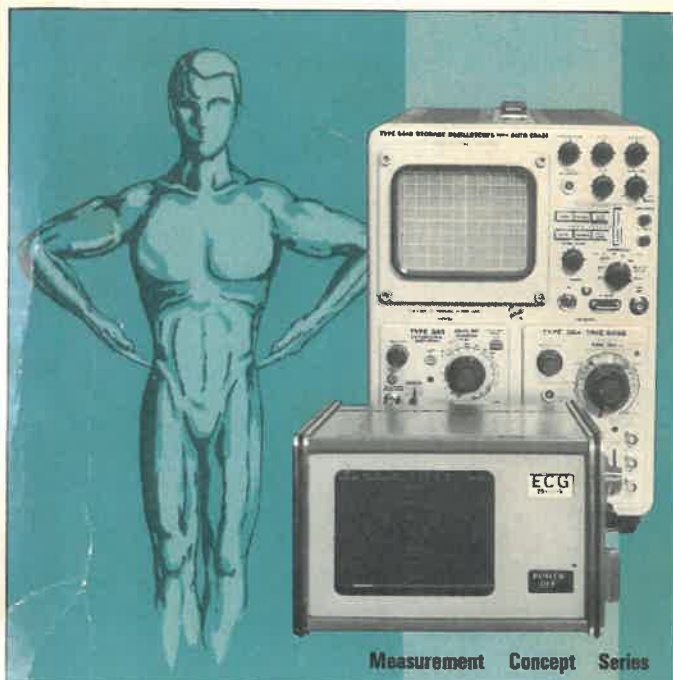




Biophysical Measurements



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BLOOD PRESSURE AND FLOW

Blood pressure measurements can be classified into three discrete groups: direct, indirect and relative. Direct blood pressure measurement involves gaining access to the circulatory system and measuring the pressure in the system directly with some form of pressure transducer. Indirect blood pressure measurement involves application of pressure external to the circulatory system and observation of the effect of this external pressure on the system. Relative blood pressure measurements are uncalibrated indirect measurements usually performed with simpler, and inherently more convenient, instrumentation. Blood flow is derived from the measurement of blood velocity which necessitates gaining access to one or more of the primary arteries within the body using surgical techniques. Information on blood pressure and blood flow is often adequate for analysis of the circulatory system, however a complete hydrodynamic analysis of the circulatory system can only be accomplished by also measuring blood volume.

8.1 DIRECT BLOOD PRESSURE MEASUREMENT

Direct blood pressure is measured by inserting a pressure transducer somewhere within the circulatory system: Figs. 2-1, 2-2 and 2-3 of Chapter 2 refer to this system. Some transducers are designed to be inserted directly into the circulatory system, however it is more common to connect to the circulatory system with either a catheter or a hypodermic needle and to record the pressure with a pressure transducer attached to the catheter or needle.

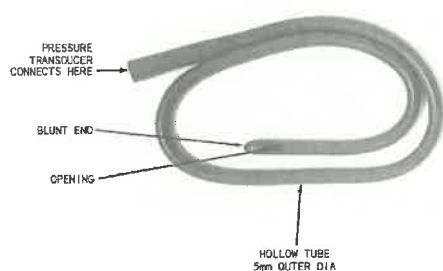


Fig. 8-1. A 5mm cardiac catheter.

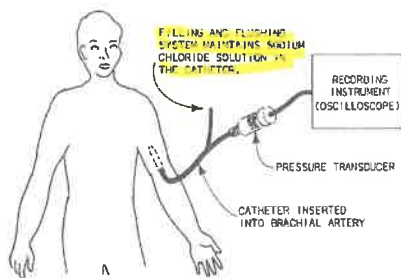


Fig. 8-2. Direct blood pressure measurement.

iac
eter

A cardiac catheter consists of a rubber, teflon or polyethylene tube with one end formed to a smooth bullet-like shape to allow its easy introduction into veins and arteries. A small opening is formed about 1 centimeter from this smooth end as shown in Fig. 8-1. The catheter shown in Fig. 8-1 is approximately 40 centimeters long and 5 millimeters in diameter. Catheters are generally available from 1 to 10 millimeters in diameter and in various lengths. Cardiac catheters are also often described by their circumference.

entry to
circulatory
system

With the catheter/pressure-transducer configuration shown in Fig. 8-2, pressures can be measured in almost any portion of the circulatory system. By gaining entry to the circulatory system at either the arms or legs a catheter may be manipulated throughout the circulatory system. It should be noted that the pressure measured will be the pressure at the blunt end of the catheter and not the pressure at the point where the catheter enters the circulatory system.

cardiac
catheteri-
zation

It is possible, with careful manipulation, to actually introduce the smooth end of the catheter into the right atrium via the inferior vena cava. Cardiac defects, including holes in the heart, can then be explored. This procedure is referred to as cardiac catheterization. Investigation of the left ventricle by catheterization via the aorta, referred to as arterial catheterization, almost always causes trouble with arterial damage and leakage into the tissues.

arterial
pressure

The most common direct pressure measurement is arterial pressure which is usually measured by introducing the catheter into the brachial artery at the elbow of either arm.

transducer

A typical blood pressure transducer for use with a catheter is shown in Fig. 8-3. As little difference in pressure is encountered throughout the arterial system, it is unnecessary to introduce the catheter any great distance into this circulatory system.



STATHAM INSTRUMENTS INC. - MODEL P23De
LENGTH - 2.5"
OUTPUT WITH 7.5VRMS EXCITATION = 75uVRMS/mmHg
FOR USE WITH CATHETERS.

Fig. 8-3. A conventional blood pressure transducer.



STATHAM INSTRUMENTS INC. - MODEL P37
TRANSDUCER LENGTH = 1.2"
OUTPUT WITH 7.5VRMS EXCITATION = 37 μ VRMS/mmHg



TRANSDUCER CONNECTED AT BRACHIAL
ARTERY PUNCTURE SITE.

Fig. 8-4. A needle blood pressure transducer.



STATHAM INSTRUMENTS INC. - MODEL SP25
OVERALL LENGTH = 9"
OUTPUT WITH 7.5VRMS EXCITATION = 37 μ VRMS/mmHg

Fig. 8-5. A syringe blood pressure transducer.

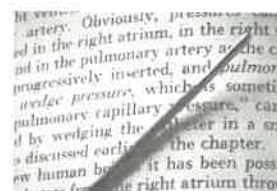
needle/
transducer

The catheter/transducer combination may be replaced by a needle and transducer as shown in Fig. 8-4. The needle/transducer combination is also available in a syringe configuration as shown in Fig. 8-5. These combinations, using needles rather than flexible catheters, are obviously far easier to introduce into the subject's circulatory system and are thus preferable for direct blood pressure measurement. They are normally introduced into the femoral artery near the groin as this artery is close to the surface at this point. The syringe configuration allows administration of an arterial injection while recording arterial pressure.

drift
catheters

For measurement of blood pressure within the heart, very small diameter (1 millimeter) catheters, known as drift catheters, are required so as not to interfere with the normal operation of the heart. These small catheters are inserted into the venous system and "drift" with the blood flow, eventually reaching the heart. They may actually be passed through the heart into the pulmonary circulatory system. The primary disadvantage of these small catheters is the damping effect they have on the pressure pulse waveform which limits the high frequency response of the system and gives erroneous readings. To avoid this problem, the catheter tip transducer shown in Fig. 8-6 incorporates a small pressure transducer built into the end of the catheter, the combination being less than 2 millimeter in diameter. This allows introduction of the actual transducer into the heart and thus avoids the damping problem inherent with small catheters.

catheter tip
transducer



STATHAM INSTRUMENTS INC. - MODEL P866
TRANSDUCER T.I.P. = .062" DIAMETER
OUTPUT WITH 7.5VRMS EXCITATION = 5 μ VRMS/mmHg

Fig. 8-6. A catheter tip pressure transducer.

dge-type
nsducers

Recording from transducers is covered in more detail in Chapter 18. The transducers shown in this chapter are all bridge-type transducers and, when excited at their maximum rated excitation voltage, they produce an output in the low millivolt or microvolt region, the smaller transducers in general producing less output. While it is possible to use DC excitation and record the output directly using a high sensitivity amplifier, superior results are obtained using a carrier amplifier system such as the Tektronix 3C66 plug-in.

ro-
ctrode
ssure
nsducer

Extremely small direct blood pressure "transducers" have recently been developed for research work. These transducers have an effective diameter of 10 microns. The transducer consists of a 10 micron microelectrode filled with an electrolyte having a different resistivity than that of blood or body fluids. A pressure system is connected to the microelectrode and the impedance between the center of this electrode and the body is monitored. A servo control system controls the pressure in the microelectrode driving pressure system to keep the impedance between the electrode and the body constant by exerting a pressure on the electrolyte in the microelectrode equal to the pressure external to the microelectrode tip. This pressure exerted on the electrolyte is therefore a measure of the blood pressure at the tip of the microelectrode.

urement
inology

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It is common terminology to refer to an arterial blood pressure of, say, 120 millimeter systolic and 80 millimeter diastolic as "120 over 80" or 120/80. As stated in Chapter 2, the pressure in the arteries is many times greater than the pressure in the veins, typical arterial pressure being 120/80 and typical venous pressure being 9/5 mm/Hg or, in the more common terminology, 12/7 cm/H₂O.

While direct blood pressure is relatively easy to measure, it does require an incision in an artery for introduction of a catheter or insertion of a hypodermic needle. Since this often results in the permanent loss of the artery used, it is regarded with some disfavor in most countries except the U.S.A. Results accurate enough for clinical use are usually obtainable by indirect methods.

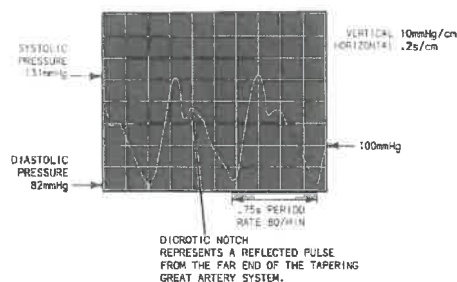
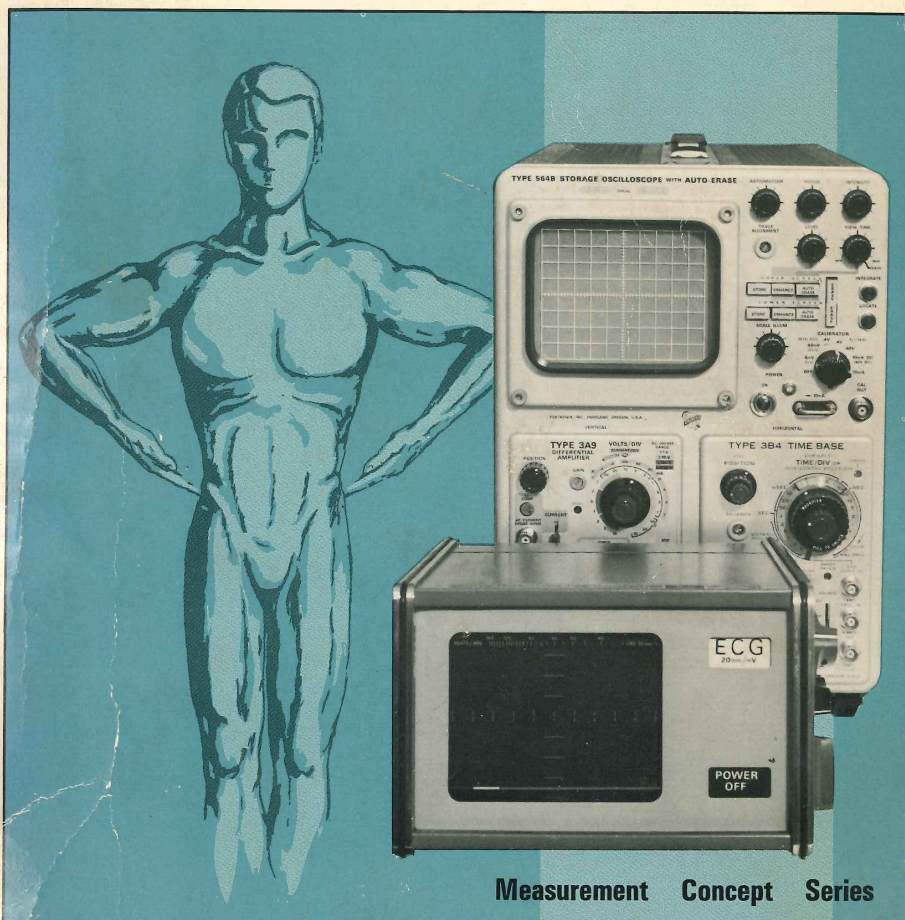


Fig. 8-7. Arterial blood pressure waveform.

Landscape Version For Better Viewing



Biophysical Measurements



Measurement Concept Series

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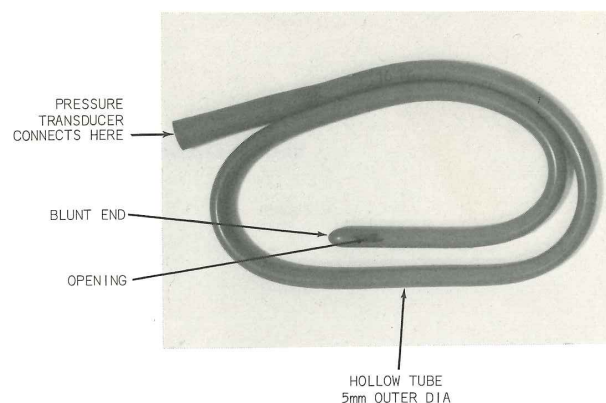


Fig. 8-1. A 5mm cardiac catheter.

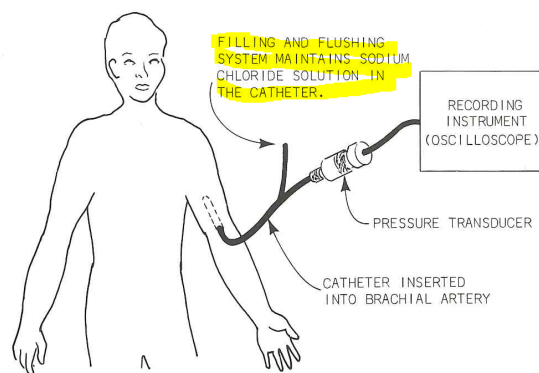


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liac
eter

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entry to
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catheteri-
zation

arterial
pressure

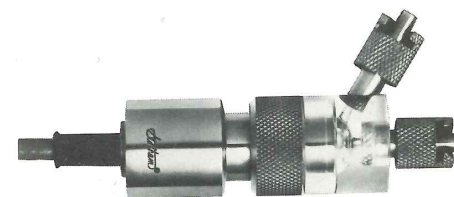
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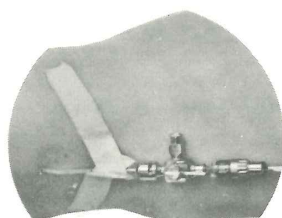


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OUTPUT WITH 7.5VRMS EXCITATION = 75μVRMS/mmHg
FOR USE WITH CATHETERS.

Fig. 8-3. A conventional blood pressure transducer.



STATHAM INSTRUMENTS INC. - MODEL P37
TRANSDUCER LENGTH \approx 1.2"
OUTPUT WITH 7.5VRMS EXCITATION = 37μ VRMS/mmHg



TRANSDUCER CONNECTED AT BRACHIAL
ARTERY PUNCTURE SITE.

Fig. 8-4. A needle blood pressure transducer.



STATHAM INSTRUMENTS INC. - MODEL SP25
OVERALL LENGTH \approx 9"
OUTPUT WITH 7.5VRMS EXCITATION = 37μ VRMS/mmHg

Fig. 8-5. A syringe blood pressure transducer.

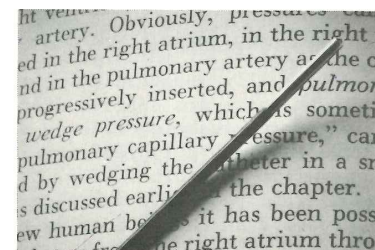
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catheter tip
transducer



STATHAM INSTRUMENTS INC. - MODEL P866
TRANSDUCER TIP - .065" DIAMETER
OUTPUT WITH 7.5VRMS EXCITATION = 5μ VRMS/mmHg

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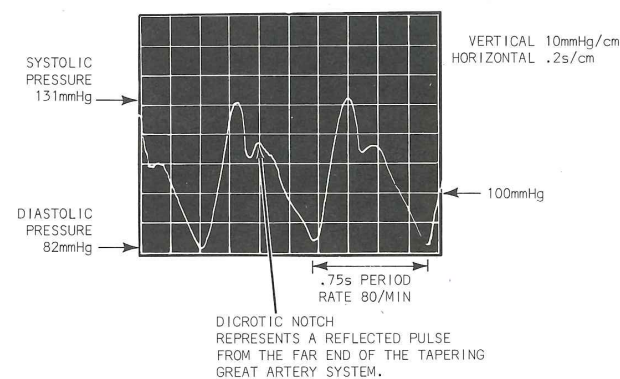


Fig. 8-7. Arterial blood pressure waveform.