The “MAP” of blood pressure: It’s not just a number!

Introduction

Blood pressure is an important tool for veterinary medicine and veterinary technicians and nurses should not only be proficient in performing and obtaining a blood pressure but should have a thorough understanding of what it is and its purpose. It truly is not just a number. This presentation will overview the physics and physiology of blood pressure, describe how it is obtained, and describe how the numbers should be utilized and interpreted in clinical practice.

Basic concept review

Blood flow to organs is what maintains their health and vitality. Major arteries direct blood flow to each major organ (cerebral, hepatic, renal arteries, etc) in an effort to keep the delivery of oxygen constant. The organ’s tissues require the constant flow of RBC’s rich in oxygen to offload oxygen to them and pick up waste products. There are several concepts required to understand blood pressure:

1- Pressure
2- Flow

Pressure is defined as force per unit area: P = F/A. This means that given a surface pressure is related to the force applied to the surface and the area of which the force is distributed. For example, the pressure will be higher when one unit of force is applied to an area with 1 square inch, versus the same one unit of pressure applied to an area of 5 square inches- in the second case the force is distributed across a larger surface area and thus the resulting pressure is less. The “force” in this case is the blood inside an artery, and the pressure is determined by the surface area of an artery. Let’s say the blood is providing one unit of force, and the artery is “normal” at 5 sq inches of surface area. Then the blood “pressure” would be X (some number). Now, if the artery vasoconstricts, you now have the same one unit of force applied to LESS surface area and so the blood “pressure” goes UP. If the artery vasodilates, you now have the same ONE unit of force applied to a LARGER surface area and the blood pressure goes down.

Flow refers to a rate of fluid through a tube. Flow is usually measured in some unit over time. So ml/min or L/hr etc. Flow of a liquid is determined through several factors: viscosity, vessel diameter and vessel length. Since we don’t change the “length” of arteries very much the two important factors are viscosity (thickness) and vessel diameter (or radius). Viscosity will come into play during an anemia state or a hemoconcentrated state, but more often a patient’s blood flow will be determined by the artery diameter- when a patient is vasoconstricted or vasodilated their organ’s blood flow will be severely altered. The diameter of a vessel affects the flow in drastic ways. If the radius of a blood vessel is reduced by half, the flow decreases by 16 times! This is because the resistance to flow is directly proportional to the length and viscosity of a blood vessel but inversely proportional to the radius to the fourth power (Poiseuille’s Law):

$$R \approx \frac{nL}{r}$$

Here is an example of flow changes:

Catheter (gauge)	Diameter (mm)	Length (Surflo Terumo) [mm]	Flow rate (ml/min)	Time to infuse 1 liter of fluid (minutes)
24	0.67	19	18	55

22	0.85	25	37	27
20	1.10	32	64	15
20	1.10	51	53	18
18	1.30	32	105	9
18	1.30	51	95	10
18	1.30	64	92	11
16	1.70	51	208	5
14	2.15	64	325	3

So what determines blood pressure? The pressure of blood inside the arterial circuit (arterial blood pressure) is equal to the cardiac output multiplied by the systemic vascular resistance:

$$ABP\ (MAP) = CO\ x\ SVR$$

CO = Cardiac Output SVR = Systemic Vascular Resistance

Systemic vascular resistance or SVR is the resistance of flow in the entire arterial circuit. This is typically representative of the arterial wall diameter and hence the arterial wall muscle tone. So a patient that is vasoconstricted would have HIGH arterial tone and HIGH resistance. A patient with vasodilation would have LOW arterial tone and LOW resistance. Knowing Pouiseille's law (above) helps reiterate this idea.

Cardiac output or CO ismeasured in liters per minute representing how many liters of blood are ejected from the heart every minute. It is a function of heart rate x stroke volume, and stroke volume is comprised of a combination of preload, afterload and cardiac contractility:

$$CO\left(\frac{L}{min}\right) = HR\ (min)x\ SV\ (L)$$

Additional definitions:

Preload	End-diastolic volume that stretches the left or right ventricle. Estimated as volume of blood in the ventricle JUST prior to ejection.
Afterload	Pressure in the left or right ventricle during systole- or the pressure which the heart has to pump against.
Contractility	Intrinsic muscular strength of cardiac myocytes.

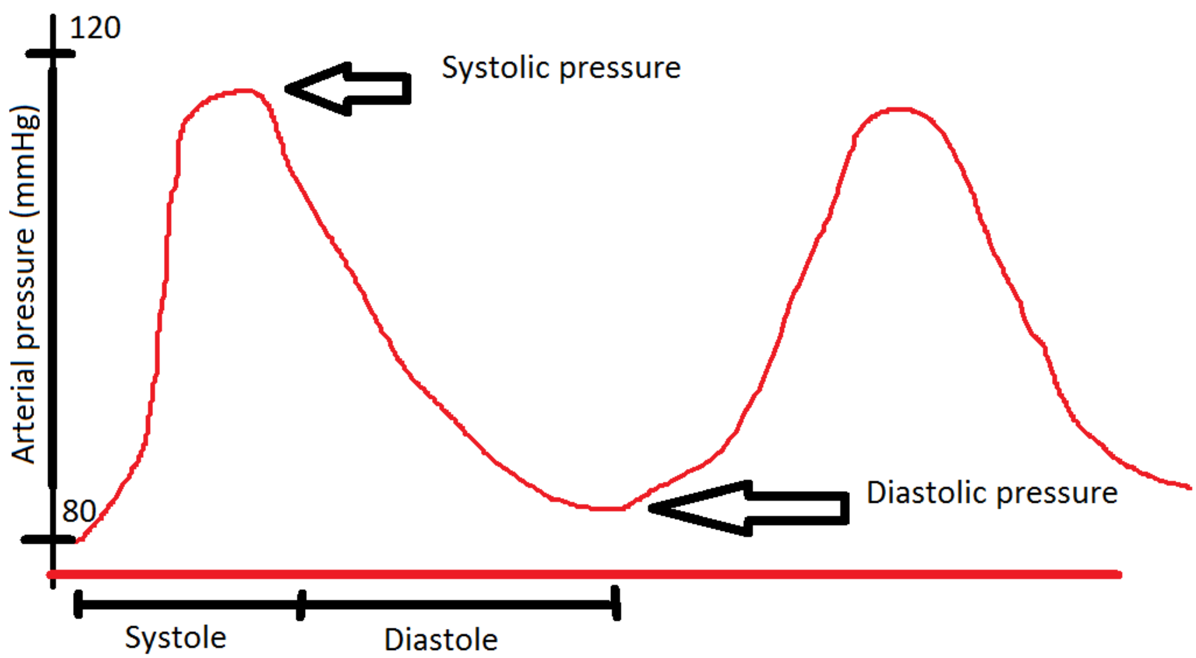
Essentially blood pressure can be affected by:

A- Vasoconstriction
B- Vasodilation
C- Hypovolemia
D- Poor contractility
E- Tachycardia
F- Bradycardia

MAP or mean arterial pressure, is the average blood pressure over a time period (typically a cardiac cycle). MAP is made up of two components: Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP). SBP is the peak blood pressure in the cardiac cycle representing the highest point of blood pressure during systole, and diastolic blood pressure is the lowest pressure. MAP is the average pressure between the two and can be calculated:

$$MAP = \frac{(SAP - DAP)}{3} + DAP$$

So if the systolic pressure is 100 mmHg and the diastolic pressure is 40 mmHg the MAP is 60 mmHg.



What does blood pressure "mean?"

So what does it mean? Blood pressure provides insight into hemodynamic status. Along with other parameters (HR, MM/CRT, pulse strength and quality, etc) it provides insight into the function of the heart and blood vessels. However, although blood pressure is a number it should be thought of qualitatively, as trends are more useful than a single number. Trends in blood pressure give us information about cardiac output, preload, afterload, contractility and blood vessel tone. So it should not be evaluated by itself but rather with other cardiovascular parameters. A patient in septic shock, cardiogenic shock, or hemorrhagic shock could be hypotensive, but each would be treated differently.

Blood pressure measurement

How do we measure blood pressure? There are two main methods: direct and indirect. Direct involves cannulating an artery and measuring the arterial waveform on a special monitor. Indirect involves use of a Doppler or oscillometric unit. Since these are more common, most of this manuscript will focus on the indirect method.

Doppler ultrasonic monitoring of blood pressure involves the application of a Doppler crystal to a peripheral arterial pulse. The crystal contains two piezoelectric crystals that sense the difference between emitted and returned ultrasonic frequencies and this makes an audible woosh on the Doppler unit. A cuff is applied slightly proximal to the crystal and inflated until the sound is lost. The cuff is slowly deflated until the sound returns and that represents the systolic blood pressure. This technique is technically easy to perform, accurate in all sorts of patients, and also accurate in hypotensive states. Three to seven consecutive measurements should be obtained and the values averaged.

The second common method of indirect arterial blood pressure measurement is oscillometry. This involves placing a cuff onto a patient's limb or tail that is directly connected to a computerized monitor that senses differences in arterial wall oscillations. The systolic and diastolic may be calculated from the MAP so the MAP might be the most accurate measurement in these devices. Advantages are that you can obtain a systolic, diastolic, MAP and heart rate measurement. Oscillometric monitors calculate a pulse rate, which should be compared to a measured pulse rate in the patient to ensure accuracy. These monitors are less reliable in nonsedated patients, but are stil widely used in awake patients. These monitors are also less accurate in patients with arrhythmias, bradycardia or tachycardia, vasoconstriction, hypothermia, and patient trembling/movement.

The least common method of measuring blood pressure is via the direct method. Direct arterial blood pressure is obtained by cannulating a peripheral artery and connecting the catheter to a pressure transducer. The pressure transducer changes the mechanical energy associated with arterial pulsewaves into electrical energy transmitted via a cable to a monitor capable of measuring invasive blood pressure. After the arterial catheter has been placed, an IV fluid bag (saline typically) is spiked and prepared. A pressure bag is attached and inflated to greater than the patient's blood pressure to prevent exanguination. Typically 250-300 mmHg is sufficient. The IV line is connected to the pressure transducer, and the pressure transducer is connected via tubing and a 3-way stopcock to the arterial catheter. The cable extending from the transducer is connected to the monitor. The 3-way stopcock is first opened to the atmosphere (open end) and the monitor, and the monitor zeroed to atmosopheric pressure. Then the stopcock is closed to the atmosphere, and opened to the patient and the monitor. The monitor will display a pulse wave and the blood pressure immediately displayed. Direct blood pressure monitoring is indicated in patients with shock or cardiovascular collapse, those requiring the use of vasopressors, patients receiving continuous drug therapy for congestive heart failure or hypertension, patients on mechanical ventilation, or those with high anesthetic risk.

Measurement of BP- general guidelines

A standard hospital procedure should be developed
Ventral or lateral recumbency OK but patient should be comfortable
Cuff should be 40% of the circumference of the limb (30-40% in cats)
Can be placed on limb or tail and the site referenced in the medical record
Discard the first measurement and take 3-7 consecutive measurements that get averaged

Additional resources

Burkitt Creedon and Davis. Advanced Monitoring and Procedures for Small Animal Emergency and Critical Care. Wiley Blackwell 2012.

Brown, et al. ACVIM Consensus Statement: Guidelines for the Identification, Evaluation and Management of Systemic Hypertension in Dogs and Cats. JVIM 2007 7(21): 542-558

Additonal references available upon request