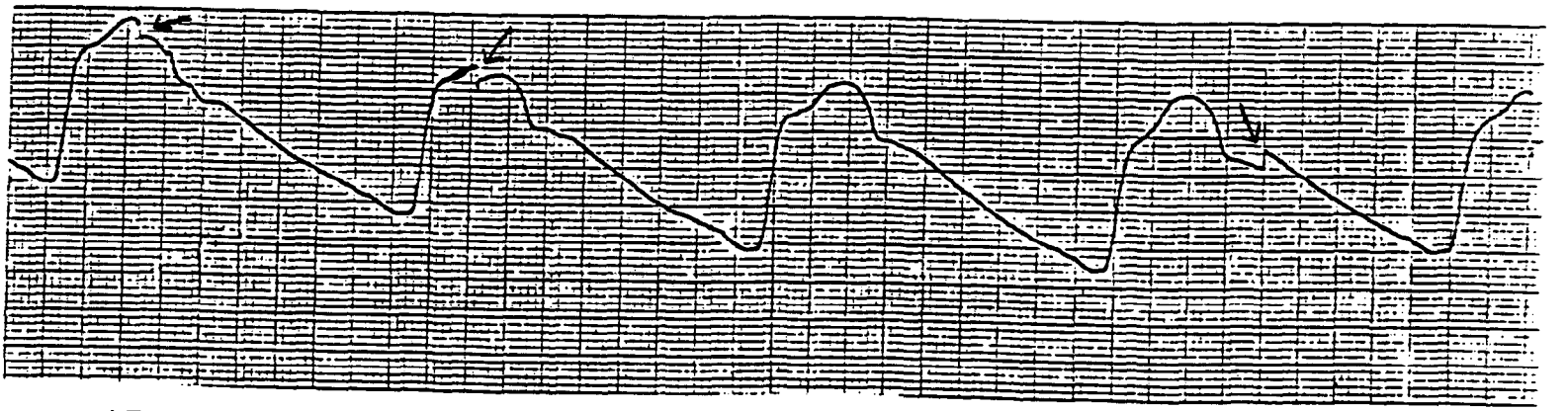
Fig.16c. The diastolic diameter is much larger or smaller (compare with Figure 14 d).



15a.

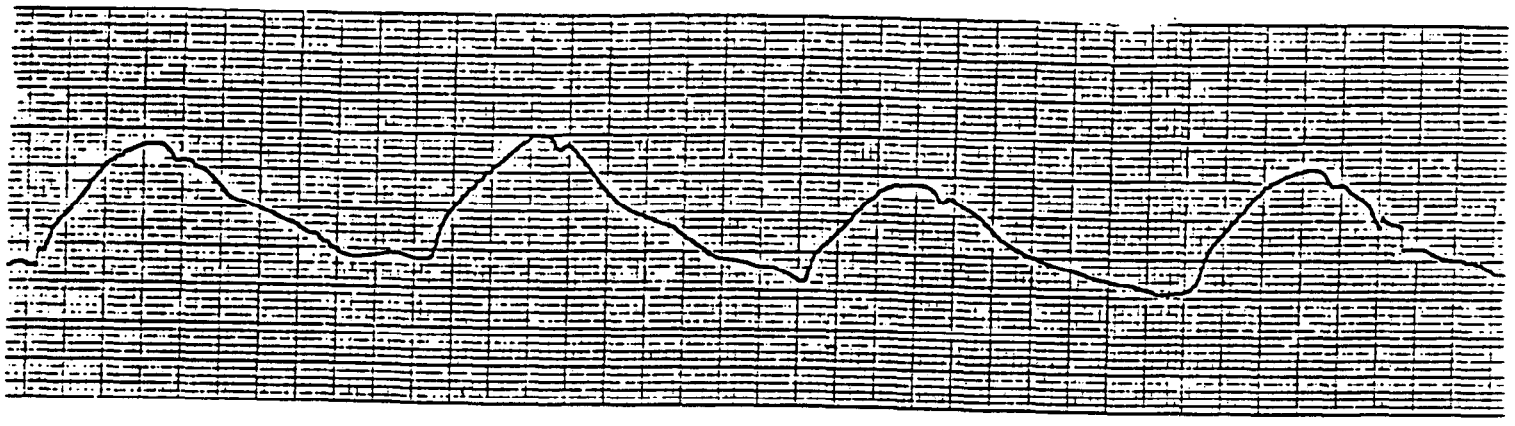


15b.

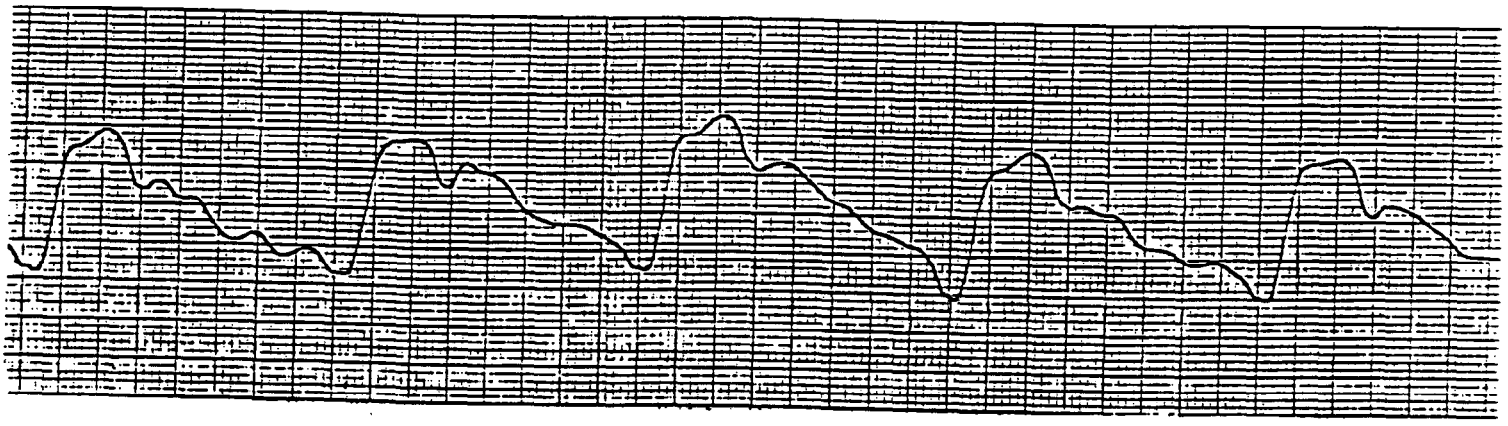


15c.

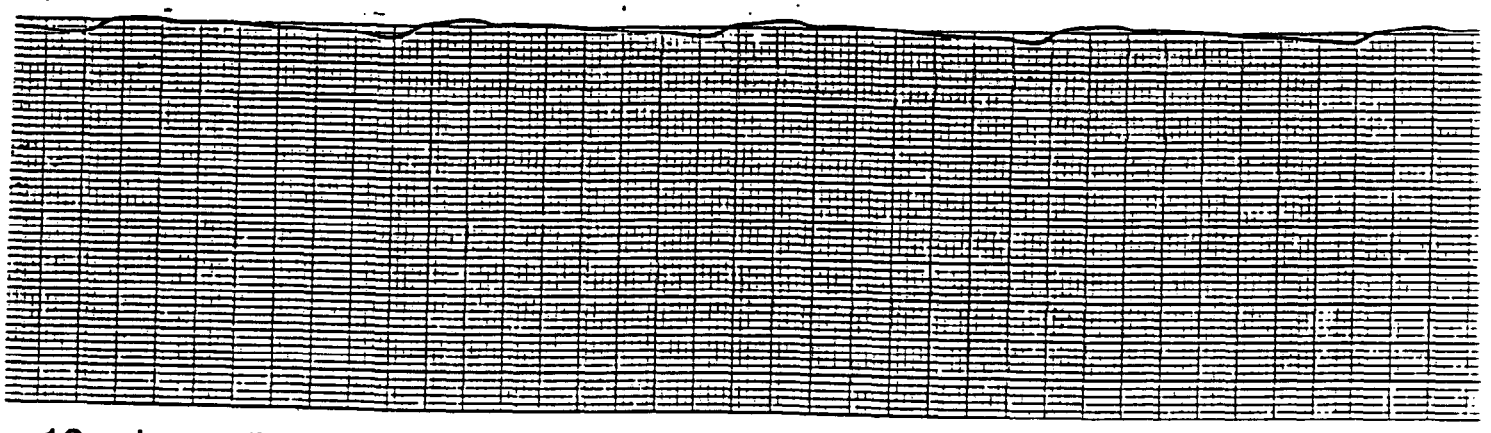
Figure 15. Tracker Jumps Indicated by Arrows



16a. slow systolic upstroke

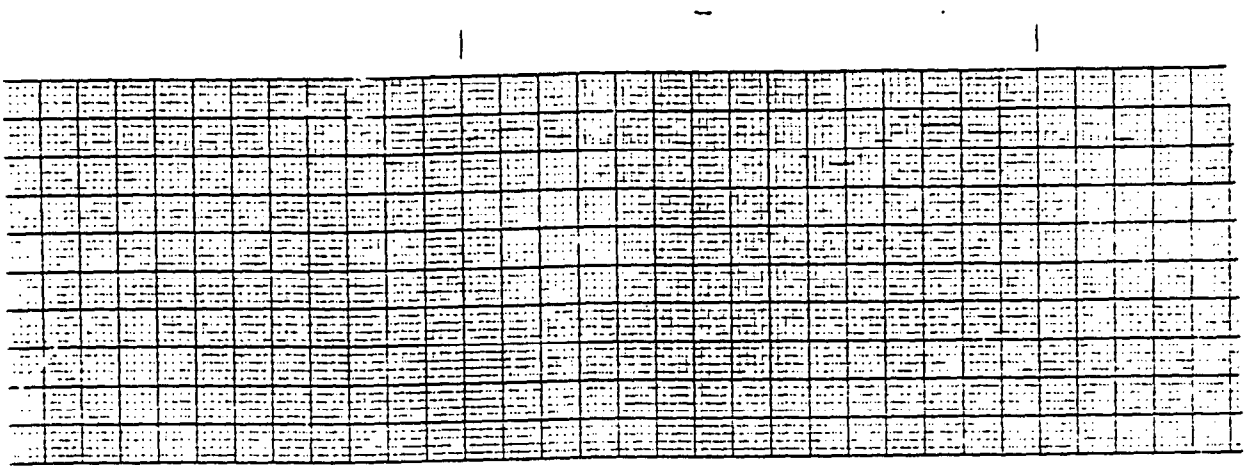


16b. wavy diastolic downstroke

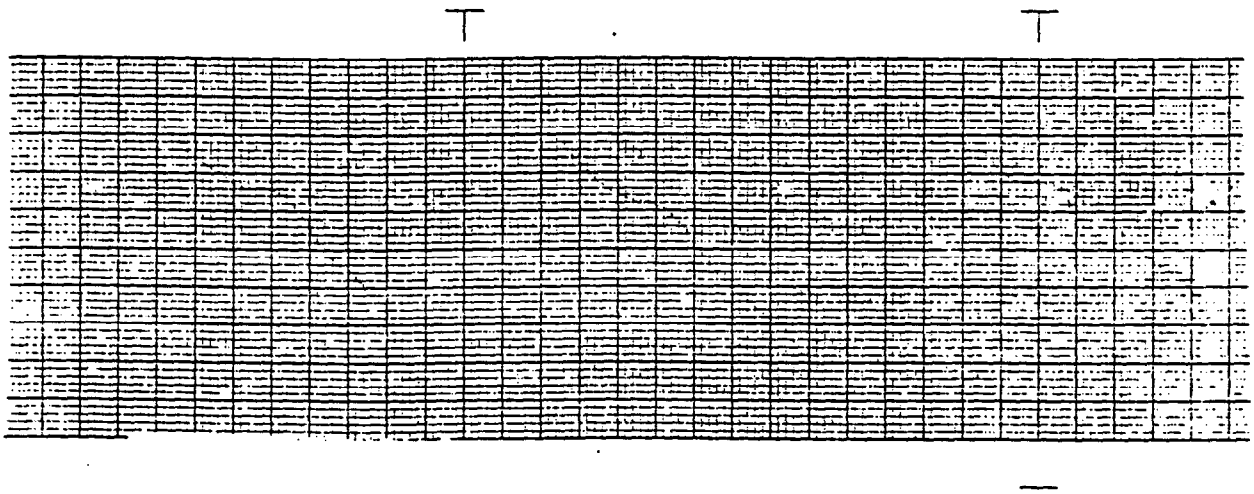


16c. large diastolic diameter (DC strip)

Figure 16. Vein Tracking



17a. Channel 1
Note: The change in diastolic diameter to systolic diameter is very large.



17b. Channel 2.
Note: The downstroke in this waveform is not valid.

Figure 17. Vein Wall and Artery Wall Tracking Waveform

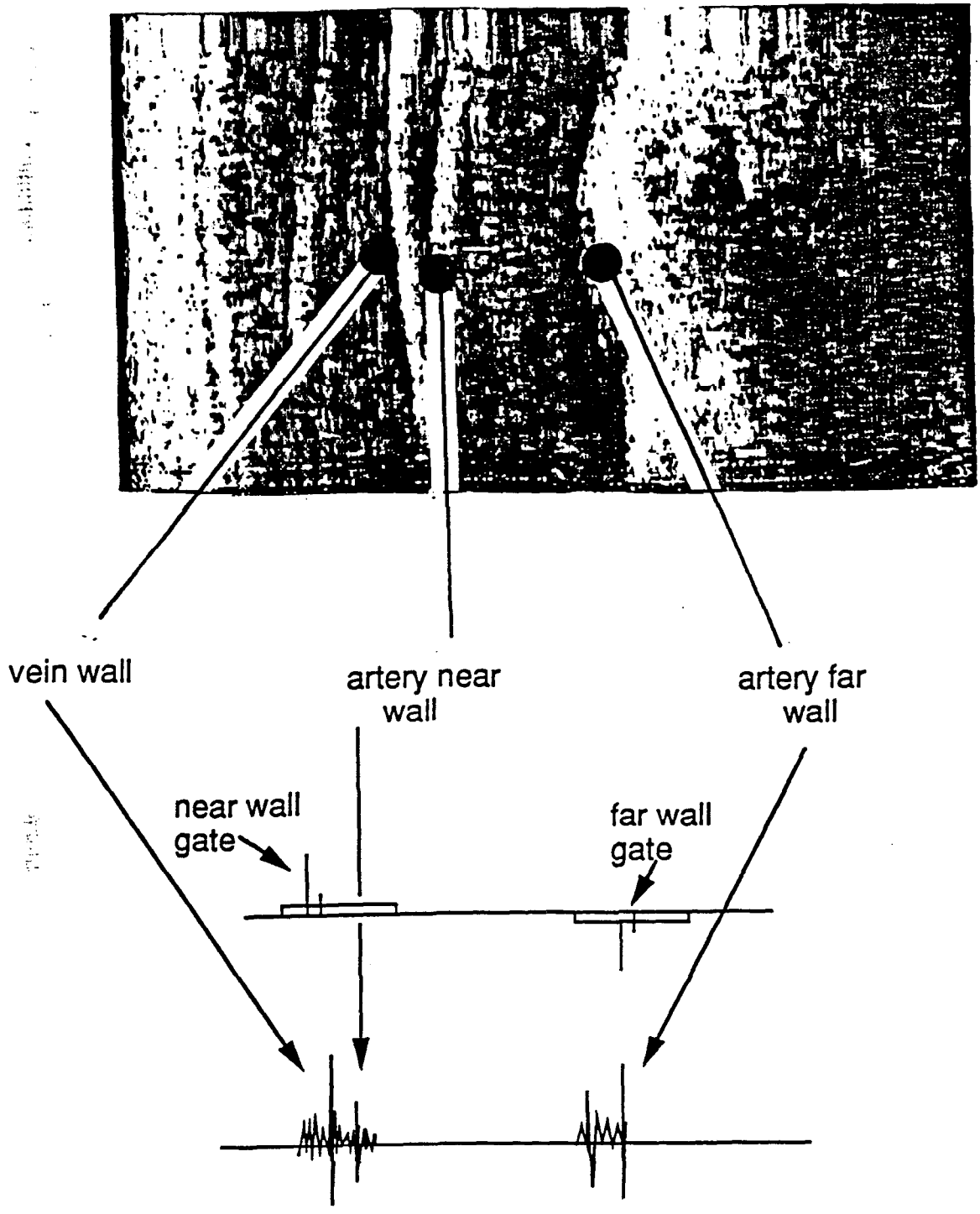


Figure 18. B-Mode Image at the Time of Data Collection with RF Signals Illustrated

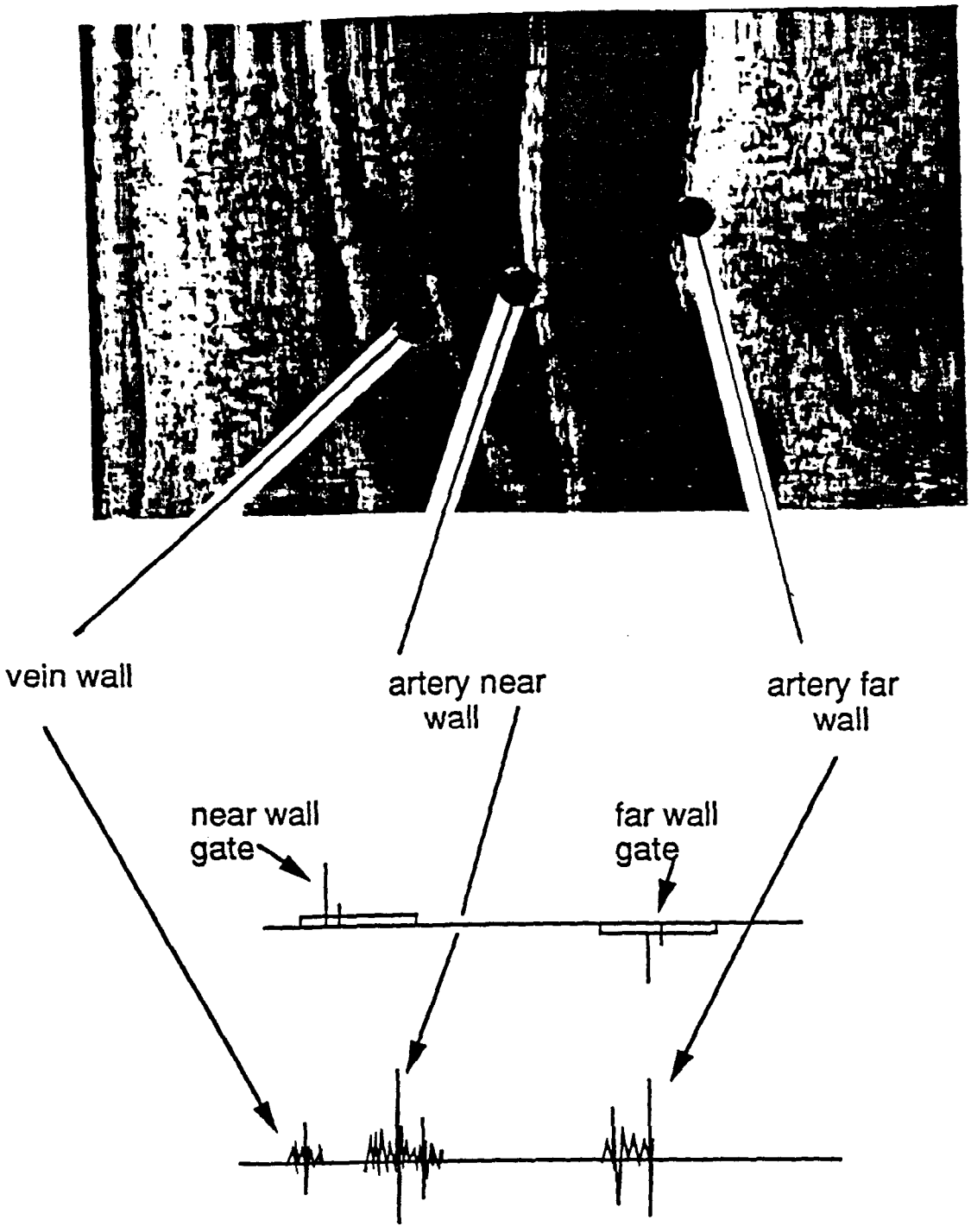


Figure 19. B-Mode Image at Opt Angle with RF Signals Illustrated

4.6.1.3 Vein Arter Wall Tracking

Figures 17, 18 and 19 are examples of the difference in B-mode images when a sonographer observes a waveform with suspicious characteristics. The characteristics of the waveform indicate that the suggestions listed in section 4.6.1.2 should be followed (see Figure 17). The B-mode image (see Figure 18) shows that the vein wall and the artery near wall are very close together and may be easily misidentified on the oscilloscope. Once the adjustments to the transducer alignment are made, it is much easier to identify the artery near wall on the oscilloscope (Figure 19).

4.6.2 Incorrect Strip Chart Sound

If a loud scratching sound is heard, this is evidence that the large spikes are not remaining on the selected interfaces; therefore, the artery walls are NOT being tracked. This sound is the pen on the strip chart traveling rapidly across the paper. When the walls are being properly tracked this scratching sound is much softer because the pen is then traveling across the paper at a much slower speed.

When loud scratching sounds are heard, the following checklist is used:

1. Are the VIDEO GAIN and the TGC gain turned all the way up to 10? If not, the signals may be too weak for the spikes to remain locked onto the appropriate interface. The gains are turned up to 10 and tracking is repeated. (See Section 4.6.4).

2. Is there much SPECKLE (interference) in the artery walls on the B-mode image? If so, this can cause "tracker jumps". Interference causes the signals to periodically (and rapidly) drop to zero. When this happens the spikes look for another strong signal to lock onto, causing them to "jump". If this appears to be the problem, the MIRROR SWITCH on the Biosound is flipped back to the SCAN position and the position of the transducer is readjusted slightly until the echoes are stronger, with less interference. Tracking is repeated. (See Section 4.6.4).

3. Is lateral wall motion causing the signals to move outside the range of the gates? This can be caused by respiration. This may be remedied by repositioning the transducer to get a slightly different angle. If, after 5 minutes, the tracker still will not stay locked on to the correct interfaces, the F1 key on the computer keyboard is pressed to EXIT the distensibility study. The cassette tape recorder is turned ON and the AUDIO RECORD FOOTSWITCH is pressed one more time. This records the stop code on the tape. The cassette tape recorder is then turned OFF and the sonographer proceeds to the postural change examination as described in Manual 11.

4.6.3 Incorrect Placement of Large Spikes

Sometimes the large spikes lock onto a signal that is near the appropriate interface but not exactly in the optimal position. If this occurs, steps (1), (2), and (3) below (which explain the use of the small spike for "fine tune" positioning) are repeated for each arterial wall.

1. Using the POSITION controls on the arterial wall tracker (see Figure 8), position the small spikes directly above interfaces 2 and 5. Assuming the large spike has already been positioned in this approximate location, the large and small spike should be close to each other at this point.

2. Press the TRACK button on the arterial wall tracker (see Figure 8) once (or several times slowly, if necessary) and observe the large spike jump over to the position of the small spike.

3. If, while moving the small spike, the large spike jumps off the strong signal, it may have to be repositioned (See section 4.3.2).

4.6.4 Repetition of Data Acquisition

When the quality of recorded data are unsatisfactory and the sonographer wants to start over, the following procedures are used.

1. Toggle the study flow panel back to LIGHT NUMBER 12 and press the AUDIO RECORD FOOTSWITCH.

2. Press a "Y" on the keyboard in response to the computer screen's message, "Repeat data acquisition?".

3. Turning the arterial wall tracker OUTPUT control back to RUN and the strip chart back on high speed, reposition the gates and spikes for tracking.

4. Wait until you have acquired approximately ten good cardiac cycles of data, (must be at least 12 seconds after pressing the "Y" on the keyboard) and, at the same time, press the AUDIO RECORD FOOTSWITCH (to end data acquisition) and turn the strip chart off. Only two attempts to acquire distensibility data are possible. After the footswitch is pressed ending data acquisition the second time, the computer program automatically exits distensibility and enters the postural change portion of the program.