RENAL HEMODYNAMICS

1. **Anatomy:**

   Interlobar, arcuate, interlobular arteries
   Afferent and efferent arterioles
   Glomerular capillaries, mesangial cells and matrix
   Renal veins

2. **Pressures and Resistances:**

   Site of major pressure drop (DP) is in the afferent arterioles: from 100 to 45 mm Hg

   In the efferent arterioles, DP is from 45 in glomerular capillaries to 20 mm Hg at peritubular capillaries.

   Because of the resistance of the intrarenal veins, pressure drops from 20 in peritubular capillaries to 5 mm Hg in the renal vein.

   The total DP is from 100 in aorta (slightly less in interlobular arteries) to 5 mm Hg in renal vein.

   Note that the glomerular capillaries and the peritubular capillaries have low resistance (because there are so many of them in parallel) and therefore have low pressure drop.

3. **Magnitude of Renal Blood Flow:**

   There is a large renal blood flow (RBF) at rest, equivalent to 1/5 of CO (1 L/min) to an organ that weighs less than 1% of body weight. Per unit mass, RBF at rest is higher than that to heart muscle or brain.

4. **Measurement of Renal Blood Flow:**

   Clearances of p-aminohippurate $Cp=V(Up)/(Pp)$, of Hippuran, or of Diodrast are about 80-90% of RPF and approximate the renal plasma flow (RPF). These clearances are called effective renal plasma flow and are less than the true RPF because (1) plasma flow through renal connective and adipose tissue is not included and (2) incomplete extraction of solutes from rapidly flowing blood in peritubular capillaries precludes total secretion of all the PAH present in the blood perfusing the tubules.

   To measure RPF accurately, the concentration of PAH in the renal venous plasma (RVp) must also be known: $RPF=V\,(Up-RVp)/(Pp-RVp)$. This requires cateterization of the renal vein, a feasible but not a common procedure.

   Note that RBF can be calculated from RPF by the equation $RBF = RPF/(1 - \text{hematocrit})$.

5. **Roles served by Renal Blood Flow:**

Sustain filtration and excretion of end products such as urea, creatinine etc.

Achieve rapid changes in body fluids volumes and composition through changes in renal excretion of water and solutes.

Serve a hemodynamic reserve function (1 L/min) in case if extreme emergency (shock). That is, the RBF can be reduced to very low levels to help sustain the blood flow in other organs (brain, heart, etc.). However, if kidney blood flow remains low for too long, renal damage will result.

Deliver sufficient oxygen and nutrients to the kidneys; usually plentiful.

6. **Regulation of RBF:**

Autoregulation (intrinsic) occurs at MAP between 70 and 210 mmHg when pressure changes but blood flow (and filtration rate) are nearly constant.

Autoregulation is by myogenic and tubulo-glomerular feedback (TGF) mechanisms. It occurs at the afferent arterioles

Myogenic autoregulation depends on stretch activated ion channels in vascular smooth muscle that, when stretched, allow Ca ions to enter and induce contraction.

TGF occurs between macula densa (MD) cells and cells of the afferent arteriole (juxtaglomerular apparatus). When fluid delivery and NaCl transport at MD increase (as with increased GFR or decreased PT reabsorption), there are increases in cell Na and Ca and release of arachidonic acid metabolites and adenosine that act on vascular smooth muscle cells of the afferent arteriole, causing contraction and reduced blood flow. The opposite happens when delivery and transport at the MD are decreased.

Renin-angiotensin system. Renin is produced at granular cells of afferent arterioles. It is released in response to decreases in renal perfusion pressure (decreased stretch reduce cell calcium which promotes renin release), by sympathetic stimulation through renal nerves and by reduced flow and transport at MD cells (which reduce cell calcium, decrease arachidonic acid release and in turn reduce cell Ca in afferent arterioles).

Renin is a protease that react with angiotensinogen (renin substrate) to produce Angiotensin I (10 amino acids) which is converted to Angiotensin II (8 amino acids) by the endothelial angiotensin converting enzyme (ACE).

Angiotensin II is a potent vasoconstrictor, preferentially of the efferent arteriole, reducing RBF but maintaining or increasing filtration. It also acts on the adrenal cortex inducing release of aldosterone (a hormone that stimulates sodium reabsorption), and in the proximal tubule stimulating Na-HCO_3 reabsorption.

At higher plasma levels AII contracts mesangial cells (which decreases filtration) and causes generalized vasoconstriction including the afferent as well as the efferent arteriole, which helps maintain central arterial blood pressure at the sacrifice of RBF and filtration.

7. **Other vasoactive agents** in the kidney:

   Vasoconstrictors such as endothelin and AVP reduce RBF. AVP reduces the medullary blood flow in particular and by acting on mesangial cells may also reduce filtration.

   Vasodilators such as prostaglandins, nitric oxide and natriuretic peptides counteract and limit the effect of vasoconstrictors. Their absence or blockade may lead to hypertension, profound renal vasoconstriction and reduced filtration.