Hypertension

Lectures from Pathological Physiology

Study materials from Pathological Physiology, 2016 – 17, dentistry

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Repetition of physiology, basic terms- 1

- What is blood pressure (BP) ?
  - Moving force of blood flow to overcome the hemodynamic (peripheral) resistance
  - Force, exerted by blood on vessel wall in arterial circulation
  - *P = F/S = N/m^2 (Pascals, Pa)*
  - *1 mmHg = 0,133 kPa*
  - **For the body the tissue perfusion is essential = oxygen supply**

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Repetition of physiology, basic terms- 2

- **Determinants of BP**
  - Heart function (pump) - catch 22
  - Circulating volume
  - Elasticity and tension of vessel wall
- **Which pressures and where ?**
  - sBP, dBP, mean arterial pressure
  - Mean filling pressure

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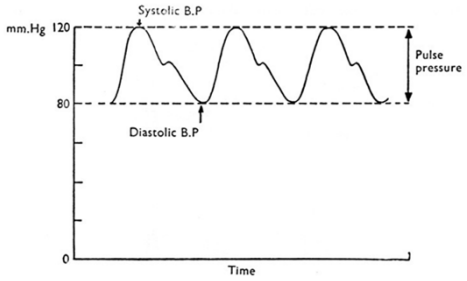
Blood pressure



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Repetition of physiology, basic terms – 3

- **Mean arterial BP**
  - = dBP + pulse pressure/3
  - 150/90; Mean = 90 + (60/3) = 110
  - = CO * TPR
    (total peripheral resistance = **microcirculation!**)
  - Peripheral resistance is the opposite of perfusion !
  - Determinant of CO is the venous return!
- **Mean filling pressure is cca 7 mmHg**
  - Experiment: Arterial pressure after heart arrest
  - This is determining the filling of right ventricle = **venous return**

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The distribution of blood in circulation

Region	%
Heart	7
Pulmonary circulation	9
Arteries	13
Arterioles, capillaries	7
Venous part of circulation	64

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Microcirculation

Resistance arterioles ∅ 0,5 – 0,15 mm
4 – 5 branchings to terminal arterioles ∅ 10 µm
Capillaries

- Blood flow velocity in aorta (∅ 3 – 4 cm^2) 0,2 – 0,3 m/s
- In capillaries 0,3 mm/s ≈ 3000 – 4000 cm^2
- Only one third of them is open ≈ 1000 cm^2
- The hemodynamic resistance is **directly proportional to the length of vessel** and **indirectly proportional to the 4th square of vessel diameter**
  - Increase of diameter by 1,2 – resistance decreases to 50 %,
  - 1,8-fold increase - decrease to 10 %
  - and conversely !!!

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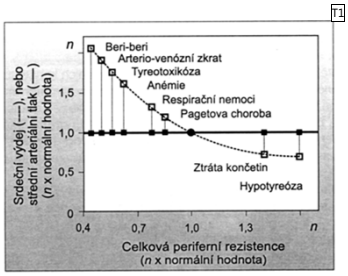
Examples of changes in resistance without changes of BP

- Hypoxia
  - Vasodilatation
  - Venous return ⇑
  - Cardiac output ⇑
  - Hyperkinetic circulation without pressure change
- A-V shunts
  - Decrease of TPR
- Amputation of LE
  - Increase of TPR
- No change in BP

T1



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Overview of blood pressure regulators

- Baroreceptors
- Chemoreceptors
- *Ischemic response of CNS*

Immediate reaction - limited effectivity

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Snímka 8

T1 Tündérke; 16. 10. 2005

Overview of blood pressure regulators

- Pressure relaxation of vessel wall
- Fluid shift (Frank – Starling)
- Renin – angiotensin – aldosterone system (& its antagonists – natriuretic hormones)
- Antidiuretic hormone

Slower reaction, limited effectivity

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Regulation of microcirculation

- **Extremely complicated mechanisms**
  - **Metabolic – hypoxia, ATP, pH, etc.**
  - **Para-, autocrine – NO, CO (endothel)**
  - **Ion equilibrium (contractility of muscle cells)**
  - **Transport systems, channels, their regulators & receptors**
- **Tissue („bed")specific!**

Regulation of „individual demand"
Signals for higher systems

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Overview of blood pressure regulators

LONG TERM, ALMOST UNLIMITED EFFECTIVITY

kidney – regulation of volume

- Proofs – kidney crosstransplantations between HT & NT rats, human kidney transplantations

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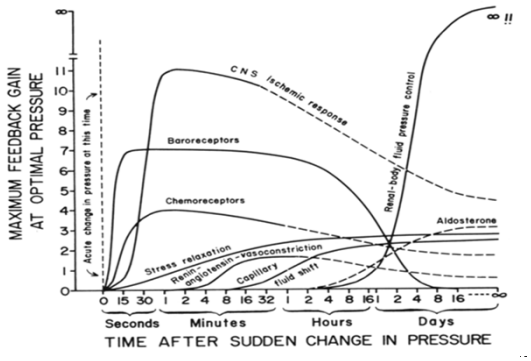
The effectivity of blood pressure regulators



Goldblatt and his experiments

- Bright 1832: Large, heavy heart and scarred kidney
- Harry Goldblatt, a recipient of final-year prize at McGill, 1916
- Cleveland 1928 - 1934
- Goldblatt H et al: Studies on experimental hypertension I. J Exp Med 59, 1934, 347-379
- Clamp on a. renalis
- The discovery of renovascular hypertension

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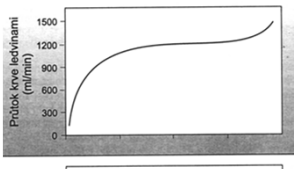
Autoregulation of blood flow and glomerular filtration in kidneys

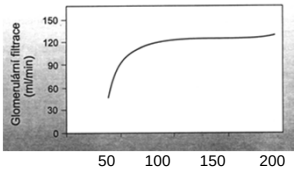
renal blood flow

ml/min



glomerular filtration,

ml/min



50 100 150 200

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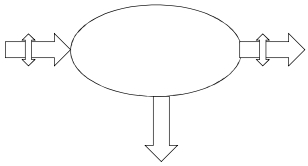
Constant filtration achieved by regulation of vas afferens a efferens tonus



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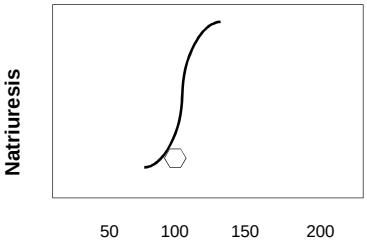
Filtration does not depend on blood pressure, diuresis & natriuresis strongly depends !!!



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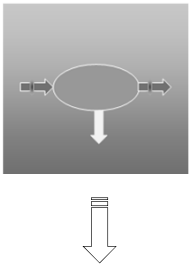
Constant perfusion – variable excretion



- Perfusion is 1,3 l/min ≈ 25 % CO
- Daily filtrate

(180 l) ≈ 25 mol = 0,5 kg sodium *(kilogramm salt)*

- Excretion ≈ 250 mmol, 5 g Na or 10 g salt, 1 %
- Resorbtion
  - 2/3 proximal tubules
  - 1/4 Henle loop
  - 1/12 distal tubules

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Pressure diuresis

- Kidney blood flow does not depend on BP
- Diuresis & natriuresis depend
- Pressure increase by 10 – 20 mmHg – twofold increase of diuresis
- Rapid response – begins in 1 minute
- Mechanism – reabsorbtion of sodium
- Regulated by macula densa

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Hypertension is always connected with change of kidney pressure diuresis !!!

Hypertension is not a „disease“ of heart
Hypertension is not a „disease“ of peripheral resistance
Hypertension is a distrubance of volume equlibrium – the kidneys are not able excrete excess water and salt at normal pressure

Definition & diagnostics of hypertension

- Scipione Riva-Rocci: Un nuovo sfigmomanometro. Gazetta Med Torino, 47, 981 – 1001, 1896
- Long term increase of systolic blood pressure ≥ 140 mmHg & diastolic blood pressure ≥ 90 mmHg (confirmed by repeated measurements), or the use of antihypertensive therapy
- Classic sphygmomanometers, digital & 24 hour monitoring of BP, continuous monitoring
- Lege artis (white coat HT)
- Measure in everybody (The Chernobyl Effect)

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Classification of hypertension

- According to values of BP, see ⇒
- According to its etiology (pathogenesis)
  - primary (95 %?)
  - secondary forms of hypertension (5%?)
- According to the stage of disease
  1. Only hypertension
  2. Manifest damage of organs – heart hypertrophy, nephropathy & *changes of ocular fundus = remodelation of small vessels*
  3. Heart and kidney failure, hemorrhagic stroke

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CATEGORY	sBP	dBP
Normal	< 120	< 80
Prehypertension	120 - 139	80 - 89
Hypertension I	140 – 159	90 – 99
Hypertension II	≥ 160	≥ 100

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Circadian changes of BP

- 24 hour monitoring
- Decrease after 8 p.m.
- 11 p.m. – 05 a.m. by 20 % (20 – 30 mmHg)
- Increase in the morning, maximum before noon
- Regulator: kidneys or catecholamines ? (both)
- New term – *non-dippers, bad prognosis*
- Surprise if the treatment is bad – *nocturnal hypotension*

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Epidemiology of hypertension

- 20 and more % of adult population
- Already in children (2 – 5%) – very bad prognosis
- Treatment often not ideal
- Association with salt intake – no hypertension in aboriginal people from New Guinea & Amazonia who do not use salt
- Deficiency of Ca, Mg
- Association with obesity

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Some more epidemiological data

- Age:
  - 20 – 30 < 10 %
  - 40 – 50 ≅ 25 %
  - 60 & more ≅ 33 %
- Sex
  - Up to age 50 y. f/m 0,6 – 0,7
  - After 50 y. f/m1,1 – 1,2
- Weight
  - Normal 8 – 15 %
  - Obesity 15 – 35 %

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Primary hypertension

- The cause and the pathogenesis is not fully clear
  - Our old and simple explanation
  - Disturbance of pressure diuretic curve of kidneys
  - Kitchen salt ?
  - Dysfunction of endothel ?
- Hypertension as a „complex“ disease
  - Arising as a consequence of external (salt, obesity) factors and genetic background

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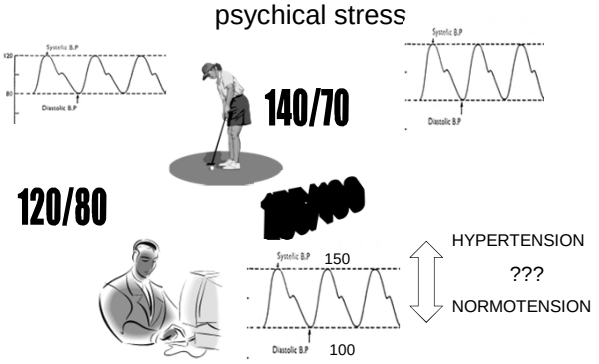
Reaction of circulation on physical and psychical stress



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„Kidney“ theory of primary hypertension

- Key role of kidneys in volume regulation – the excretion of Na and water is strongly pressure dependent.
- Primary hypertension is caused by disturbance of this function ???
- Why and how ???

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Secondary hypertension - 1

- Renal
  - Renoparenchymal (decrease of nephron number)
  - Renovascular (stenosis of a. renalis – RAAS)
- Endocrine
  - Phaeochromocytoma – paroxysmal HT
  - Conn, Cushing, other diseases of adrenal cortex
  - Acromegaly
- HT during gravidity, EPH gestosis (preeclampsia)

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Secondary hypertension - 2

- Cardiovascular
  - Coarctation of aorta (upper part of body)
  - Isolated systolic: loss of flexibility of vessel wall in advanced age
  - Isolated systolic in aortal regurgitation & AV shunts
- Neurogenic
  - High intracranial pressure – transitory
  - Lead intoxication
- Iatrogenic

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Secondary hypertension - ???

- How to classify hypertension
  - Associated with obesity ?
  - Associated with insuline resistance ?
  - Associated with Type 2 diabetes mellitus ?
  - Associated with sleep apnoea syndrome ?
- How to classify stress hypertension ?
- *A LOT OF PRIMARY HTs ARE NONDIAGNOSED CONNs ?*

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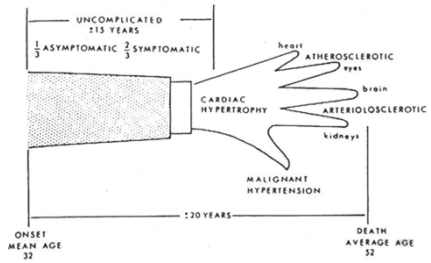
Natural history of hypertension



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