How to Achieve Abdominal Perfusion Pressure?

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**Intra-abdominal Pressure**

**Intra-Abdominal Pressure (IAP)**
- **Steady-state pressure** concealed within the abdominal cavity
- Normal range in critically ill adults: 5-7mmHg

- Sustained or repeated pathological elevation in IAP >12mmHg

**Intra-Abdominal Hypertension (IAH)**

- Sustained IAP >20mmHg that is associated with new organ dysfunction

**Abdominal Compartment Syndrome (ACS)**

*WSACS. Intensive Care Med 2006;32:1722*
IAH in Critically ill patients

• First documented in 1863 (Marey)
  IAP → effect respiratory function
  Severe IAH → respiratory failure

• In 1911, IAH → cause death by cardiovascular collapse
  ...gastroschisis, Trauma, abdominal surgery, AAA rupture, laparoscopy...

• 2000~ → Clinical Impact in Critically Ill Patients were described

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Malbran ML. Intensive Care Med 2004;30:822
Clinical Effect of IAH

IAH was associated with Severe organ dysfunction independent predictor of mortality

Malbrain et al. Crit Care Med 2005;33;315

Predicted Mortality

IAH 38.8%
No IAH 22.2%

Relative risk: 1.85 ;95% CI 1.12-3.06, p=0.01
**Pathophysiology**

- **Directly or Indirectly on Every organ system**
  - Kidney
    - Reduction in renal blood flow and function
    - Direct parenchymal compression
  - GI tract
    - Reduction in mesenteric blood flow
  - Liver
    - Reduction in hepatic a, portal vein, hepatic vein

- **Cardiovascular**
- **Respiratory**
- **Hepatobiliary**
- **Gastrointestinal**
- **CNS**
- **Renal**

Directly on **intra-abdominal organ**
**Abdominal Perfusion Pressure**

- Abdominal perfusion pressure (APP)
  \[
  \text{MBP} - \text{IAP}
  \]

  ➤ **Surrogate** of the driving pressure for the perfusion of intra-abdominal organ

  ➤ major pathophysiologic mechanism underlying regional hypoperfusion

  ➤ suggested as a more **accurate predictor** of visceral perfusion

  better **goal of resuscitation** than isolate IAP/MBP
**Abdominal Perfusion Pressure: A Superior Parameter in the Assessment of Intra-abdominal Hypertension**

Michael L. Cheatham, MD, Mark W. White, MD, Scott G. Sagraves, MD, Jeffrey L. Johnson, MD, and Ernest F. J. Black, MD

APP was significantly superior to any other resuscitation endpoint

AUC

APP = 0.726

significantly greater than that of both MAP & IAP
Target APP

- **APP ≥ 50 mmHg**: predict improved survival
  
  *J Trauma 2000;49:621-6*

- **APP ≥ 60 mmHg**: appropriate resuscitation goal
  
  *Vincent JL (ed) Yearbook of intensive care and emergency medicine. Springer, Berlin Heidelberg New York, pp 792–814*

**WSACS recommendation**

APP should be maintained

**above 50–60 mmHg** in patients with IAH/ACS

*WSACS. Intensive Care Med 2006;32:1722*
Use of APP as a Resuscitation Goal?

Improving APP results in improved outcomes?

- Unclear
- No clinical evidence
  - Indiscriminate fluid administration to raise MBP and APP
    - Worsen IAH → should be avoided
  - Use of vasopressor to raise MBP
    - Unknown

WSACS recommendation

No recommendation regarding the use of APP in the resuscitation of critically ill patients with IAH
How To Achieve APP?

APP = MBP

Raise MBP

Fluid resuscitation
Inotropics
vasopressor

Reduce elevated IAP

According to pathophysiologic mechanism of IAH
Reducing elevated IAP
**Characteristics of IAH**

- Various Patients Population
- Various Cause

- difficult to make a standardized therapeutic approach

- should consider **pathophysiological mechanism**

- application of **comprehensive management** algorithm
**Pathophysiologic Mechanism**

1. Diminished abdominal wall compliance
   - *Improvement of abdominal wall compliance*

2. Increased abdominal contents
   - *Evacuation of intraabdominal space-occupying lesions*

3. Increased Intra-luminal contents
   - *Evacuation of intraluminal contents*

4. Capillary leak / fluid resuscitation
   - *Optimization of fluid administration and balance*
Regarding direction and strength according to the **quality of evidence**
1. Diminished abdominal wall compliance

- Acute respiratory failure, ventilator dyssynchrony
- Abdominal surgery with tight closure
- Major trauma/burn eschar
- High BMI, central obesity
- Prone position/ head of bed > 30
Improvement of abdominal wall compliance

Step 1
- Adequate analgesia
- Adequate sedation

Simple, rapid, effective methods

should be titrated to ensure patient comfort minimize voluntary contractions

Step 2
- Body Position

<table>
<thead>
<tr>
<th>Body position</th>
<th>IAP (mm Hg)</th>
<th>APP (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>9.84 ± 3.581</td>
<td>76.95 ± 14.925</td>
</tr>
<tr>
<td>10°</td>
<td>10.11 ± 3.583 *</td>
<td>74.52 ± 13.783 *</td>
</tr>
<tr>
<td>20°</td>
<td>10.52 ± 3.781 *</td>
<td>71.40 ± 13.888 *</td>
</tr>
<tr>
<td>30°</td>
<td>13.95 ± 3.600 *</td>
<td>68.08 ± 14.235 *</td>
</tr>
<tr>
<td>45°</td>
<td>16.56 ± 3.862 *</td>
<td>63.44 ± 14.879 *</td>
</tr>
</tbody>
</table>


Risk & benefit for VAP/Aspiration pneumonia and IAH
Step 3

- Consider **neuromuscular blocking agents**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Time</th>
<th>T0</th>
<th>T15</th>
<th>T30</th>
<th>T60</th>
<th>T120</th>
<th><strong>p</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>IAP</td>
<td></td>
<td>18 (16-20)</td>
<td>14 (12-16)*</td>
<td>14 (13-17)**</td>
<td>15 (14-17)</td>
<td>17 (14-19)</td>
<td>0.002</td>
</tr>
<tr>
<td>MAP</td>
<td></td>
<td>71 (64-76)</td>
<td>72 (62-77)</td>
<td>69 (64-77)</td>
<td>70 (63-77)</td>
<td>70 (62-88)</td>
<td>0.969</td>
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<tr>
<td>APP</td>
<td></td>
<td>53 (48-63)</td>
<td>58 (48-66)</td>
<td>59 (45-69)</td>
<td>56 (48-69)</td>
<td>54 (44-65)</td>
<td>0.674</td>
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<tr>
<td>CVP</td>
<td></td>
<td>18 (13-19)</td>
<td>16 (13-17)</td>
<td>15 (13-17)</td>
<td>15 (14-18)</td>
<td>18 (15-20)</td>
<td>0.146</td>
</tr>
<tr>
<td>HR</td>
<td></td>
<td>109 (93-113)</td>
<td>109 (94-115)</td>
<td>109 (96-116)</td>
<td>105 (94-111)</td>
<td>104 (99-110)</td>
<td>0.280</td>
</tr>
</tbody>
</table>


- Effects only **mild to moderate IAH**
- **Temporary** effect
- **Risks of prolonged paralysis**
- Considered while **other interventions** are performed to reduce IAP
Increased abdominal contents

- Hemoperitoneum/pneumoperitoneum
- Ascites/ liver dysfunction
- Solid mass

→ Function as space-occupying lesion
Evacuation of intraabdominal space-occupying lesions

- Percutaneous catheter drainage (PCD)
  - Simple, safe, Bedside procedure with US guided

**Chest 2011;140:1428-35**

<table>
<thead>
<tr>
<th>Physiologic Variable</th>
<th>Percutaneous Decompression</th>
<th>Open Abdomen</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, No.</td>
<td>31</td>
<td>31</td>
<td>.39</td>
</tr>
<tr>
<td>Predecompression MAP, mm Hg</td>
<td>78 ± 14</td>
<td>74 ± 14</td>
<td>.39</td>
</tr>
<tr>
<td>Postdecompression MAP, mm Hg</td>
<td>78 ± 12</td>
<td>79 ± 14</td>
<td>.89</td>
</tr>
<tr>
<td>Δ IAP, mm Hg</td>
<td>−7 ± 6</td>
<td>−12 ± 14</td>
<td>.30</td>
</tr>
<tr>
<td>Predecompression APP, mm Hg</td>
<td>55 ± 16</td>
<td>48 ± 18</td>
<td>.21</td>
</tr>
<tr>
<td>Postdecompression APP, mm Hg</td>
<td>64 ± 13</td>
<td>65 ± 17</td>
<td>.96</td>
</tr>
<tr>
<td>Δ APP, mm Hg</td>
<td>10 ± 15</td>
<td>15 ± 26</td>
<td>.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physiologic Variable</th>
<th>Successful PCD</th>
<th>Failed PCD</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, No.</td>
<td>25</td>
<td>6</td>
<td>.00001</td>
</tr>
<tr>
<td>Fluid drained first 4 h, mL</td>
<td>2.654 ± 1.650</td>
<td>478 ± 237</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Fluid drained first 24 h, mL</td>
<td>5.338 ± 3.372</td>
<td>1.225 ± 655</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

`⇒` drain < 1,000 mL & ΔIAP < 9 mmHg within first 4 h → should consider urgent surgical decompression
Increased Intra-luminal Contents

- Excessive air and fluid in GI tract
  - Gastroparesis
  - Ileus
  - Colonic pseudo-obstruction
Evacuation of intraluminal contents

Step 1

- Nasogastric tube
- Rectal tube

⇒ Simple and relatively Noninvasive methods
mild to moderate IAH in patients with GI distension

Step 2

- Prokinetics → erythromycin, metoclopramide, neostigmine

⇒ Clinical response: 100%
Time to response: 4 min
Recurrence: 0%
Abd circumference: 4cm ↓

⇒ No data about the effect of prokinetics on IAP

4 Capillary leak / fluid resuscitation

- Acidosis
- Hypotension
- Hypothermia
- Polytransfusion
- Coagulopathy

- Massive fluid resuscitation
- Pancreatitis
- Oliguria
- Sepsis
- Major trauma / burn

Fluid resuscitation for shock → Total body fluid third spacing/edema

Perfusion ↓ Organ failure ↑

Reduced cardiac output → Vena cava compression

Bowel edema Elevated IAP
Positive Fluid Balance

- Fluid resuscitation → restore circulating blood volume
  → correct hypovolemia
  → restore organ perfusion

- Maxwell et al. J Trauma 1999;47:995
  → IAH & ACS developed in patients receiving massive fluid resuscitation

  → 9% standardized shock resuscitation patients developed secondary ACS
  → Mortality 54%

  → Positive net fluid balance, positive cumulative fluid balance were predictor of poor outcome
  → Nonsurvivor 6L vs survivor 1L

- Daugherty et al. J intensive Care Med 2007;22:294
  → Positive net fluid balance (>5L) in MICU
  → IAH 85%, secondary ACS 25%

Fluid resuscitation: must be a balance

- Early massive resuscitation & maintain perfusion
- Avoid unnecessary fluid infusion
- Avoid over-resuscitation
- Use more advanced monitoring (→ PPV, SSV, PLR)
Correct positive fluid balance

Step 1
• Avoid excessive fluid resuscitation
• Consider hypertonic fluid / Colloids

Step 2
• Diuretics (when shock state has resolved)

Step 3
• Oliguria/anuria → Consider hemodialysis/ultrafiltration

Severe sepsis with positive 12500 ml
Perform CVVH with fluid removal of 250–300 ml/h
After 18hr (negative -4200ml)
IAP: 29mmHg → 12mmHg

Kula R et al, Intensive Care Med 2004;30:2138
### Should we use abdominal perfusion pressure (APP) as a resuscitation endpoint?

No recommendation

<table>
<thead>
<tr>
<th>Intervention</th>
<th>GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedation and analgesia</td>
<td>2D</td>
</tr>
<tr>
<td>Neuromuscular blocker</td>
<td>2D</td>
</tr>
<tr>
<td>Body positioning</td>
<td>2D</td>
</tr>
<tr>
<td>Nasogastric/colonic decompression</td>
<td>1D</td>
</tr>
<tr>
<td>Promotility agent</td>
<td>2D</td>
</tr>
<tr>
<td>PCD</td>
<td>2C</td>
</tr>
<tr>
<td>Decompressive laparotomy</td>
<td>1D</td>
</tr>
</tbody>
</table>

### Should we keep fluid balance neutral or negative?

GRADE 2C

<table>
<thead>
<tr>
<th>Interventions</th>
<th>GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diuretics</td>
<td></td>
</tr>
<tr>
<td>Renal replacement therapy</td>
<td></td>
</tr>
<tr>
<td>Damage control resuscitation</td>
<td>2D</td>
</tr>
</tbody>
</table>

should try to conduct _high quality_ experimental and clinical research!

*Intensive Care Med. 2013;39:1190*
Surgical Management

- If IAP > 25mmHg (and/or APP < 50mmHg) and new organ dysfunction is present

Refractory to medical management

- Strongly consider open abdominal decompression
Raising MBP to achieve APP
Optimizing regional tissue perfusion

**Fluid therapy**

- Overaggressive fluid therapy → worsen gut wall edema → IAP ↑
- Fluid → restore CO, but not Renal blood flow


**Inotropics**

- Dobutamine → restore CO, but not SMA blood flow


**Vasopressor**
**Rationale of vasopressor**

**Etiology of IAH**
- Surgery, Sepsis, Bleeding, ileus, & trauma

**Abdominal Compartment syndrome**
- Cytokine

→ **SIRS**

→ **distributive shock**

→ **detrimental effects on organ perfusion**

the controlled use of **vasopressor** therapy may be preferable

**No clinical data** describing the effects of attempts to **normalize APP**

....only small **experimental data**
Effects of norepinephrine on tissue perfusion in a sheep model of intra-abdominal hypertension

Sheep (N=24) 

IAP 20mmHg 

IAP control 

IAP 20 mmHg 

IAP +NE 

IAP 20 mmHg & APP 60mmHg 

Sham group (no IAH) 

IAP 20 mmHg 

Intensive Care Medicine Experimental 2015;3:11 

Keep CO By fluid infusion 

Intestine - SMA flow - Intramucosal PCO2 

Kidney - Renal blood flow - Urine output 

Measurement
Intestinal perfusion

- SMA flow → unchanged in the three groups
  - Control
  - IAH
  - IAH+NE

- Intramural PCO2, villi microvascular variable → unchanged

- No relationship between SMA flow and APP

In conclusion

- Intestinal flow remained unaffected by IAP 20mmg, even after increased in APP
**Renal perfusion**

- **Renal blood flow**
  - Decreased in the IAH
  - Not increased after achieve APP by NE (IAH+NE)

- **Significant correlation** between RAF and APP
  \[ R^2 = 0.25, \ P < 0.0001 \]
  - Correlation between RAF and urinary output

**In conclusion**
- Renal blood flow was linearly related to APP, however, not fully recovered after increased in APP
Effects of norepinephrine during intra-abdominal hypertension on renal blood flow in bacteremic dogs

Zhi Y. Peng, MD, PhD; Lester A. Critchley, MD, FFARCSI; Gavin M. Joynt, MBCh, FJFICM; Pascale C. Gruber, MBBS, FRCA; Caroline R. Jenkins, MBBS, FRCA; Anthony M-H. Ho, MD, FCCP

Dogs (N=10)

IAP 10 mmHg | NE APP restored
---|---
IAP 20 mmHg | NE APP restored
IAP 30 mmHg | NE APP restored

Control model (only IAP)

Bacteremia With E coli

IAP 10 mmHg | NE APP restored
---|---
IAP 20 mmHg | NE APP restored
IAP 30 mmHg | NE APP restored

Bacteremia model (IAP+sepsis)

Measurement: CO, Renal blood flow, Renal perfusion fraction
IAH model

Reversed the decreases in RBFI, but not to baseline values

⇒ minimal effect on RPF

| APP | 75  | 65→79 | 53→84 | 39→83 |
Bacteremia Model (IAH+Sepsis)

Use of norepinephrine targeted to restore APP should be considered, especially with distributive shock.

- Completely reversed RBFI back to baseline bacteremic levels.
- Increased the RPF to baseline or above the bacteremic baseline level.
Raising MBP to achieve APP

• In animal studies...

Renal blood flow was increased by achieving APP by vasopressor

Especially with distributive shock, Use of vasopressor to restore APP should be considered

→ Very limited animal study
Summary

To achieve APP...

IAP ➔ MBP

✓ should consider pathophysiologic mechanism
✓ specific medical procedures

Analgesia/sedation
Position
NMB
Percutaneous drainage

NG/rectal tube
Prokinetics
Negative fluid balance
CVVH

✓ Vasopressor

SMA flow & APP → No correlation
Renal blood flow & APP → significant correlation
→ Combined septic shock

➡️ Suggestion with low grade evidence

➡️ Only animal study, need human clinical study
Thank you for your attention