Lecture 27: Cardiac Output, Venous Return, and Their Regulation II

Guyton and Hall Chapter 20
A more quantitative analysis of cardiac output regulation
Cardiac Output Curves

Cardiac output (L/min)

Intrathoracic pressure = −5.5 mm Hg
Intrathoracic pressure = −4 mm Hg
Intrathoracic pressure = −2 mm Hg
Intrathoracic pressure = +2 mm Hg

Cardiac tamponade

Right atrial pressure (mm Hg)
Normal Venous Return Curve

Venous return (L/min) vs. Right atrial pressure (mm Hg)

- Plateau
- Transitional zone
- Down slope

Mean systemic filling pressure
Quantitative Analysis of Cardiac Output Regulation

It is necessary to distinguish separately the two primary factors:
1. The *pumping ability of the heart*
2. The peripheral factors that affect flow of blood from the veins into the heart - represented by *venous return curves*.

“cardiac pumping ability”

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<table>
<thead>
<tr>
<th>Right atrial pressure</th>
<th>Cardiac output (L/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0</td>
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<tr>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>+4</td>
<td>10</td>
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<tr>
<td>+8</td>
<td>15</td>
</tr>
<tr>
<td>+12</td>
<td>20</td>
</tr>
</tbody>
</table>

Hypereffective—increased intrapleural pressure

Normal

Hypoeffective—reduced intrapleural pressure
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“venous return curves”

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\( Psf = 7 \)

\( \frac{1}{2} \) resistance

Normal resistance

2X resistance

PSF = 7
Volume - pressure curves of systemic arterial and venous systems

Figure 15-1, Guyton
Psf therefore reflects the “degree of filling” or the “fullness” of the systemic circulation.

Mean systemic filling pressure (Psf)

Recall, \( C = \frac{\Delta V}{\Delta P} \) so, \( P = \frac{\Delta V}{C} \)

\[ \text{Psf (mmHg)} = \frac{\text{Total Volume (ml)}}{\text{Total compliance (ml/mmHg)}} \]

In excess of “unstressed volume”
Based on Figure 20-10, Guyton

**Psf (mmHg)**

- 14
- 7
- 0

**Blood volume (ml)**

- 0
- 2000
- 4000
- 6000

“Sympathetic stimulation”

“Sympathetic inhibition”
Volume - pressure curves of systemic arterial and venous systems

Figure 15-1, Guyton

- Normal
- Complete sympathetic inhibition
- Strong sympathetic stimulation
Venous return curves - effects of pure change in blood volume. Figure 20-11, Guyton
Venous return curves depicting effects of altering the “resistance to venous return” (RVR). Figure 20-12, Guyton

Recall: \[ VR = P_{sf} - R_{AP} \]

RVR
Combinations of major venous return curves showing effects of simultaneous changes in Psf and RVR. Figure 20-13, Guyton
Analysis of cardiac output and right atrial pressure.
Figure 20-14, Guyton

Transfusion of blood
~ 20% increase.
Arteriovenous fistula

Arteriovenous fistula (A-V fistula) (or A-V shunt)
Analysis of successive changes in cardiac output and right atrial pressure in a human being. Figure 20-16, Guyton

A. normal conditions

B. opening A-V fistula (immediate changes)

C. 1 min after sympathetic reflexes become active.

D. week after blood volume has increased and cardiac hypertrophy has begun
Pulsatile blood flow in the root of the aorta recorded by an electromagnetic flowmeter of ultrasonic flowmeter.

Figure 20-17

Figure 14-4  electromagnetic

Figure 14-5  Ultrasound
Fick principle for determining cardiac output. Figure 20-18, Guyton

\[ CO \ (L/min) = \frac{O_2 \ absorbed \ per \ min \ from \ lungs \ (ml/min)}{Arteriovenous \ O_2 \ difference \ (ml/L \ of \ bld)} \]

\[ CO = \frac{200 \ ml/min}{200 - 160 \ ml/L} = \frac{200}{40} = 5 \ L/min \]
Indicator dilution cardiac output measurement. Figure 20-19, Guyton

\[
CO = \frac{\text{amount dye injected (mg) } \times 60}{\text{average conc of dye in each ml for duration of curve } \times \text{duration of the curve in seconds}}
\]
Indicator dilution method of cardiac output measurement

\[ CO = \frac{\text{amount dye injected (mg) x 60 sec}}{\text{average conc of dye in each ml for duration } \times \text{the curve in seconds}} \]

\[ CO = \frac{5\text{mg x 60 sec}}{0.25 \text{mg/100ml x 12 sec}} = \frac{300\text{sec}}{3 \text{sec}} = 100 = 2 \text{L/12 sec} = 10 \text{L/min} \]

\[ CO = \frac{5\text{mg x 60 sec}}{0.25 \text{mg/100ml x 23 sec}} = \frac{300\text{sec}}{5.75 \text{sec}} = 52 = 2 \text{L/23 sec} = 5.2 \text{L/min} \]