PHY 3171
Clinical and Experimental Cardiovascular Physiology

Cardiovascular Responses to Stress

Cardiovascular Homeostasis

1. Changes in blood volume/central blood volume

Reduced: Haemorrhage, head-up tilt, standing, lower body negative pressure, crucifixion
Increased: blood or plasma transfusion, head-out water immersion

2. Changes in energy/organ blood flow requirements

Organ specific control of vascular resistance

- Exercise
- Diving

Definitions

Arterial Pressure = Cardiac Output X Total Peripheral Resistance

Arterial Pressure = Cardiac Output / Total Peripheral Conductance

- Reducing conductance will increase arterial pressure

Organ Blood Flow = Arterial Pressure / Organ Vascular Resistance

Organ Blood Flow = Arterial Pressure X Organ Vascular Conductance

Intrinsic

- Increased ventricular end-diastolic volume
- Frank-Starling Law increases stroke volume
- Increases CO = Increases Arterial Pressure

Note: This is not contractility, as that's at the same volume of blood, using calcium

Arterioles and Resistance

Resistance = Length X Viscosity / Radius ^{4}

- Small radius with the largest drop in blood pressure
- They control resistance and flow of blood

Veins

- Large but not muscular
- Vascular tone plays a role in venous return to increase SV and CO

Factors That Alter the Diameter of Resistance Vessels

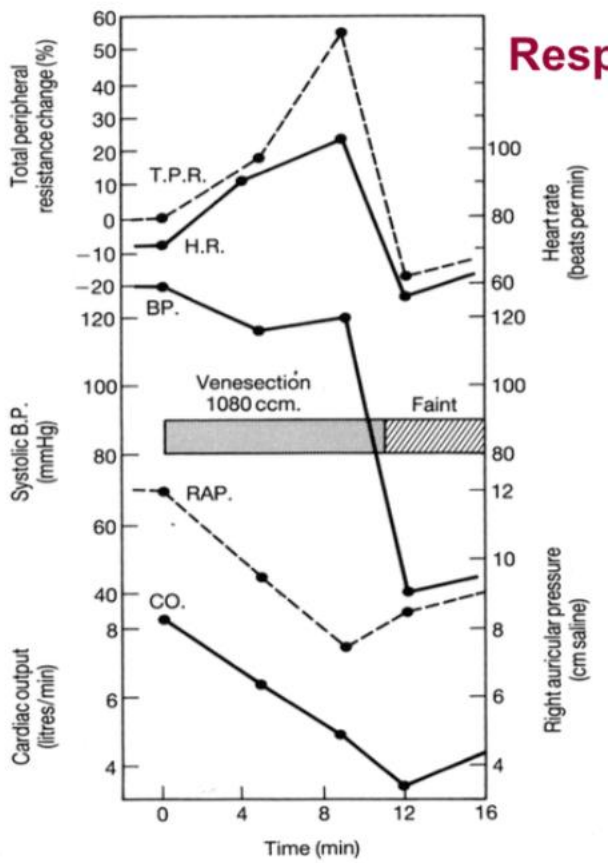
- Local/Metabolic/Intrinsic factors
- Nerves
- Hormones (endocrine, paracrine, autocrine)

Myogenic and Intrinsic Mechanisms

Matching blood flow to metabolic demand
Active Hyperaemia: Blood flow increases with increasing metabolic need - exercise
Reactive Hyperaemia: Repayment of blood flow debt – shock
Autoregulation: Matching blood flow to the kidney and brain constantly

Factors Contributing to Active and Reactive Hyperaemia

- Carbon dioxide
- Hypoxia
- Lactic acid
- Decreased pH
- Adenosine
- Endothelial derived NO



Challenge of Acute Blood Loss

- AP = CO X TRP
- CO decreases so AP decreases
- TPR as a result increases
- Arterioles to kidneys, brain and heart do not change constriction

Phase 1: Compensatory Phase

- Vasoconstriction
- Blood pressure maintained

Phase 2: Decompensatory Phase

- Vasodilation of organs
- Blood pressure plummets

Neural Mechanisms in the Cardiovascular System

Divisions of the CNS

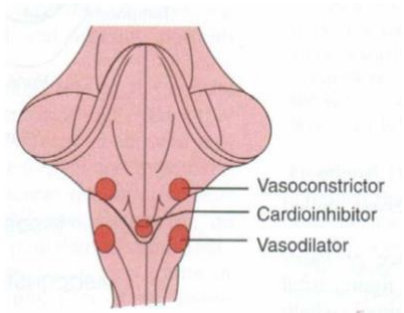
Afferent

- Arterial baroreceptors
- Arterial chemoreceptors
- Cardiac baroreceptors and chemo receptors
- Renal baroreceptors
- Brain chemoreceptors

Efferent

- Sympathetic (intermediolateral cell column) IML
- Parasympathetic nerves come from higher brain centres
- Both have Nicotinic Ganglionic Receptors

Note: When removing rostral medulla, that's when blood pressure decreased



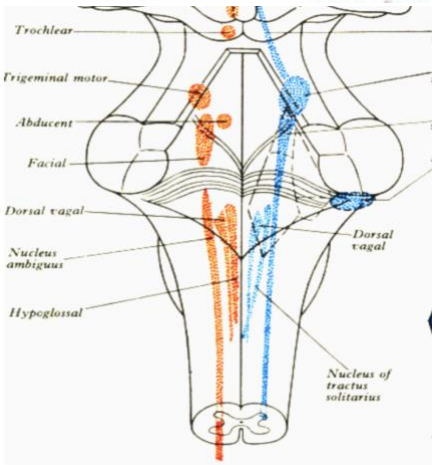
Anatomy of the Efferent Nerves

The vasomotor centre in the medulla oblongata (brainstem) and its control of the circulation through the sympathetic and parasympathetic branches of the ANS

Vasoconstrictor: Rostral Ventrolateral Medulla – Main source of pre-motor drive to blood vessels

Cardioinhibitor: Nucleus Ambiguus

Vasodilator: Caudal Ventrolateral Medulla – Talks with vasoconstrictor centre



Nucleus Ambiguus

Long strip of cells that runs down each side the length of the brain stem

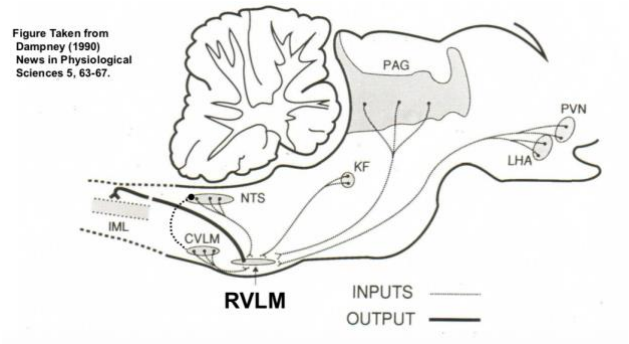
Parasympathetic Pathway

- Feedback from afferents and other CNS regions
- Nucleus Ambiguus and Dorsal Vagal Nucleus (DVN) via pre-ganglionic parasympathetic vagal cholinergic nerve
- Cardiac parasympathetic ganglia
- Post ganglionic parasympathetic vagal cholinergic nerve
- Sino-Atrial Node to reduce heart rate

Neuroanatomy – Vasoconstrictor and Vasodilator Centre (Sympathetic)

Inputs to and outputs from the

- RVLM
- CVLM
- Nucleus Tractus Solitarius
- IML



Pathway for Sympathetic

- Feedback from afferents and other CNS regions
- Synapse to RVLM via Bulbo-spinal pathways
- To the Intermediolateral cell column via preganglionic sympathetic cholinergic nerves
- Sympathetic ganglia (at a distance from target organ)
- Release of noradrenaline in target organ

Afferent Inputs for Cardiovascular Function

Baroreceptors (pressure sensing)

- Aortic Arch and Carotid Sinus
- Cardiac (atrial and ventricular)

Chemoreceptors (carbon dioxide and oxygen)

- Carotid sinus
- Brain

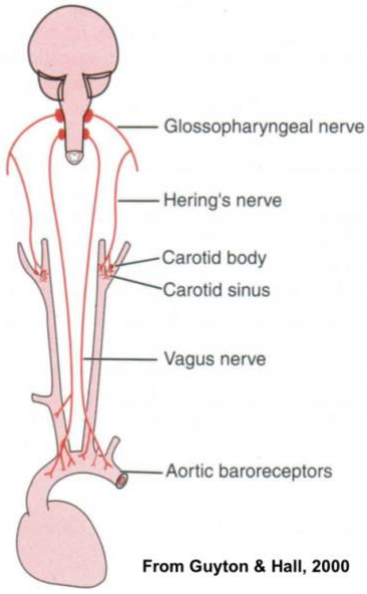
Others

- Pulmonary stretch receptors
- Trigeminal afferents

Note: All afferents nerves synapse with the NTS

Baroreceptors

- Spray type nerve endings in the walls of blood vessels
- Respond to stretch and increase firing with increase in pressure
- Baroreceptor firing is proportional to pressure
- First synapse with the NTS
- Rapidly reset and contribute to short term control of blood pressure
- Acts to buffer blood pressure and if removed, greater variability, but the same mean blood pressure



Aortic Arch

- Travel via the Vagus nerve to the Nucleus Tractus Solitarius in the brain stem

Carotid Sinus

- Travel via Hering's nerve to the Glossopharyngeal nerve and onto the NTS