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Quick Review: Hemodynamics

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Abstract

Before discussing basic hemodynamics, we should remind ourselves of the systemic circuit:
1. Cardiac Anatomy
2. Circulatory Pathways
This brief review discusses the basics of hemodynamics.

CARDIAC ANATOMY

The Heart: 2 Separate Volume Pumps !

The in-series nature of these two systems implies that the output of the Right Heart becomes the input of the Left Heart, and therefore, the output of the Left Heart becomes the input of the Right Heart

FLOW VIA SERIES: DEMONSTRATED BY WILLIAM HARVEY, 1628

Desaturated Blood returns from the Systemic Vessels via the SVC & IVC

Saturated Blood is then returned to the Left Atrium via the Pulmonary Veins !

MYOCARDIAL PERFUSION OCCURS PRIMARILY DURING DIASTOLE

MYOCARDIAL BLOOD FLOW:

MYOCYTE CONTRACTION

At the cellular level, electrical depolarization of the myocardial cell membrane allows ionized calcium flux into the cytoplasm - leading to hydrolysis of ATP by Myosin.

This leads to a conformational change in the Actin-Myosin Cross Bridge producing sliding of myosin filaments relative to actin & overall shortening of the sarcomere [Sliding Filament Theory]

Calcium is then removed from the cell by Active Transport in the Sarcoplasmic Reticulum - allowing Relaxation, while ATP is regenerated by Metabolic Processes

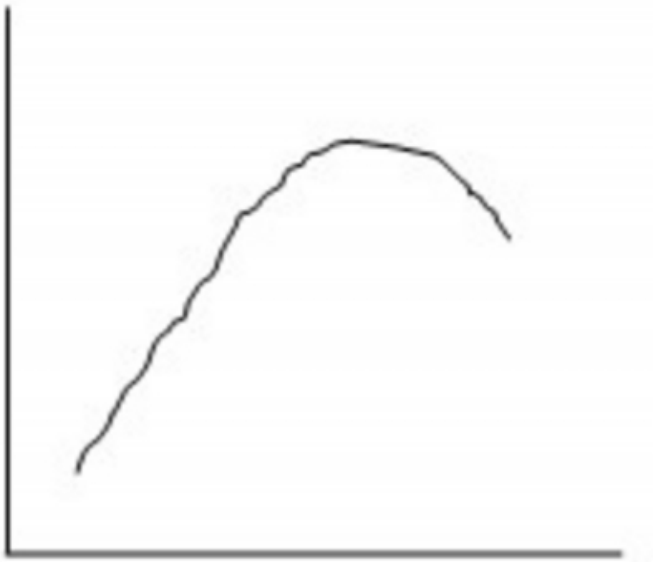
Over the physiologic range of sarcomere length (1.6 - 2.0 um), the amount of metabolic energy converted to mechanical work is dependent on the available Surface Area of Cross-Bridge Interactions !

Work is directly proportional to End-Diastolic Sarcomere Length

This “Length Dependency” is the fundamental basis for the Frank-Starling Law !

Otto Frank, 1885 (Frog Heart Preparations): “the output of a normal heart is influenced primarily by the volume of blood in the ventricle at the end of diastole”

Figure 1



CARDIAC OUTPUT

CO = HR x SV “the amount of blood pumped by the heart per unit time”

NORMAL C.O. : 3.5 - 8.5 L/MIN

Manipulation of the factors can lead to augmentation of CO at the lowest possible energy cost !

DETERMINANTS OF CARDIAC PERFORMANCE & OUTPUT

Preload: EDV (the load that stretches a muscle prior to contraction) Afterload: SVR (the load that must be moved during muscle contraction) Contractility: the velocity of muscle shortening at a constant preload and afterload Compliance: the length that a muscle is stretched by a given preload. Determined by the inherent Elasticity ! Heart Rate: several effects on overall Cardiac Function : Tachycardia/Bradycardia

PRELOAD

PCWP = LAP = LVEDP (best approximation)

But Remember, the relationship between LVEDP & LVEDVis NOT Linear!! PCWP is by definition an ESTIMATE of EDV& thus, an ESTIMATE of Preload

Elevation of CVP to Equal PAD& PCWP Square Root Sign : characteristic RA waveform in patients with Constrictive Pericarditis

AFTERLOAD

The impedance to LV Ejection and is usually estimated by the Systemic Vascular Resistance. Remember: changes in afterload have no effect on the contractility of a normal heart

SVR = {(MABP - CVP)/CO} x 80

MBAP (Mean Arterial Blood Pressure) = DBP + [1/3(SBP - DBP)]

SVR units: dynes-second/cm^5

Decreasing Afterload exchanges Pressure Work for Flow Work and serves to increase vital organ perfusion !

Pressure Work.....Flow Work

Plus, since pressure work is more costly than flow work in terms of myocardial oxygen consumption, by decreasing afterload - you also decrease the overall energy requirement

PVR = {(MPAP - PWP)/CO} x 80
Remember:

CONTRACTILITY

the inotropic state: an intrinsic property of myocardial muscle which is manifested as a greater force of contraction for a given preload

By increasing intropic state, you increase both Pressure Work & Flow Work - thus, the cost in myocardial oxygen consumption may be high !!

COMPLIANCE & ELASTICITY

“Compliance”: the tendency of an object to return to it's original shape when it has been deformed or altered

(Compliance = change in Volume / change in Pressure)

HEART RATE

Heart Rate can Influence Cardiac Function in Several Ways:

Cardiac Physiology is based on a thorough understanding of the underlying mechanics !

References

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