Shock
definition, classification & pathogenesis

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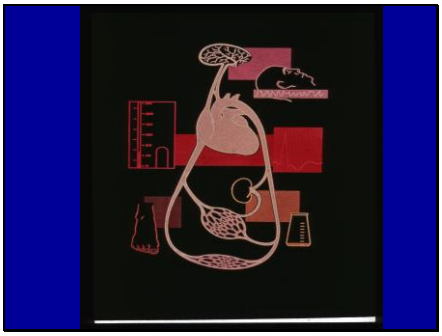
This presentation covers the topic of shock in general. We will cover shock, its definition, pathophysiology, classification and its relationship to multiple organ failure.



All of the clinical manifestations such as hypotension, altered mental status, oliguria and cold-clammy extremities are secondary to reduced blood flow to various organs.

Shock-Guyton

A state of circulation in which tissues in widespread areas of the body are being damaged by nutritive insufficiency resulting from inadequate cardiac output.

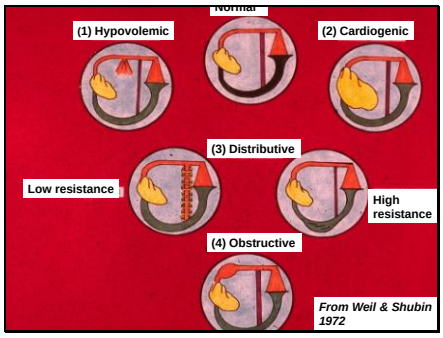
The definition of shock by Guyton refers to inadequate nutritive blood flow to wide-spread areas of the body. The operative word is nutritive as we know that in some forms shock such as septic shock, cardiac output is normal or high and yet there is evidence for tissue hypoxia.

Shock classification
Revised 1972

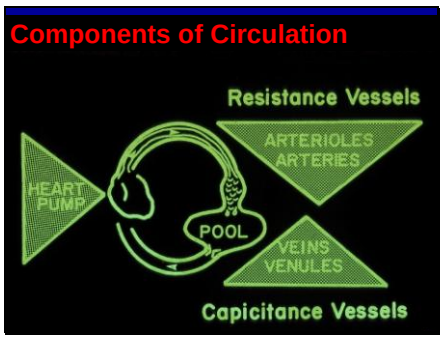
1. Hypovolemic
2. Cardiogenic
3. Distributive
   1.) High resistance
   2.) Low resistance
4. Obstructive

Weil & Shubin

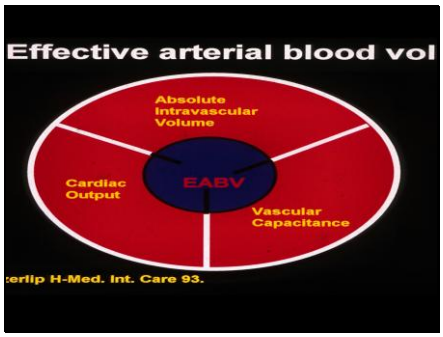
In 1972 Max Harry Weil and late Herbert Shubin classified shock into four kinds based on a mechanistic basis. This classification is well accepted by most authorities and clinicians. In this classification the commonest form of shock observed is hypovolemic shock. Other synonyms for hypovolemic shock are hemorrhagic & traumatic shock.



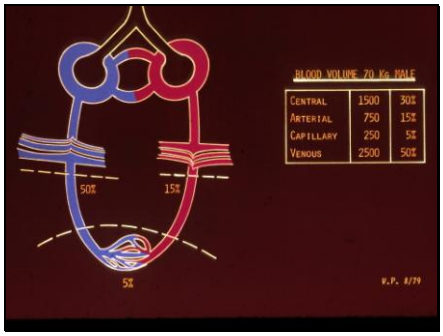
Hypovolemic shock is the commonest form of shock observed in hospitalized patients. The blood and plasma volume losses may extrinsic such as injury to an artery, burns or intrinsic e.g. ruptured aortic aneurysm, pancreatitis, peritonitis and bowel obstruction. 2) Cardiogenic shock or pump failure in most cases is due to acute myocardial infarction. 3) Distributive shock is of 2 kinds, more common low resistance variety as in septic shock where the cardiac output is normal or increased and less commonly of high resistance variety. Spinal cord injury can also be associated with low resistance variety of shock. Obstructive shock is the least common variety of shock when an actual obstruction to central circulation exists e.g. a saddle pulmonary embolism.



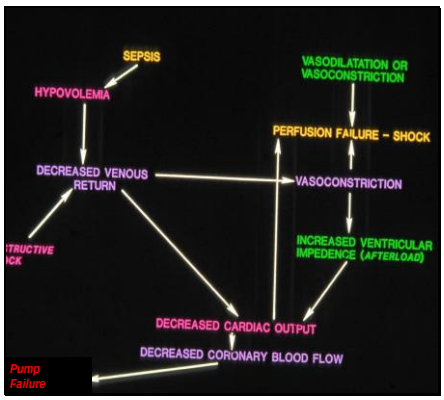
These three components of circulation, the cardiac pump, intravascular volume (pool) and two kinds of vessels, resistance & vascular capacitance must be considered in the pathophysiology of shock.



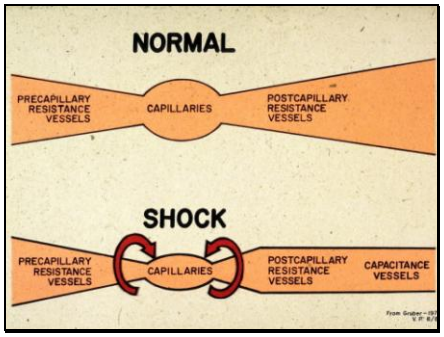
Effective arterial blood volume (EABV) is normally only 15% of total blood volume. It is affected by total blood volume, cardiac output and capacitance. EBABV is an important entity as it determines organ perfusion.



Normally 50% of the blood volume is contained in the large veins of the body (capacitance vessels), 30% in the central circulation i.e. heart and lungs, 15% in the arteries and only 55 in the capillary circuit. Thus the importance of capacitance vessels in the behavior of the circulation is obvious.



In the maintenance of shock different mechanisms prevail. That may make it difficult to ascertain what is more important than other in a patient who remains in shock. Thus sepsis is associated with hypovolemia that would tend to decrease cardiac output. Intense increases in vascular resistance may reduce the cardiac output which in turn reduces coronary blood flow.



Precapillary and post capillary sphincters determine the capillary pressure. The ratio of resistance in these sphincters determines whether fluid enters or leaves the capillary circuit.

Shock
Ischemia-new definitions

- **O_2 deficit**
  - Anaerobic metabolism
- **CO_2 excess**
  - Tissue and venous hypercarbia

It is now recognized that shock is associated with both lack of O2 and venous & tissue hypercarbia. Increased tissue CO2 production in shock has been documented in experimental and clinical studies.

Shock-hypovolemic Compensatory responses

- Increased sympathetic vascular tone- 'auto-regulation'.
- Increased sympathetic activity- increased HR to augment SV, myocardial contractility and venous return.
- Decreased capillary hydrostatic pressure-ingress of fluid from IF, reduces viscosity.
- Acidosis-R shift of P_{50}- more O_2 available
- Hyperventilation
- Reduced renal blood flow- Na & H_2O retention.

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The list of the compensatory changes in hypovolemic shock also applies to other forms shock. Renal and endocrine mechanism that attempt to retain Na and H2O are the most significant in restoring blood volume towards normal.

Peripheral vascular failure Shock

- Loss of fluid from vessels to interstitial space.
- Increased capillary permeability (?).
- Decreased precapillary resistance and decreased postcapillary resistance.
- Loss in gut mucosa.
- " Sluggish" blood flow- plugging of vascular beds.

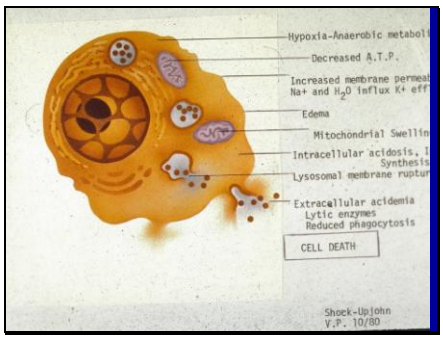
Peripheral circulation eventually fails in shock. The accompanying mechanisms are listed. In hypovolemic shock increased capillary permeability is not an issue.

Cell Ischemia Loss of viability

1. K^+
2. Lactate
3. $NH4^-$
4. Phospholipid metabolites

Ca^{++} & Mg^{++} depletion adversely affect viability

Progressive cellular ischemia is manifested by increases in K, lactate and ammonia. In this process depletion of Ca and Mg hastens the process of lack of viability of cells.



The cellular changes in shock result in swelling of cell membrane, decreased ATP synthesis, cellular swelling due to movement of water and Na inside the cell and movement of K into extracellular fluid. Impairment of mitochondrial respiration eventually results in lysosomal rupture and cell death.

Venous hypercarbia Shock

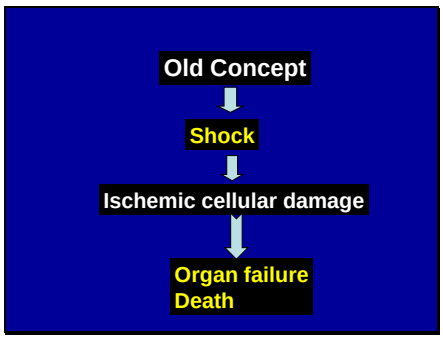
- Hemorrhagic shock-inversely related to decrease in CO
- Tissue PO_2 decreased proportionately to decreased CO & preceded tissue hypercarbia.
- Cardiac arrest- VF- myocardial tissue pCO_2 > 400 mm Hg, resuscitation futile.
- CPR-humans mixed venous hypercarbia.
- Septic shock- venous hypercarbia with low CO

In this slide evidence of tissue & venous hypercarbia in shock is summarized.

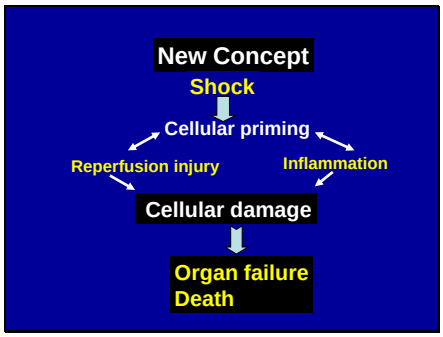
Hypercarbia during perfusion failure-mechanism

- Decreased CO_2 clearance due to reduced or absent blood flow.
- Continued aerobic CO_2 production
- Anaerobic CO_2 production
  - Buffering of excess acid by bicarbonate
  - Decarboxylation

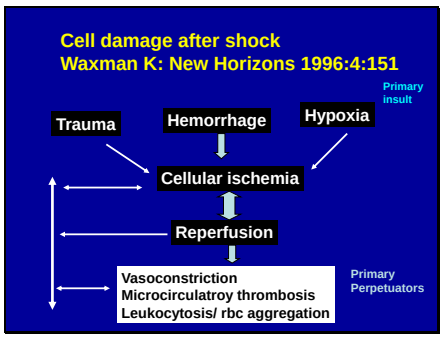
The mechanism of hypercarbia is thought to be related to reduced or absent blood flow in low cardiac output states.



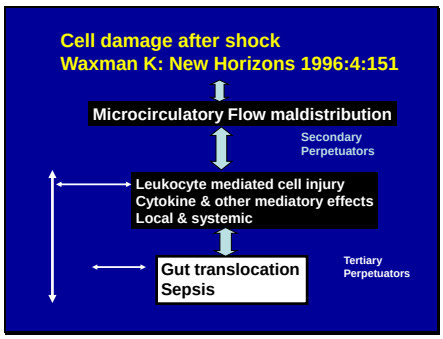
The old concept of shock causing cellular damage due to ischemia has been revised.



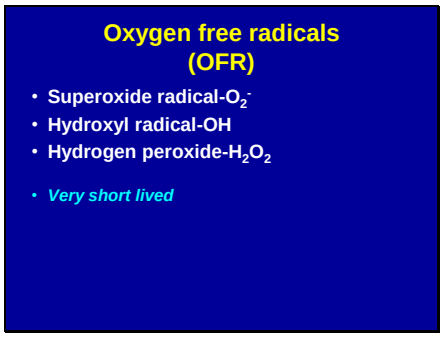
The new concept implies that cellular priming in shock through reperfusion injury and inflammation amplifies cell damage.



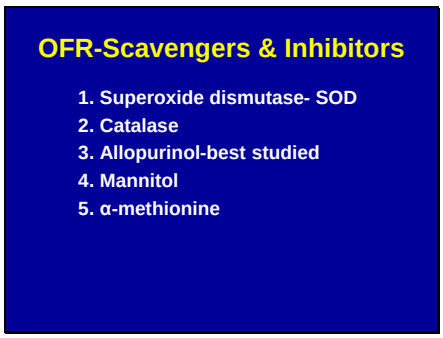
The primary insults of trauma, hypoxia and hemorrhage cause cell injury, magnified by reperfusion during resuscitation. The primary perpetuators in this process are vasoconstriction & plugging of capillary circuits by red & white cells.



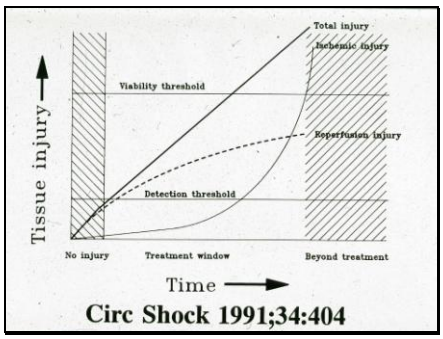
Uneven blood flow in the capillaries is magnified by the secondary perpetuators i.e. cytokines that cause intense vasoconstriction and vasodilatation. Even after 'successful' resuscitation, the tertiary perpetuators such as translocation of endotoxin and live bacteria via intact gut mucosa are responsible for organ failure. Most patients with multiple organ failure have suffered a well-defined period of shock.



These three are the most common free oxygen radicals. All of the free oxygen radicals are very short-lived i.e. 30 seconds. Thus in human beings it is difficult to prevent damage due to free O2 radicals.



This is a list of free O2 radical scavengers.



In animals, there appears to be a window of opportunity to treat to reduce total cellular injury.

Reperfusion Damage

1. **Due to reperfusion of a previously ischemic organs.**
2. **Counteracted by allopurinol**
3. **A therapeutic window**
4. **Endothelium derived factor(EDRF or NO) blood flow-inactivated by O_2^-**
5. **Clinical importance (?) ARDS, MSOF, bacterial translocation.**

Hogalund U, Gerdin B.
Circ Shock 1991;34:405

This is a general summary of reperfusion injury. EDRF is now known to be Nitric oxide (NO).

Shock-Monitoring

- Hemodynamics-HR, BP, CVP, PCWP, CO
- Organ perfusion- urine output
- Tissue perfusion- skin temp., lactate, gastric tonometry (pHim), sublingual capnometry(PS_{LCO2})

For monitoring of shock primary measurements of heart rate, right and left sided cardiac filling pressures and cardiac output are listed. All of these measurements may not be required in every patient. Organ perfusion is assessed by measuring hourly urine output. Tissue perfusion is assessed clinically by capillary refill, feel of lower extremities and feet and laboratory determination of lactate. Newer methods such as gastric tonometry and sublingual capnometry may also be considered.

Shock-Monitoring
CVP vs. PCWP

- In pts with prior cardiopulmonary disease, poor correlation r^2= 0.28
- Without H/O cardiopulmonary disease, r^2= 0.68

  Touissant –Arch Surg 1974

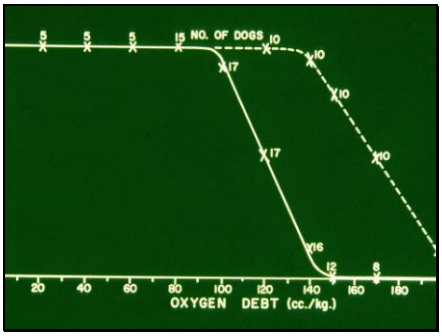
  Shoemaker- Surg 1975.
- *Cardiogenic & septic shock- more often require PA catheter for management.*

Studies have indicated that central venous pressure monitoring may be adequate in patients without cardiopulmonary disease. But in patients with pre-existent cardiopulmonary disease, Swan-Ganz catheter is required.

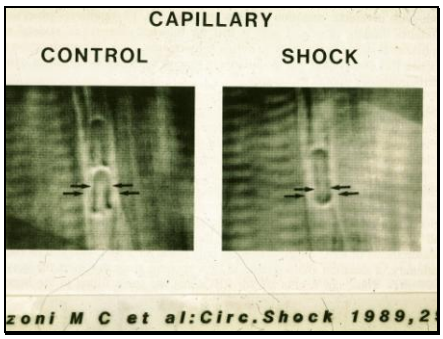
Irreversible Shock
Guyton

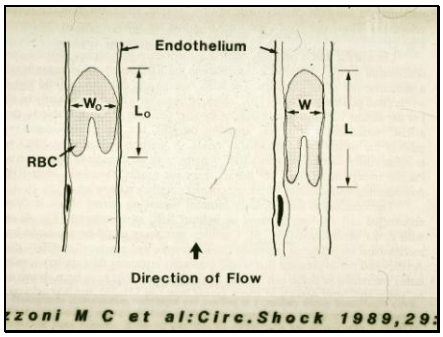
Beyond a critical point, transfusions or any other therapy will not save life. Heart can still pump large quantities of blood, but contributes to deteriorate.

Irreversible shock as defined by Guyton in the laboratory does exist. In human beings, a vigorous attempt at resuscitation must be made before declaring shock to be irreversible



Experimentally, Guyton and colleagues measured oxygen debt in hemorrhagic shock and found a figure of 144 ml/kg to predict irreversible shock. All dogs in this experiment died. When the dogs were digitalized, they survived a little longer but still succumbed to their injury. In a patient with shock it is not possible to estimate basal O2 consumption. Thus O2 debt as a concept is not very helpful in clinical medicine.



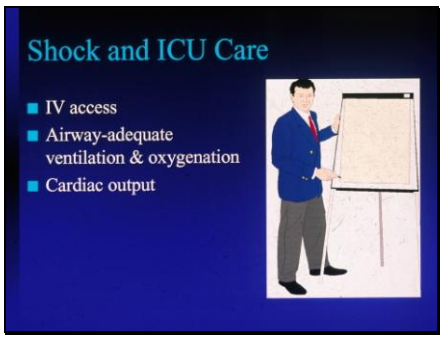


Therapeutic problem of shock

William shoemaker-1989

- **Reduced or inadequate VO_2- tissue hypoxia is primary pathogenic mechanism.**
- **DO_2 may limit VO_2 by low flow or uneven blood flow.**
- **VO_2 represents the sum of all oxidative metabolic activity.**
- **VO_2 is the regulatory mechanism of circulatory failure.**
- ***Shock Sates, pathophysiology, monitoring, outcome.***

Shoemaker has emphasized the importance of oxygen consumption (VO2) in shock.



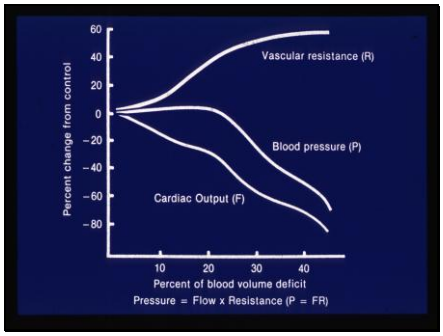
For the treatment of shock, an approach that was termed VIP (ventilation, infusion and pumping) by Weil and Shubin has stood the test of time. Now we recognize that all the interventions such intravenous access and airway protection have to be performed almost simultaneously. Immediate attention to a tension pneumothorax or pericardial tamponade is required. Added to the mnemonic VIP are P.S that stand for pharmacologic and specific therapy.

Time-dependent discriminants
Cerra FB: 1990

	Surv	Died	Day
PaO_2/FIO_2 mm Hg	311± 25	233± 14	1
Lactate Mmol/L	1.1± 0.2	3.4± 0.7	2
Bilirubin mg/dl	2.2± 0.6	8.5± 0.5	6
Creatinine mg/dl	1.9± 0.6	3.9± 0.3	12

92 trauma, sepsis, hem shock

Cerra has identified some time dependent variable that correlate with outcome in hemorrhagic and septic shock. Arterial PaO2/FIO2 or the so called P/F ratio seems to be most useful in the early prediction or survival or death in hemorrhagic and septic shock. By day 2, lactate and by first week serum bilirubin predict survival. On the other had renal function as determined by serum creatinine does not attain predictive value until almost 2 weeks after shock.

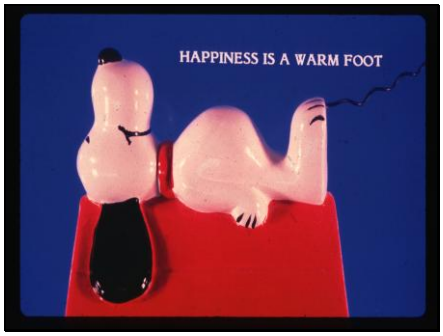


It may be erroneous to base the clinical diagnosis on blood pressure (B.P.) alone. Cardiac output may be reduced by 20% prior to a decrease in B.P. The B.P. is maintained by intense peripheral vasoconstriction as the cardiac output is decreased.

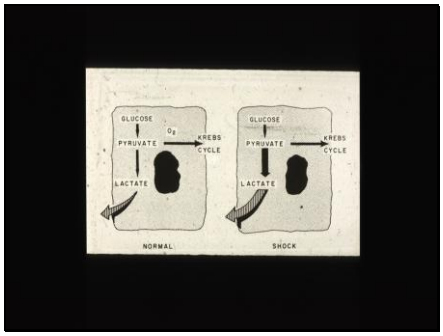
Gastric tonometry in shock
Maynard N et al
JAMA 1993;270:1203

Category	pHim 7.35	Lact > 2 mmol/L	VO_2I < 135 ml.min.m^2
Sensitivity %	88	73	84
Specificity %	62	52	18
Likelihood Ratio	2.32	1.52	1.02

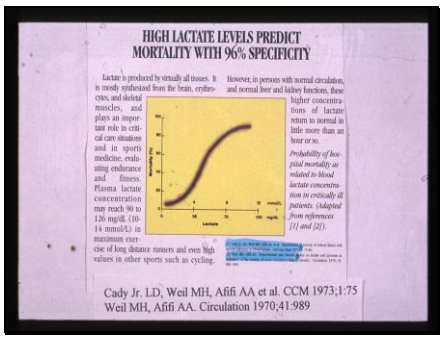
In the next few slides we will discuss various methods of assessing tissue perfusion in shock. Gastric tonometry which implies measurement of gastric intramucosal pH (pHim) has been demonstrated to be somewhat better than lactate measurement in shock in one study. During shock ischemia of the gastric mucosa is postulated as the cause of reduced pHim & occult acidosis.



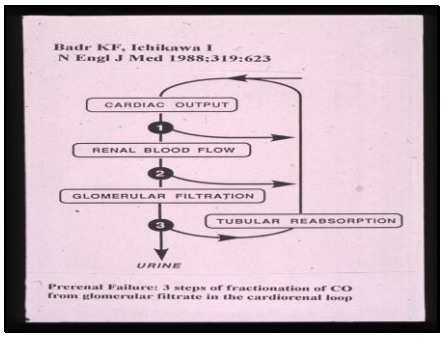
Toe- temperature measurements have been used to document tissue perfusion in shock.



There are sound physiologic reasons for the measurement of lactate to assess adequacy of tissue perfusion. See Lactate presentation.



In a landmark study of lactate measurement in shock, Weil and associates described a survival curve based on lactate levels.

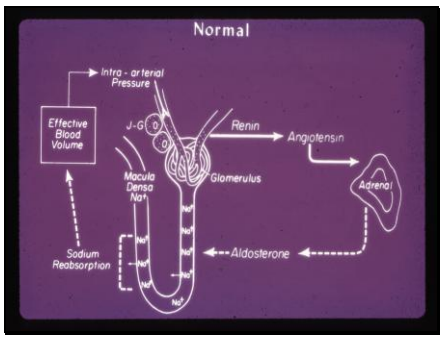


In shock, organ perfusion is assessed by measurement of urine output. This slide points out the steps by which cardiac output is fractionated before urine is produced. Clinically it makes sense to assess renal function prior to the use of diuretics, loop or osmotic or agents such as dopamine which cause diuresis & natriuresis.

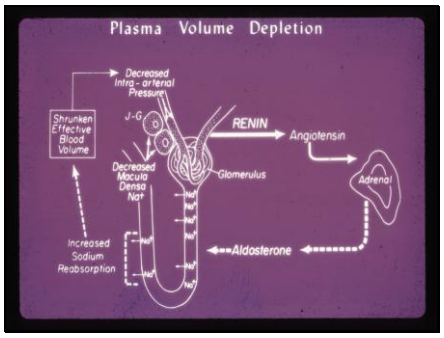
Renal Regulatory Mechanisms

1. Fractional blood flow- RBF/ CO
2. Filtration fraction- GFR/ glomerular plasma flow rate
3. Fractional tubular reabsorption-tubular reabsorption/ GFR

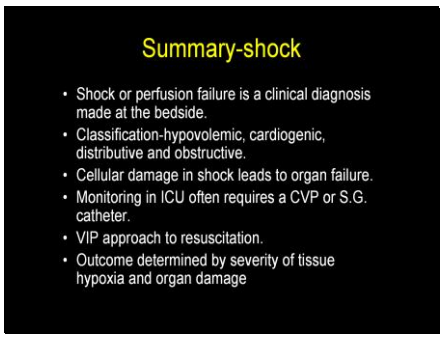
The concept of pre-renal failure is significant in patients with congestive heart failure or low cardiac output who quickly suffer renal failure with hypotension and shock.



Reduced plasma volume in shock decreases the intra-arterial pressure in the glomerulus, which in turn activates the JG apparatus. The rennin-angiotensin mechanism is activated to increase reabsorption of Na & H2O I the proximal tubule. Similarly increased aldosterone secretion increases Na & H2O absorption in the distal tubules. These renal-endocrine mechanisms are the most significant for replenishment of the plasma volume.



Normally pressure in the afferent loop of the renal glomerulus is maintained by normal plasma volume. The juxta-glomerulus (JG) apparatus adjacent to the afferent loop is exquisitely sensitive to the pressure inside.



In summary, shock is a serious complication of critical illness and injury. It is clinical diagnosis made at the bedside. Classification and pathophysiology of shock are presented. Methods of monitoring a patient in shock and assessing tissue perfusion are discussed. Basic principles of resuscitation are also outlined.