

Invasive Pressure

An Overview

Application Note



Introduction

This document provides an overview of invasive pressure for anyone interested; however, it is written for field personnel not familiar with the subject. Specifically, you'll gain a basic understanding of blood pressure (BP)

and invasive pressure (IP) monitoring, which should help prepare you for appropriate sales calls (e.g., interfacility transport customers) and/or for supporting existing customers with IP needs.

PHILIPS

Blood Pressure Basics

Before discussing invasive pressure monitoring, it's helpful to first review basic concepts of blood pressure (BP) monitoring. BP is the pressure or force created by the heart through its pumping action as it pushes blood through the major arteries into smaller arteries (arterioles) into tiny capillaries into venules and then into veins leading back to the heart. What determines BP?

Two factors:

- ▶ the force with which the heart pumps blood to the body and
- ▶ the arteries' resistance to blood flow.

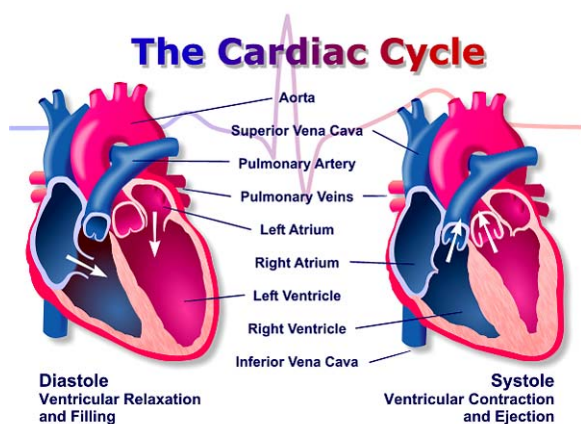
BP Measurement

BP measurement consists of the following parameters: systolic, diastolic, and mean.

- ▶ *Systolic* represents the maximum or peak pressure measured in the arteries during the cardiac cycle* when the heart contracts (described as "systole") and pumps blood out of the ventricles.
- ▶ *Diastolic* represents the minimum or lowest pressure measured in the arteries during the cardiac cycle* between heart beats or when the heart relaxes and fills with blood.

Figure 1 depicts the diastole-to-systole cardiac cycle. Go to <http://ananimation.com/> to see a good cardiac cycle animation.

Figure 1 **Diastole-to-Systole Cycle** ²



- ▶ *Mean* represents the average driving force in the arterial system throughout the cardiac cycle, also known as the mean arterial pressure (MAP). The arithmetic mean (midpoint between systolic and diastolic pressure) is not a valid way of determining mean arterial pressure. You can approximate MAP with the following formula: **systolic + (diastolic x 2) divided by 3**; however, the formula is usually invalid because it assumes diastole is two-thirds of the cardiac cycle (heart rate of 60 beats per minute) and a fixed heart rate of 60 beats/minute is not a clinical reality. ³

FAST FACT: The first (higher) number in your blood pressure reading is systolic and the second (lower) number is diastolic, such as 120/80 mmHg, which are the typical values for a resting, healthy adult human. BP measurement units are stated in millimeters of mercury (mmHg).

BP measurements are not static and thus exhibit variations from one heart beat to the next due to factors such as:

- ▶ cardiovascular disorders,
- ▶ neurological conditions,
- ▶ kidney and urological disorders,
- ▶ disease (e.g., diabetes, which is tied to hypertension),
- ▶ psychological factors (e.g., stress) and
- ▶ medication. ^{4, 5}

BP Measurement Methods

There are basically four ways to obtain BP measurements: *palpation*, *auscultatory*, *oscillometric*, and *invasive*. The first three are indirect, non-invasive (i.e., no skin penetration) measurement methods that depend on blood flow within the body part used for pressure measurement³. Here is how they differ in technique and equipment:

Palpation: This simple but highly subjective method requires a blood pressure cuff and an aneroid gauge or manometer (pressure measurement instrument) and is used when it is difficult to hear pressures. The radial or brachial artery is palpated (felt by the hand) and the cuff is inflated 20-30 mmHg above the point where the loss of the pulse is noted. The cuff is then slowly deflated and

*. The "cardiac cycle" is all or any of the events related to blood flow that occur from the beginning of one heart beat to the beginning of the next. ¹

the point at which the pulse returns is recorded as the systolic pressure. Palpation may be used to verify auscultatory or oscillometric measurements.³

FAST FACT: In pre-hospital settings, blood pressure may be estimated by palpation when vascular sounds are hard to hear with a stethoscope because of environmental noise. However, palpation is less accurate than auscultation⁷.

Auscultatory: This very common method involves listening to internal body sounds using a stethoscope to measure systolic BP. The stethoscope may be used with a sphygmometer or sphygmomanometer (see Figure 2), which is a blood pressure measuring instrument comprised of an inflatable cuff (placed around the upper arm at roughly the same vertical height as the heart) and a mechanical or mercury manometer. The mercury manometer (see Figure 3), considered the gold standard for blood pressure measurement, measures the height of a column of mercury, giving an absolute result without need for equipment calibration⁵. See Figure 4 for a complete auscultatory setup.

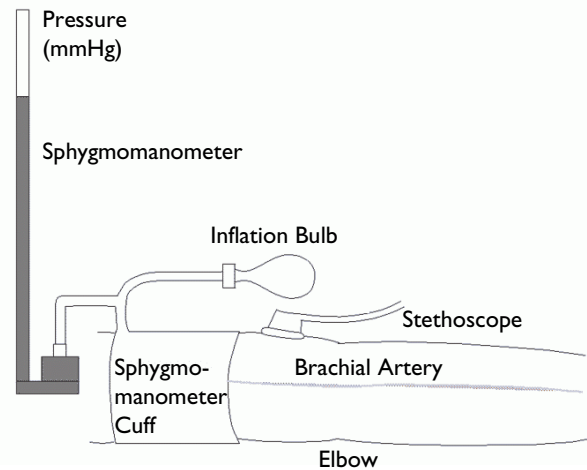
Figure 2 **Sphygmometer and Stethoscope**⁵



Figure 3 **Mercury Manometer**⁵



Figure 4 **Auscultatory Setup**⁶



Oscillometric: This method uses equipment functionally similar to the auscultatory method, but with an electronic pressure cuff (sensor) fitted to detect blood flow, instead of using the stethoscope and the clinician's ear⁵. The pressure cuff is a calibrated device with a numerical readout of blood pressure (see Figure 5 for a non-invasive blood pressure cuff sampling.) In most cases, the cuff is fitted on the upper arm (close to heart height), inflated, and released by an electrically operated pump and valve. As the cuff deflates, pulsatile flow in the form of oscillometric pulses (heart beats) is detected by an algorithm. An oscillometric curve is created from all of the oscillometric pulses. The curve is used to calculate a mean value, and then systolic and diastolic values.

Cuffs vary widely in accuracy and should be checked at specified intervals and if necessary calibrated, unlike the inherently accurate mercury manometer.

Figure 5 **NIBP Cuffs**



TIP: False measurement readings are typically due to incorrect cuff sizing (i.e., a cuff is too small or large for a patient), so it is a good idea to have customers order a range of pedi-to-adult cuffs depending on the patient population they care for.

The auscultatory and oscillometric measurements are simpler and quicker than invasive measurements, require less expertise in fitting, have less complications, and can be less unpleasant and painful for most patients. However, non-invasive measures may yield somewhat lower accuracy and small systematic differences in numerical results⁴.

Invasive: This method involves direct measurement from an artery by inserting a catheter (tube) into the artery. Invasive pressure monitoring is also referred to as invasive hemodynamic (blood dynamic) monitoring. Hemodynamic monitoring is most useful for assessing and managing patients with hypertensive emergencies, shock, pulmonary edema, sepsis, and multiple organ failure. It requires special equipment to produce waveforms (on a monitor) that reflect the cardiac cycle phases and monitor various types of arterial and venous pressure⁷. A more detailed examination of IP follows.

FAST FACT: In 1733, Reverend Stephen Hales introduced invasive catheterisation by inserting a long glass tube upright into an incision in a horse's artery. The pumping action of the heart generated a pressure force, causing the blood level to rise in the tube⁸.

Auscultatory (Manual Cuff)

This technique uses an occluding cuff and a sound detector or a stethoscope over the occluded artery to detect the sound which is emitted as the cuff is deflated. The cuff pressure at which the sound is first emitted indicates the systolic pressure. When the sound disappears, or when the sound quality changes, the cuff pressure is approximately equal to the diastolic pressure.

Auscultation Assisted with Doppler Flow Detectors

This technique requires a sphygmomanometer and a handheld Doppler device. The pulse detector is placed over the brachial or radial artery distal to the cuff and the characteristic hushing sound (shhh, shhh, shhh) signifying blood flow and vascular motion, is listened for as cuff pressure is reduced. The pressure at which the first hushing sound is heard is recorded as the systolic pressure. The hushing sounds continue as long as the device is held over the open artery.

Oscillometric

Oscillometric devices measure the amplitude of pressure changes in the occluding cuff as the cuff is deflated from above systolic pressure. The amplitude suddenly increases as the pulse breaks through the occlusion in the artery. The pressure at which this occurs is very close to the systolic pressure. As the cuff pressure is decreased further, the pulsations increase in amplitude, reach a maximum (which approximates to the mean pressure), and then diminish rapidly. The index of diastolic pressure is taken where this rapid transition begins.

Invasive Pressure Basics

Let's take a closer look at invasive pressure, starting with different measurement sites, followed by an example of monitoring system set-up, and finally related benefits and drawbacks.

IP Measurement Sites

Table 1 lists the IP sites, related descriptions, and displayed measurement value for those available on the HeartStart MRx monitor/defibrillator:

Table 1 IP Measurements

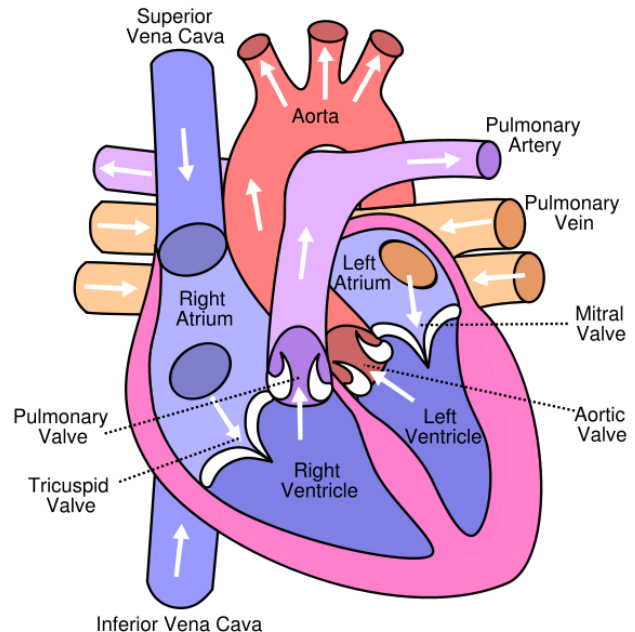
Site	Description	Value(s)
ABP	<ul style="list-style-type: none"> Arterial (pressure of large arteries delivering blood to body parts other than the lungs) Sites: Radial, femoral, dorsalis pedis, and brachial (the latter is not recommended) 	Systolic, diastolic, or mean
ART	<ul style="list-style-type: none"> Alternative Arterial (pressure same as above) Used when monitoring two different arterial pressures 	Systolic, diastolic, or mean
AO	<ul style="list-style-type: none"> Aortic (aortic artery pressure) Supported by an intraaortic balloon pump (IABP), a mechanical cardiac assist device that benefits patients with circulatory problems 	Systolic, diastolic, or mean
PAP	<ul style="list-style-type: none"> Pulmonary artery (pressure of artery leading from heart's right ventricle to the lungs) Also known as Swan-Ganz Also measures RAP, pulmonary artery wedge pressure (PAWP)*, cardiac output**, and mixed venous oxygen saturation * helps determine left ventricular function **not available on HeartStart MRx 	Systolic, diastolic, or mean
RAP	<ul style="list-style-type: none"> Right atrial (right atrium heart chamber pressure) Also reflects right ventricular pressure and monitors central venous return 	Mean

Table 1 IP Measurements (Continued)

Site	Description	Value(s)
LAP	<ul style="list-style-type: none"> Left atrial (left atrium heart chamber pressure) Also indicator of left ventricular pressure Inserted in operation room (OR) 	Mean
CVP	<ul style="list-style-type: none"> Central venous (superior vena cava pressure—vein from upper body to right atrium) Provides insight on right atrium (RAP) 	Mean
ICP	<ul style="list-style-type: none"> Intracranial (pressure exerted by the cranium on brain tissue, fluid, and circulating blood volume in the skull) 	Mean
P1, P2	<ul style="list-style-type: none"> Non-specific 	Based on associated pressure

Figure 6 provides a visual reference for the first seven pressure sites listed in Table 1, which are at or around the human heart.

Figure 6 Human Heart



FAST FACT: If you are ever asked “Why doesn’t my ABP equal my NBP?”, the answer is: “There is no direct relationship between non-invasive and invasive blood pressure because *non-invasive* techniques detect *blood flow* and *invasive* techniques measure *pressure*”.

IP Measurement Setup

Preparation for invasive pressure measurement is far more complicated than for non-invasive measurement, such as oscillometric. Figure 7 provides an illustration of an arterial line setup, which we will discuss in more detail.

- ▶ As mentioned earlier, the catheter (or cannula) is inserted invasively into the patient. Figure 8 shows examples of arterial cannulae.

Figure 7 Arterial Line Setup

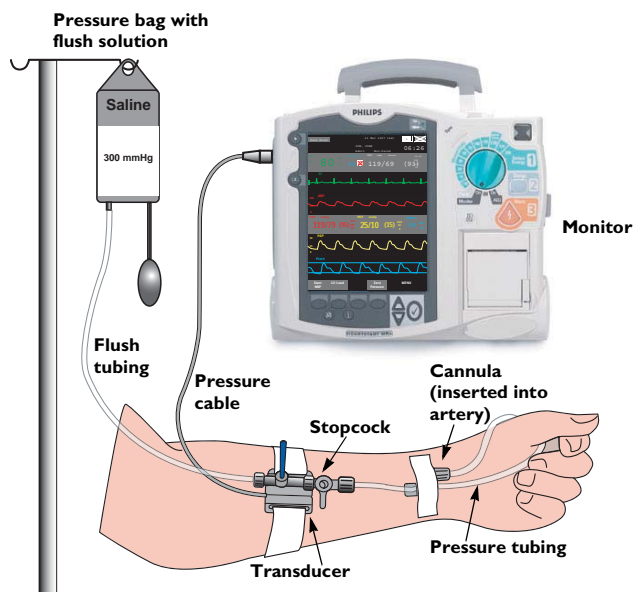


Figure 8 Arterial Cannulae

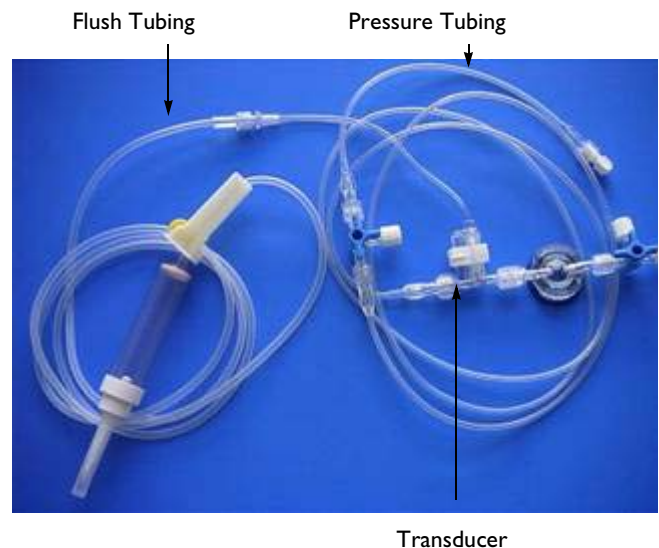


- ▶ The cannula is connected to a sterile pressure tubing (or line), which is full of fluid that moves with pressure changes. Tubing should be as short as possible to prevent attenuation of the pressure and should not drape up/down or hang.
- ▶ The pressure tubing is connected to an electronic pressure transducer that is positioned level with the heart (or at the top of the patient’s ear for ICP measurement), sensing pressure change applied to it and converting it into an electronic signal. The transducer placement is referred to as “leveling”, which eliminates the influence of hydrostatic pressure exerted by the fluid in the pressure tubing. A stopcock (valve) is used to open and close the flow of fluid from the transducer through the tubing.

Flush solution (saline) from an IV set is delivered through the transducer and pressure tubing (see Figure 9) to keep the line patent (open). Delivery is 3 drops (gtts)/min. and 3 cc/hour, which is controlled by the pressure bag.

NOTE: ICP should not have a pressure bag.

Figure 9 Flush Tubing, Pressure Tubing, and Transducer



- ▶ The transducer is attached to a pressure cable that transmits the electronic signal to the monitor. There are a variety of reusable and disposable transducers and related pressure cables available through manufacturers for invasive pressure measurement. *Customers are responsible for purchasing and servicing transducers and invasive pressure cables.* For the

HeartStart MRx, the following disposable transducers have been validated for use from the respective manufacturers:

Table 2 Disposable IP Transducers

Transducer	Manufacturer
Transpac® IV	ICU Medical, Inc.
Truwave® PX212	Edwards Lifesciences
DTX Plus™ DT-4812	Becton Dickinson

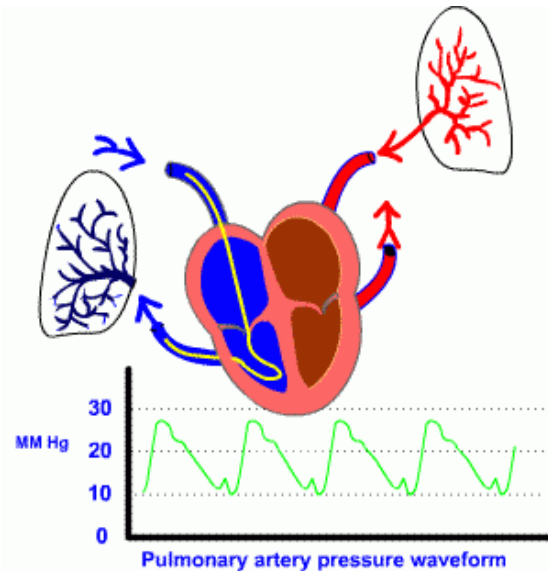
Philips offers the following invasive pressure supplies:

- CPJ840J6 Reusable Pressure Transducer
 - CPJ84022 Sterile Disposable Pressure Dome for use with CPJ840J6
 - CPJ84046 Transducer holder for CPJ840J6
 - M1567A Single channel disposable blood pressure kit (*available in Europe and Asia only*)
 - M1568A Dual Line blood pressure kit for measuring CVP, ABP, and other pressure measurements (*available in Europe and Asia only*)
 - M1634A Reusable adapter cable (*available in Europe and Asia only*)
- ▶ You must select a pressure to monitor by assigning a related pressure label, which is specific to the monitoring device. Then, you need to “zero” the assigned pressure on the monitor to ensure accurate pressure readings. It involves turning the transducer stopcock off to the patient and open to air (atmospheric pressure). Zeroing is done according to EMS/hospital policy as well as for circumstances such as:
- change of shift,
 - after a patient is moved from one location to another (e.g., stretcher to bed),
 - when you change monitors,
 - when you use a new transducer or tubing,
 - when pressure readings are questionable, or
 - changes in altitude and reaching a cruising altitude aboard an aircraft.
- ▶ Once monitoring begins, the monitor has an invasive pressure algorithm that calculates the mean or average pressure over time, and then calculates systolic and diastolic pressures. Time is calculated from the end of

one diastolic to the end of the next diastolic. The algorithm updates every second and suppresses artifact.

Figure 10 depicts a sample PAP catheterization and normal waveform:

Figure 10 PAP Catheterisation and Normal Waveform⁹



For details on invasive pressure monitoring on the HeartStart MRx including equipment setup, pressure label selection, and pressure zeroing, check out the “Invasive Pressures” chapter of the latest *HeartStart MRx Instructions for Use*.

IP Measurement Pros and Cons

The primary benefit of invasive pressure monitoring is that pressure is constantly measured beat-by-beat, providing a more accurate reading of the patient's current hemodynamic pressure or volume. Other benefits include:

- ▶ BP measurement that is directly in the vessel where it occurs (as opposed to non-invasive methods),
- ▶ immediate indication of the state of the circulatory arterial and venous system,
- ▶ detection of subtle changes in the cardiovascular system, and
- ▶ continuous and accurate measurement of peripheral or central vascular pressures, even in cases of shock when all indirect methods fail⁷.

Drawbacks include:

- ▶ infection that could lead to sepsis (a serious medical condition involving the presence of pathogenic organisms and their toxins in the blood or other tissues)⁷,
- ▶ excessive bleeding that could lead to exsanguination (total blood loss),
- ▶ embolization,
- ▶ vessel/tissue damage,
- ▶ circulatory or neurologic impairment, or
- ▶ arrhythmia caused by central venous, pulmonary artery (Swan-Ganz), and other catheter placed in the cardiac chambers.

Conclusion

Invasive pressure measurement is used to closely monitor clinically unstable patients in pre-hospital critical care transport situations as well as intensive and specialty care units in hospitals. Though far more complicated than non-invasive measurement, its benefits can outweigh its drawbacks in determining patient outcome. By reading this overview, it is hoped you have enough of an understanding on the subject to determine if invasive pressures may be an HeartStart MRx option that meets your customer's clinical needs and help you position it accordingly.



Philips Healthcare is part
of Royal Philips Electronics

On the web

www.philips.com/heartstart

By e-mail

healthcare@philips.com

By fax

+31 40 27 64 887

By postal service

Philips Healthcare
3000 Minuteman Road
Andover, MA 01810-1085

Asia

Tel: +852 2821 5888

Europe, Middle East, and Africa

Tel: +49 7031 463 2254

Latin America

Tel: +55 11 2125 0744

North America

Tel: +425 487 7000

1 800 285 5585 (USA only)

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