Overview of shock and hemodynamic monitoring

Prof Xavier MONNET
Medical Intensive Care Unit
Bicêtre Hospital
Assistance publique – Hôpitaux de Paris
FRANCE

1 Definition

2 Pathophysiology
   2.1 Different shock states
   2.2 Pathophysiological schema
   2.3 Mechanisms of shock
   2.4 Shock-induced consequences

3 Diagnosis
   3.1 of shock
   3.2 of shock-induced consequences
   3.3 etiology

4 Basic hemodynamic monitoring
Definition

Clinical definition:

Combination of

-low arterial pressure
  (systolic arterial pressure ≤ 90 mmHg)
  or mean arterial pressure ≤ 65 mmHg
and
-signs of impaired organ perfusion

Pathophysiological reality

reduction of tissue perfusion
leading to an inadequation
between tissue requirements and supply

Overview of shock and hemodynamic monitoring

1 Definition
2 Pathophysiology
   2.1 Different shock states
   2.2 Pathophysiological schema
   2.3 Mechanisms of shock
   2.4 Shock-induced consequences
3 Diagnosis
   3.1 of shock
   3.2 of shock-induced consequences
   3.3 etiology
4 Basic hemodynamic monitoring
4 types of shock: hypovolemic shock, cardiogenic shock, septic shock, anaphylactic shock.
4 types of shock: hypovolemic shock, cardiogenic shock, septic shock, anaphylactic shock

Primum movens: fall in central blood volume

- cardiac output
- cardiac preload
- blood volume
- O₂ distribution
- tissue hypoxia
Pathophysiology hypovolemic shock

Adaptative mechanisms

arterial vasoconstriction

cardiac output is "shared"
Pathophysiology: hypovolemic shock

Adaptative mechanisms

arterial vasoconstriction

- heart rate
- inotropy

- O₂ extraction

venous constriction
→ circulating blood volume
Vasodilatation of microvessels

recruitment of collapsed capillaries

⇒ increase in $O_2$ diffusion surface

Adaptative mechanisms

$\Rightarrow O_2$ extraction

Pathophysiology hypovolemic shock
**Pathophysiology** hypovolemic shock

**Adaptative mechanisms**

- Arterial vasoconstriction

- Heart rate

- Inotropy

- O2 extraction

- Venous constriction

- Circulating blood volume

**Causes**

- **Hemorrhage**: plaie artérielle traumatique, hémorragies digestives…

- **Extra-cellular dehydration**: diarrhea, vomiting, burns…

- **Internal fluid sequestration**: bowel occlusion, crush syndrome…
4 types of shock:
- hypovolemic shock
- cardiogenic shock
- septic shock
- anaphylactic shock

*Primum movens*: failure of cardiac pump

**O₂ distribution**

- cardiac output
- tissue hypoxia
Pathophysiology: cardiogenic shock

Adaptive mechanisms:

arterial vasoconstriction

- heart rate
- inotropy
- O₂ extraction
Pathophysiology cardiogenic shock causes

Myocardial infarction:
  - large size infarction
  - mechanical complication: septal defect, free wall rupture, mitral regurgitation
  - ventricular arrhythmia, A-V block

Decompensation of chronic cardiopathy
Acute valvular regurgitations, valvular prothesis thrombosis
Severe arrhythmias
Cardiotropes intoxication

Right ventricular myocardial infarction
Massive pulmonary embolism
Cardiac tamponade
Pneumothorax

Pathophysiology differents shock states

4 types of shock:
  - hypovolemic shock
  - cardiogenic shock
  - septic shock
  - anaphylactic shock
Primum movens: severe infection

Micro-organism
endotoxines, wall components

activation C3A, C5A, factor XII
activation monocytes and macrophages

cytokines

vasodilation  myocardial dysfunction  occlusion of microvessels

Pathophysiology septic shock

Primum movens: severe infection

vasodilatation

O$_2$ extraction
Due to impairment in O$_2$ extraction obstruction of microvessels

Impairment in O$_2$ extraction

Due to obstruction of microvessels

Impairment in endothelial function
Pathophysiology  septic shock

Adaptative mechanisms

- cardiac output

Pathophysiology  septic shock  causes

All severe infections including

- **Gram negative bacilles**
  - digestives infections, pyelonephritis…

- **Gram positive cocci**
  - S pneumoniae pneumonia and meningitis, cellulitis…

- **Gram negative cocci**
  - N meningitidis meningitis
4 types of shock: hypovolemic shock, cardiogenic shock, septic shock, anaphylactic shock.

Pathophysiology: anaphylactic shock

Primum movens: allergic reaction

- Histamine
  - Arterial vasodilation
  - Capillary vasodilation
    - Rash, swelling
  - Venous vasodilation
    - Relative hypovolemia
    - Shock
**Pathophysiology** anaphylactic shock

*Primum movens*: allergic reaction

**Pathophysiology** anaphylactic shock

Adaptative mechanisms

**Pathophysiology** anaphylactic shock

Arterial vasodilatation
Causes

Medications
β lactamines, ASA...

Food
...

Envenimation
...

Pathophysiology
anaphylactic shock
Causes

Overview of shock and hemodynamic monitoring

1 Definition

2 Pathophysiology

2.1 Different shock states
2.2 Pathophysiological schema
2.3 Mechanisms of shock
2.4 Shock-induced consequences

3 Diagnosis

3.1 Definition of shock
3.2 Definition of shock-induced consequences
3.3 Etiology

4 Basic hemodynamic monitoring
1. vasoconstriction of some territories

2. tissue hypoxia

   can affect all organs
   can lead to irreversible damage
Overview of shock and hemodynamic monitoring

1 Definition
2 Pathophysiology
   2.1 Different shock states
   2.2 Pathophysiological schema
   2.3 Mechanisms of shock
   2.4 Shock-induced consequences
3 Diagnosis
   3.1 of shock
   3.2 of shock-induced consequences
   3.3 etiology
4 Basic hemodynamic monitoring
1. Arterial hypotension

mean arterial pressure < 65 mmHg

can lack

at the very early phase
in case of pre-existing hypertension
5. We recommend a target blood pressure during initial shock resuscitation of:
For uncontrolled hemorrhage due to trauma: MAP of 40 mmHg until bleeding is surgically controlled.
Level 1; QoE moderate (B)
For traumatic brain injury (TBI) without systemic hemorrhage: MAP of 90 mmHg.
Level 1; QoE low(C)
Level 1; QoE moderate (B)
2. Tachycardia

heart rate > 100 beats/min

can lack
  in case of A-V block
  in case of beta blocking treatment

3. Clammy extremities (skin hypoperfusion)

4. Skin mottling (skin hypoperfusion)

5. Oliguria (kidney hypoperfusion)

  always present
  hard to evaluate in the first hours

6. Altered mental status (brain hypoperfusion)

  more frequent in case of sepsis:
  "septic encephalopathy"

7. Polypnea (stress and metabolic acidosis)
Diagnosis of shock-induced organ dysfunction

This diagnosis is based upon biological examinations

1. 🆙 arterial lactate
   
   indicates tissue hypoxia

2. Functional renal failure
   
   🆚 urea et creatinine blood concentration

   functional pattern:
   
   - $\frac{Na}{K_u} < 1$
   - $\frac{U/P \text{ urea}}{U/P \text{ creat}} > 40$
   - 🆚 urea > 🆚 creatinine in plasma: $\frac{\text{urea}}{\text{creat}} P > 100$
   - $\text{FE Na} < 1%$

3. Liver cytolysis and cholestasis: liver hypoxia

4. Disseminated intravascular coagulopathy:
   
   - 🆙 platelet count
   - 🆙 coagulation factors
   - 🆙 fibrinogen
   - 🆙 D-dimers

5. Metabolic acidosis:
   
   due to lactic acidosis and renal failure
Overview of shock and hemodynamic monitoring

1 Definition
2 Pathophysiology
   2.1 Different shock states
   2.2 Pathophysiological schema
   2.3 Mechanisms of shock
   2.4 Shock-induced consequences
3 Diagnosis
   3.1 of shock
   3.2 of shock-induced consequences
   3.3 etiology
4 Basic hemodynamic monitoring
Basic hemodynamic monitoring

Arterial pressure

Echocardiography

Venous oxygen saturation

From physiology, we know that a huge amount of hemodynamic information is contained in the AP signal.

We must consider all values of arterial pressure.
Hemodynamic information from the AP signal

diastolic arterial pressure

- SAP
- Pulse pressure
- MAP

- Low DAP indicates vasodilation
- Low DAP indicates septic origin of shock
- Low DAP promotes vasopressor administration
Hemodynamic information from the AP signal

Mean Arterial Pressure (MAP) is the perfusion pressure of all organs (except the heart).
Hemodynamic information from the AP signal

Mean arterial pressure (MAP) is an independent prognostic indicator during septic shock and a therapeutic target for vasopressor treatment.

<table>
<thead>
<tr>
<th>Hemodynamic variables related to outcome in septic shock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistic regression</td>
</tr>
<tr>
<td>$p$</td>
</tr>
<tr>
<td>SvO$_2$ area under 70%</td>
</tr>
<tr>
<td>CVP, mean</td>
</tr>
</tbody>
</table>

MAP is an independent prognostic indicator during septic shock.

A therapeutic target for vasopressor treatment.

Increasing mean arterial pressure in patients with septic shock:
Effects on oxygen variables and renal function

Aurélie Bourgoin, MD; Marc Leone, MD; Anne Delmas, MD; Franck Garnier, MD; Jacques Albanèse, MD; Claude Martin, MD, FCCM

Crit Care Med 2005 Vol. 33, No. 4

Effects of perfusion pressure on tissue perfusion in septic shock

David LeDoux, MD; Mark E. Attiz, MD, FCCM, Charles M. Carpatti, MD; Eric C. Rankow, MD, FCCM

Crit Care Med 2000 Vol. 28, No. 6
Hemodynamic information from the AP signal

mean arterial pressure

Increasing mean arterial pressure in patients with septic shock:
Effects on oxygen variables and renal function

Aurélie Bourgoin, MD; Marc Leone, MD; Anne Delmas, MD; Franck Garnier, MD; Jacques Albanèse, MD; Claude Martin, MD, FCCM

28 septic shock patients
two levels of mean arterial pressure as therapeutic target

Blood lactate

Creat clearance

Oxygen delivery

Oxygen consumption

There is no advantage to increase the MAP above 65 mmHg
F. Vasopressors

1. We recommend that (grade 1C).

Hemodynamic information from the AP signal mean arterial pressure

Surviving Sepsis Campaign: International guidelines for management of severe sepsis and septic shock: 2008

1. We recommend that vasopressors should be considered for patients with a MAP <65 mmHg and septic shock, with the aim of increasing the MAP to the lowest value needed to maintain organ perfusion.

5. We recommend a target blood pressure during initial shock resuscitation of:
   - For uncontrolled hemorrhage due to trauma: MAP of 40 mmHg until bleeding is surgically controlled.
   - Level 1: QoE moderate (B)
   - For traumatic brain injury (TBI) without systemic hemorrhage: MAP of 90 mmHg.
   - Level 1: QoE low (C)
   - Level 1: QoE moderate (B)
Hemodynamic information from the AP signal

**Pulse arterial pressure**

- SAP
- MAP
- DAP

Pulse pressure = \( k \cdot \frac{\text{stroke volume}}{\text{compliance}} \)

Hemodynamic information from the AP signal arterial pulse pressure

**Arterial Pulse Pressure and Its Association With Reduced Stroke Volume During Progressive Central Hypovolemia**

Victor A. Comet, PhD. William H. Cooke, PhD. and John B. Holcomb, MD

*J Trauma*. 2006;61:829–834

13 healthy subjects

Low body negative pressure

- SV, mL
- PP, mmHg
- Sympathetic activity, b/min
- PAM, mmHg

\[ r^2 = 0.59 \]

\[ r^2 = 0.94 \]

\[ r^2 = 0.96 \]
vasodilation

Hemodynamic information from the AP signal  arterial pulse pressure

vasodilation

septic shock  cardiogenic shock  hypovolemic shock

Conclusion

- remember a schematic representation of cardiovascular system
- arterial pressure provides a huge amount of hemodynamic information
- previous hypertension must be considered for diagnosing shock