Time is an issue

Time is tissue

http://go.to/funpic
Abdominal Perfusion Pressure, the neglected mechanism

Manu LNG Malbrain, Antwerpen, Belgium
ZiekenhuisNetwerk Antwerpen - Campus Stuivenberg

7th TSIS Symposium, Munich, Germany, March 13-17, 2007
Manu Malbrain

ICU Director and manager ZNA STER
Founding President WSACS (www.wsacs.org)
Chairman WCACS 2007 (www.wcacs.org)
Educational Grant: 2003 ESICM Chris Stoutenbeek Award
Member Medical Advisory Board
  - Pulsion Medical Systems
  - KCI Benelux
  - Spiegelberg
  - Holtech Medical
  - Neutec
European Patent Holder CiMON (PMS)
Research Project: Draeger, Edwards Lifesciences
Fees - Honoraria: GSK, MSD
Vlerick Leuven Gent Management School

WE DON’T TEACH YOU ANYTHING
WE DEVELOP WHAT’S ALREADY INSIDE YOU

€3500
Just like Robbie Williams...

Let me entertain you!!!
ACS Recognition?

- Problematic Issue
- No consensus so far…
### Abdominal compartment syndrome: it’s time to pay attention!

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Respondents</th>
<th>Questionnaires</th>
<th>Response rate</th>
<th>Know ACS</th>
<th>Measure IAP diagnosis</th>
<th>threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirkpatrick</td>
<td>2006</td>
<td>Trauma physicians</td>
<td>102</td>
<td>86 (84%)</td>
<td>100%</td>
<td>Clinical (21%)</td>
<td>25 mmHg + OF</td>
</tr>
<tr>
<td>Nagappan</td>
<td>2006</td>
<td>ICU registrars</td>
<td>40</td>
<td>36 (90%)</td>
<td>92%</td>
<td>IBP (83%)</td>
<td>20 mmHg (63.9%)</td>
</tr>
<tr>
<td>Mayberry</td>
<td>1999</td>
<td>Trauma surgeons</td>
<td>292</td>
<td>292 (100%)</td>
<td>85%</td>
<td>Clinical + IBP (71%)</td>
<td>20 cmH2O (11%)</td>
</tr>
</tbody>
</table>

- ACS: Abdominal Compartment Syndrome
- IAP: Intra-abdominal Pressure
- IBP: Intra-arterial Pressure
- CT: Computed Tomography
Conclusions

- General lack of clinical awareness...
- Many ICUs never measure the IAP
- When it is measured, the intravesical route is used exclusively
- No consensus exists on optimal timing of measurement or when decompressive laparotomy should be performed
- Variation between surgeons, intensivists, ...

Results - awareness

> Still 14.4% of the respondents are not familiar with IAH or the effects of increased IAP on organ function

> and 1.1% of those familiar with IAH never heard about ACS

www.wsacs.org/survey.htm
Consensus Definitions
MISSION Statement

The mission of the WSACS is to foster education, promote research, and thereby improve the survival of patients with IAH and ACS by bringing together physicians, nurses, and others from throughout the world and from a variety of clinical disciplines.
Results from the International Conference of Experts on Intra-abdominal Hypertension and Abdominal Compartment Syndrome.

I. Definitions
Results from the International Conference of Experts on Intra-abdominal Hypertension and Abdominal Compartment Syndrome.

II. Recommendations
Gold Standard IAP measurement

<table>
<thead>
<tr>
<th>Definition 1</th>
<th>IAP is the steady-state pressure concealed within the abdominal cavity.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition 2</td>
<td>APP = MAP – IAP</td>
</tr>
<tr>
<td>Definition 3</td>
<td>FG = GFP – PTP = MAP – 2 * IAP</td>
</tr>
<tr>
<td>Definition 4</td>
<td>IAP should be expressed in mmHg and measured at end-expiration in the complete supine position after ensuring that abdominal muscle contractions are absent and with the transducer zeroed at the level of the mid-axillary line.</td>
</tr>
<tr>
<td>Definition 5</td>
<td>The reference standard for intermittent IAP measurement is via the bladder with a maximal instillation volume of 25 mL of sterile saline.</td>
</tr>
</tbody>
</table>
## Abdominal compartment syndrome (ACS)

| Definition 6 | Normal IAP is approximately 5-7 mmHg in critically ill adults. |
| Definition 7 | IAH is defined by a sustained or repeated pathologic elevation of IAP ≥ 12 mmHg. |
| Definition 8 | IAH is graded as follows:  
  • Grade I: IAP 12-15 mmHg  
  • Grade II: IAP 16-20 mmHg  
  • Grade III: IAP 21-25 mmHg  
  • Grade IV: IAP > 25 mmHg |
| Definition 9 | ACS is defined as a sustained IAP > 20 mmHg (with or without an APP < 60 mmHg) that is associated with new organ dysfunction / failure. |
It is time to pay attention!

IAP values

42. [*] At what level of IAP do you think organ dysfunction may occur in patients with intra-abdominal hypertension (IAH)?

- 5 mmHg: 0 (0.00%)
- 10 mmHg: 51 (2.77%)
- 12 mmHg: 115 (6.24%)
- 15 mmHg: 364 (19.75%)
- 20 mmHg: 587 (31.85%)
- 25 mmHg: 249 (13.51%)
- > 25 mmHg: 424 (23.01%)
- Other: 53 (2.88%)
Total Answers: 1843

26. [*] What is "normal" IAP?

- 0-5 mmHg: 672 (36.48%)
- 6-10 mmHg: 814 (44.10%)
- 11-15 mmHg: 248 (13.46%)
- > 16 mmHg: 41 (2.23%)
- Other: 67 (3.64%)
Total Answers: 1842

28. [*] What IAP level defines intra-abdominal hypertension (IAH)?

- 5 mmHg: 7 (0.38%)
- 10 mmHg: 111 (6.03%)
- 12 mmHg: 293 (15.91%)
- 15 mmHg: 474 (25.73%)
- 20 mmHg: 546 (29.64%)
- 25 mmHg: 91 (4.94%)
- > 25 mmHg: 283 (15.36%)
- Other: 37 (2.01%)
Total Answers: 1842

30. [*] What IAP level defines abdominal compartment syndrome (ACS)?

- 5 mmHg: 0 (0.00%)
- 10 mmHg: 10 (0.55%)
- 12 mmHg: 18 (0.99%)
- 15 mmHg: 62 (3.40%)
- 20 mmHg: 490 (26.89%)
- 25 mmHg: 222 (12.18%)
- > 25 mmHg: 850 (46.65%)
- Other: 170 (9.33%)
Total Answers: 1822
# Recurrent ACS

<table>
<thead>
<tr>
<th>Definition 10</th>
<th>Primary ACS is a condition associated with injury or disease in the abdomino-pelvic region that frequently requires early surgical or interventional radiological intervention.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition 11</td>
<td>Secondary ACS refers to conditions that do not originate from the abdomino-pelvic region.</td>
</tr>
<tr>
<td>Definition 12</td>
<td>Recurrent ACS refers to the condition in which ACS redevelops following previous surgical or medical treatment of primary or secondary ACS.</td>
</tr>
</tbody>
</table>
WHEN AND HOW TO MEASURE IAP AND APP?

- WHY?
- HOW?
- WHEN?
- SO ... WHAT?
- DO IT!
Abdominal Perfusion Pressure, the neglected mechanism

WHY?
WHY IAP, WHY APP?

- Did you ever see patients swollen up after massive fluid resuscitation?
- Did you ever see patients with distended abdomens and renal failure or in need for RRT?
- Did you ever see patients with MOF that died?

If So, did you know their IAP and APP???
Heinricius G. (Bern 1890) Wendt E. (1876)

“Ueber den einfluss der bauchfulling auf circulation und respiration”
Zeitschrift f Biol, 1890; 26:113-202
Archive fur Physiologische Heilkunde 1876; 57: 527-575
Landois (1899)

“Increase in IAP decreased BP and Pulse”

Lehrbuch der physiologie des Menschen, Berlin 1899, 1st Halfe p 218.
CRITICAL IAP

- Even small elevations in IAP can impact survival
- The critical IAP that mandates intervention has been revised downward
- The IAP that defines IAH / ACS varies from patient to patient and even within the same patient
- A single threshold value of IAP cannot be universally applied to all critically ill patients
- IAP is a specific, but non-sensitive predictor of illness and resuscitation adequacy
Question: Why do some patients tolerate high IAPs while others do not?
MAKING IAP BETTER

Question: Why do some patients tolerate high IAPs while others do not?

Answer: Their **perfusion pressure** remains adequate despite the elevated IAP.

A MAP of 85 with an IAP of 20 is different from a MAP of 65 with an IAP of 7! Namely APP = 65 versus 58!
PERFUSION PRESSURE

- The pressure difference across an organ or anatomic compartment
- Dependent upon three factors:
  1) Arterial inflow pressure
  2) Venous outflow pressure
  3) Compliance of the compartment

Perfusion pressure = \( \text{Pressure}_{\text{inflow}} - \text{Pressure}_{\text{outflow}} \)
CORONARY PERFUSION PRESSURE

- A primary goal in any resuscitation
- Calculated as the perfusion pressure (PP) across the coronary artery during maximal blood flow (diastole)
  - DBP = coronary artery inflow
  - PAOP = coronary artery outflow during diastole

Coronary PP = DBP - PAOP

- Goal: To maintain coronary PP above 50 mmHg
CEREBRAL PERFUSION PRESSURE

- An essential parameter in the head-injured patient with elevated ICP
- Maintenance of an adequate cerebral PP is associated with improved long-term outcome
- Calculated as the perfusion pressure across the brain
  - MAP = cerebral inflow
  - ICP = cerebral outflow

Cerebral PP = MAP - ICP

- Goal: To maintain cerebral PP above 70 mmHg
ABDOMINAL PERFUSION PRESSURE

- Calculated as the perfusion pressure across the abdomen
  - MAP = abdominal inflow
  - IAP = abdominal outflow

\[
\text{Abdominal PP or APP} = \text{MAP} - \text{IAP}
\]

- Goal: To maintain APP above 50-60 mmHg
## Analogy with the Head

<table>
<thead>
<tr>
<th></th>
<th>Head</th>
<th>Abdomen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contents</strong></td>
<td>Brain</td>
<td>Abdominal organs</td>
</tr>
<tr>
<td><strong>Fluid</strong></td>
<td>CSF</td>
<td>ascites</td>
</tr>
<tr>
<td><strong>Closed box</strong></td>
<td>Skull</td>
<td>Abdominal cage</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>ICP</td>
<td>IAP</td>
</tr>
<tr>
<td><strong>Perfusion</strong></td>
<td>CPP = MAP–ICP</td>
<td>APP = MAP–IAP</td>
</tr>
</tbody>
</table>
Effect of curarisation

Filtration gradient

Renal filtration gradient (FG)

- Key factors in development of IAP-induced renal failure

FG = GFP – Proximal tubular pressure (PTP)

- GFP = MAP - PTP
- Under sustained increased IAP, PTP = IAP
- Thus GFP = MAP - IAP

Thus, FG = GFP – IAP

= (MAP – IAP) – IAP
= MAP – 2*IAP
WHEN AND HOW TO MEASURE IAP/APP?

HOW?
Clinical Examination?
IAP Assessment
IAP Assessment
IAP Assessment
Clinical Estimation?

- 150 IAP measurements
- in 110 pts
  - Sensitivity: 60.9%
  - Specificity: 80.5%
  - PPV: 45.2%
  - NPV: 88.6%

Bland and Altman:
  - Mean bias: $-1 \pm 4.1$ mmHg

Clinical Idea ?
Clinical Idea?
Clinical Idea ?
Clinical Idea?
Clinical Idea?
Clinical Idea?
Abdominal Pressure Measurement
If you don’t take a temperature you can’t find a fever

S Shem in “The House of God”
If you want to make a diagnosis of IAH or ACS you need to measure IAP
Definitions of IAH or ACS stand or fall with the accuracy and reproducibility of the IAP measurement method used!
INTERMITTENT ABDOMINAL PRESSURE MEASUREMENT
Leaky and kinky!
Harrahill Technique

Foley Manometer Technique

Height of column of fluid from meniscus = bladder pressure (cm H2O) to pubic symphysis
Different techniques to measure intra-abdominal pressure (IAP): time for a critical re-appraisal

Manu L. N. G. Malbrain

DOI 10.1007/s00134-003-2107-2

Sugrue Technique

AbViser Technique
CONTINUOUS ABDOMINAL PRESSURE MEASUREMENT (CIAP)
CONTINUOUS ABDOMINAL PERFUSION PRESSURE MEASUREMENT (CAPP)
Rapid Oscillation Test: overdamping, underdamping. Oscillations better transmitted via bladder.

Rapid Oscillation test

Pulse artefacts

Hyperinflation: “overwedging”
Continuous Trend

Continuous IAP and APP trend in a patient on CAPD with Spiegelberg/CiMON Monitor: No recalibration necessary
Maybe it is the AUC above IAP of 12 that is important?
Maybe it is the time with IAP of 12 that is important?

Continuous IAP and APP trend in a patient on CAPD with Spiegelberg Monitor: No recalibration necessary
Compartmental intrathoracic-intraabdominal MONitoring

CiMON Technique
CiMON Animal Data

IAP during abdominal saline infusion

IAP [mmHg]

step

CiMON IAPs

IAPb

Spie IAPpg

CiMON IARpg
CiMON Animal Data

IAP with abdominal fluid infusion

CiMON IAPs
Spiegelberg IAPs
IAPb
IAPp
Continuous IAP trend

A Wilmer, J Wouters: Pig lab, University of Leuven, UZ Gasthuisberg, Leuven, Belgium
WHEN AND HOW TO MEASURE IAP/APP?

WHY?
ACS Publications

WHY? – Simply because others also do...
WHEN AND HOW TO MEASURE IAP/APP?
Prospective Study of 71 IAH-patients

<table>
<thead>
<tr>
<th>Etiologic Factors</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal Surgery</td>
<td>27</td>
<td>38</td>
</tr>
<tr>
<td>Pneumoperitoneum</td>
<td>1</td>
<td>1.4</td>
</tr>
<tr>
<td>Abdominal Infection</td>
<td>12</td>
<td>16.9</td>
</tr>
<tr>
<td>Pancreatitis</td>
<td>1</td>
<td>1.4</td>
</tr>
<tr>
<td>Bile Peritonitis</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Faecal Peritonitis</td>
<td>7</td>
<td>9.9</td>
</tr>
<tr>
<td>Massive Fluid Resuscitation</td>
<td>55</td>
<td>77.5</td>
</tr>
<tr>
<td>Hemoperitoneum</td>
<td>10</td>
<td>14.1</td>
</tr>
<tr>
<td>Hemoretroperitoneum</td>
<td>3</td>
<td>4.2</td>
</tr>
<tr>
<td>Hemoperitoneum</td>
<td>7</td>
<td>9.9</td>
</tr>
</tbody>
</table>

Sugrue (1996): surgery (100%); ileus and tissue edema (85%); ascites (7%); hemorrhage (7%)
Prospective Study of 71 IAH-patients

<table>
<thead>
<tr>
<th>Etiologic Factors</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ileus</td>
<td>41</td>
<td>57.8</td>
</tr>
<tr>
<td>Paralytic</td>
<td>32</td>
<td>45.1</td>
</tr>
<tr>
<td>Ogilvie syndrome</td>
<td>3</td>
<td>4.2</td>
</tr>
<tr>
<td>Volvulus</td>
<td>1</td>
<td>1.4</td>
</tr>
<tr>
<td>Colonic Obstruction</td>
<td>3</td>
<td>4.2</td>
</tr>
<tr>
<td>Gastric Dilatation</td>
<td>2</td>
<td>2.8</td>
</tr>
<tr>
<td>Ideopathic</td>
<td>8</td>
<td>11.3</td>
</tr>
<tr>
<td>With paralytic ileus</td>
<td>3</td>
<td>4.2</td>
</tr>
<tr>
<td>Without paralytic ileus</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>More then one (other then paralytic ileus)</td>
<td>37</td>
<td>52</td>
</tr>
</tbody>
</table>

Malbrain, 1999 Crit Care 3 (suppl 1): 20
## Prospective Study of 71 IAH-patients

### Predisposing Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidosis (pH&lt;7.2)</td>
<td>36</td>
<td>50.7</td>
</tr>
<tr>
<td>Hypothermia (core temp &lt; 34°)</td>
<td>4</td>
<td>5.6</td>
</tr>
<tr>
<td>Polytransfusion (&gt;5U PC/24h)</td>
<td>29</td>
<td>40.9</td>
</tr>
<tr>
<td>Coagulopathy</td>
<td>34</td>
<td>47.9</td>
</tr>
<tr>
<td>Septic Shock</td>
<td>47</td>
<td>66.2</td>
</tr>
<tr>
<td>Liver dysfunction</td>
<td>22</td>
<td>31</td>
</tr>
<tr>
<td>Decompensated Cirrhosis (Child C)</td>
<td>4</td>
<td>5.6</td>
</tr>
<tr>
<td>Other Liver failure with Ascites</td>
<td>18</td>
<td>25.4</td>
</tr>
<tr>
<td>Paraneoplastic</td>
<td>4</td>
<td>5.6</td>
</tr>
<tr>
<td>Cardiac Failure</td>
<td>7</td>
<td>9.9</td>
</tr>
<tr>
<td>Portal Vein Thrombosis</td>
<td>2</td>
<td>2.8</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>None</td>
<td>2</td>
<td>2.8</td>
</tr>
<tr>
<td>More then one</td>
<td>54</td>
<td>76.1</td>
</tr>
<tr>
<td><strong>Ideopathic without predisposing conditions</strong></td>
<td>1</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Deadly TRIAD leads to ACS

Malbrain, 1999 Crit Care 3 (suppl 1): 20
WHEN AND HOW TO MEASURE IAP/APP?

SO...

WHAT
Clinical data
An IAH pig model
Abdomino-thoracic transmission

Peso: 62%

CVP: 21%

Pplat: 52%
Renal dysfunction: mechanism

Renal flow

Renal venous pressure ≈ IAP

Renal perfusion pressure

- Diuresis ↓, creat ↑, GFR ↓
- Renal arterial/venous flow ↓
- Redistribution away from kidney
- RPP ↓ = MAP ↑ - RVP ↑↑
- Renal vascular resistance ↑

Wauters, 2006
Effect of norepinephrine on APP

↓ 10 bacteremic dogs
CLINICAL EVIDENCE

- **Retrospective** study
- **144 surgical patients** with IAH (IAP ≥ 15 mmHg)
- IAP and APP were calculated every 4 hrs
- Liberal abdominal decompression was performed for symptomatic IAH and ACS
- Multivariate logistic regression analysis was utilized to identify resuscitation endpoints significantly associated with survival

# PREDICTORS OF SURVIVAL IN IAH / ACS

<table>
<thead>
<tr>
<th></th>
<th>Survivors</th>
<th>Non-Survivors</th>
<th>Multiple Logistic Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest APP (mmHg)</td>
<td>52 ± 17</td>
<td>39 ± 18</td>
<td>0.002</td>
</tr>
<tr>
<td>Lowest MAP (mmHg)</td>
<td>74 ± 14</td>
<td>69 ± 14</td>
<td>0.05</td>
</tr>
<tr>
<td>Highest IAP (mmHg)</td>
<td>29 ± 12</td>
<td>38 ± 14</td>
<td>0.21</td>
</tr>
<tr>
<td>Highest arterial lactate (mmol/L)</td>
<td>5.4 ± 2.2</td>
<td>8.0 ± 3.7</td>
<td>0.38</td>
</tr>
<tr>
<td>Highest base deficit</td>
<td>9.0 ± 7.0</td>
<td>13.1 ± 6.9</td>
<td>0.44</td>
</tr>
<tr>
<td>Lowest arterial pH</td>
<td>7.24 ± 0.10</td>
<td>7.14 ± 0.13</td>
<td>0.66</td>
</tr>
<tr>
<td>Lowest urinary output (mL/hr)</td>
<td>47 ± 48</td>
<td>44 ± 68</td>
<td>0.85</td>
</tr>
</tbody>
</table>
# PREDICTORS OF SURVIVAL IN IAH / ACS

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Threshold</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 mmHg</td>
<td>0.53</td>
<td>0.70</td>
<td>15 mmHg</td>
<td>0.00</td>
<td>0.91</td>
</tr>
<tr>
<td>50 mmHg</td>
<td><strong>0.76</strong></td>
<td><strong>0.57</strong></td>
<td>20 mmHg</td>
<td>0.08</td>
<td>0.80</td>
</tr>
<tr>
<td>60 mmHg</td>
<td>0.92</td>
<td>0.29</td>
<td><strong>25 mmHg</strong></td>
<td><strong>0.19</strong></td>
<td><strong>0.63</strong></td>
</tr>
<tr>
<td>70 mmHg</td>
<td>0.99</td>
<td>0.17</td>
<td>30 mmHg</td>
<td>0.27</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35 mmHg</td>
<td>0.48</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>40 mmHg</td>
<td>0.60</td>
<td>0.11</td>
</tr>
</tbody>
</table>

ROC CURVES

SENSITIVITY vs. 1-SPECIFICITY

IAP = 15 mmHg
IAP = 20 mmHg
IAP = 25 mmHg
APP = 40 mmHg
APP = 50 mmHg
APP = 60 mmHg

APP
IAP
IAH / ACS IN THE GENERAL ICU

- **Prospective** 12 month evaluation of IAH in the ICU
- **405 mixed** medical / surgical ICU patients
- IAP and APP were routinely measured

<table>
<thead>
<tr>
<th>Metric</th>
<th>Survivors</th>
<th>Non-Survivors</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest APP (mmHg)</td>
<td>76 ± 23</td>
<td>61 ± 23</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lowest MAP (mmHg)</td>
<td>83 ± 22</td>
<td>72 ± 22</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Highest IAP (mmHg)</td>
<td>7 ± 4</td>
<td>11 ± 4</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
## IAH / ACS IN THE GENERAL ICU

<table>
<thead>
<tr>
<th></th>
<th>Threshold</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>ROC area</th>
</tr>
</thead>
<tbody>
<tr>
<td>APP</td>
<td>60 mmHg</td>
<td>55%</td>
<td>76%</td>
<td>0.69</td>
</tr>
<tr>
<td>MAP</td>
<td>70 mmHg</td>
<td>58%</td>
<td>64%</td>
<td>0.64</td>
</tr>
<tr>
<td>IAP</td>
<td>9 mmHg</td>
<td>65%</td>
<td>72%</td>
<td>0.76</td>
</tr>
</tbody>
</table>
Incidence and prognosis of intraabdominal hypertension in a mixed population of critically ill patients: A multicentre epidemiological study

Manu L. N. G. Malbrain, MD; Davide Chiumello, MD; Paolo Pelosi, MD, PhD; David Bihari, MD; Richard Innes, MD; V. Marco Ranieri, MD, PhD; Monica Del Turco, MD; Alexander Wilmer, MD, PhD; Nicola Brienza, MD; Vincenzo Malcangi, MD; Jonathan Cohen, MD; Andre Japiassu, MD; Bart L. De Keulenaer, MD; Ronny Daelemans, MD; Luc Jacquet, MD, PhD; Pierre-François Laterre, MD, PhD; Günther Frank, MD; Paulo de Souza, MD; Bruno Cesana, MD; Luciano Gattinoni, MD, PhD

**Cut-off = 12 mmHg** 55%

**Cut-off = 15 mmHg** 35%

Cut-off = 12 mmHg

Cut-off = 15 mmHg

CIAH STUDY

Critically Ill and Abdominal Hypertension Study

> Prospective, multi-center screening trial
> 265 mixed ICU patients (145 with IAH)
> IAH (IAP ≥ 12 mmHg) screening twice daily

<table>
<thead>
<tr>
<th></th>
<th>Survivors</th>
<th>Non-Survivors</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest APP (mmHg)</td>
<td>65 ± 23</td>
<td>52 ± 14</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Highest IAP (mmHg)</td>
<td>17 ± 5</td>
<td>17 ± 4</td>
<td>ns</td>
</tr>
</tbody>
</table>

Malbrain et al. CCM 2005
## CIAH STUDY

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>ROC area</th>
</tr>
</thead>
<tbody>
<tr>
<td>APP 60 mmHg</td>
<td>79%</td>
<td>62%</td>
<td>0.73</td>
</tr>
<tr>
<td>MAP 70 mmHg</td>
<td>69%</td>
<td>61%</td>
<td>0.71</td>
</tr>
<tr>
<td>IAP 12 mmHg</td>
<td>75%</td>
<td>59%</td>
<td>0.68</td>
</tr>
</tbody>
</table>
**ROC-curves: APP**

- **Sensitivity** = 72.2%
- **Specificity** = 72.7%
- **AUROC**
  - > 0.777
  - > (.709 -.844).

![ROC curve](image)

Critically Ill Renal Failure and Abdominal Hypertension Study

- **Prospective, multicenter**, epidemiological study of acute renal failure
- **60 mixed** medical / surgical ICU patients
- IAP / APP evaluated as predictors of outcome
- The presence of IAH and a low APP by day 3 was able to discriminate between survivors and nonsurvivors
CIRFAH STUDY
Evolution of IAP and APP

- IAP lower in NS on day 1
- APP lower in NS from day 2

Respiratory failure

N = 258
Evolution SOFA score

SOFA higher in NS from day 1
Evolution Fluid Balance

Fluid balance higher on day 1

Cumulative balance higher from day 2

Daily balance

Cumulative balance
Keep them Filled

Get them Killed!
When do I STOP?
WARNING: Normally there should now play a video with an exploding dog (not my mother-in-law’s) however Marco Ranieri (president ESICM) has forbidden further distribution of this video because of animal rights considerations...
Fatal Capillary Leak Syndrome

Non-survivors
Survivors
Negative Fluid balance by day 3 carries good prognosis
### SOAP Investigators
#### Independent Outcome Predictors

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Mean, S.E.</th>
<th>Odds ratio (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancer</td>
<td>1.473</td>
<td>0.521</td>
<td>4.4 (1.6-12.1)</td>
<td>0.005</td>
</tr>
<tr>
<td>High tidal volume</td>
<td>0.842</td>
<td>0.332</td>
<td>2.3 (1.2-4.4)</td>
<td>0.011</td>
</tr>
<tr>
<td>Mean SOFA score</td>
<td>0.353</td>
<td>0.052</td>
<td>1.4 (1.3-1.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean fluid balance</td>
<td>0.382</td>
<td>0.128</td>
<td>1.5 (1.1-1.9)</td>
<td>0.003</td>
</tr>
<tr>
<td>Constant</td>
<td>-2.663</td>
<td>0.433</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
Strong Correlation Between: 

Dry Lungs are happy lungs

Fluid Balance
IAH
SOFA score

Keep ‘em dry, watch ‘em die
Not Convinced Yet?

Wait

Fluid Balance
IAH
SOFA score

And See
Worst Case Scenario
CT ABDOMEN

- Man
- 54 yrs
- AML-M4
- RI: ARA-c
- diarrhea

MAP = 55
IAP = 26
HR = 130
APP = 29
pO2/FiO2 = 158
UO = 10mL
Lactate = 5
CVP = 20
Free Air

Ascites
Caecum dilatation (16 cm)
Infiltration meso
Thickened colon wall (4-6 cm)
Free air caecum

SHOCK!

Man
54 yrs
AML-M4
RI: ARA-c
diarrhea

MAP = 55
IAP = 26
HR = 130
APP = 29
pO2/FiO2 = 158
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Free Air

Ascites
Caecum dilatation (16 cm)
Infiltration meso
Thickened colon wall (4-6 cm)
Free air caecum

SHOCK!
CHEST X-RAY

High ITP

Baby lungs

IAP

IAP
Relation IAP vs oxygenation

\[ y = -16.947x + 540.07 \]
\[ R^2 = 0.4017 \]
Definitions

- **Pulmonary ARDS**
  - Primary ARDS
  - Medical ARDS

- **Abdominal ACS**
  - Primary ACS
  - Surgical ACS

- **Extra-pulmonary ARDS**
  - Secondary ARDS
  - Surgical ARDS

- **Extra-abdominal ACS**
  - Secondary ACS
  - Medical ACS

High PEEP
Total weight of the colon = 8.4 Kg!
Casus: Colitis
Next Step ?
## Hemodynamic Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI (L/min/m²)</td>
<td>3.4</td>
<td>3.6</td>
<td>4.2</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>134</td>
<td>110</td>
<td>102</td>
</tr>
<tr>
<td>CVP (mmHg)</td>
<td>18</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>GEDVI (mL/m²)</td>
<td>560</td>
<td>634</td>
<td>731</td>
</tr>
<tr>
<td>ITBVI (mL/m²)</td>
<td>700</td>
<td>792</td>
<td>914</td>
</tr>
<tr>
<td>GEF (%)</td>
<td>18</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>SVV (%)</td>
<td>26</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>PVPI</td>
<td>1.5</td>
<td>1.6</td>
<td>2.2</td>
</tr>
<tr>
<td>EVLWI</td>
<td>14</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>PEEP (cm H₂O)</td>
<td>15</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Paw (cm H₂O)</td>
<td>35</td>
<td>30</td>
<td>26</td>
</tr>
<tr>
<td>PaO₂/FiO₂ (ratio)</td>
<td>76</td>
<td>105</td>
<td>168</td>
</tr>
<tr>
<td>IAP</td>
<td>21</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>UOP (mL/hr)</td>
<td>12</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
<td>6.1</td>
<td>4.7</td>
<td>3.2</td>
</tr>
</tbody>
</table>

### Hemodynamic Parameters Guidelines

- **GEDVI**: 600 – 850 mL/m²
- **ITBVI**: 850 – 1100 mL/m²
- **EVLWI**: 3 – 7
- **PVPI**: 1-3
- **SVV and PPV**: <10%
Evolution of baro- and volo-indicators
Casus: Colitis

LaPO: CO = 9.8
Vigileo: CO = 12.7
PiCCCO: CO = 11.1
What did we do?

- Nasogastric tube - gastroprokinetics
- Rectal tube - colonoprokinetics
- Sedation and paralysis
- Optimisation fluid balance
  > albumin – furosemide
  > dialysis – UF
- Body Positioning
- Surgical decompression – TAC
  > Continuous abdominal suction VAC
- Optimisation APP (APP = MAP – IAP)
WHEN AND HOW TO MEASURE IAP/APP?

DO IT!
WSACS Guidelines

Patient meets ONE of the following criteria and has at least ONE risk factor for IAH:
1. New intensive care unit admission
2. Evidence of clinical deterioration

Measure patient’s IAP to establish baseline pressure

IAP measurements should be:
1. Expressed in mmHg (1 mmHg = 1.36 cm H₂O)
2. Measured at end-expiration
3. Performed in the supine position
4. Zerod at the level of the mid-axillary line
5. Performed with an instillation volume of no greater than 25 mL of saline (for bladder technique)
6. Measured 30-60 seconds after instillation to allow bladder detrusor muscle relaxation (for bladder technique)

Measuring = knowing

Risk Factors for IAH / ACS
- Acidosis (pH < 7.2)
- Hypothermia (core temperature < 33°C)
- Polytransfusion (>10 units of blood / 24 hours)
- Coagulopathy (platelets < 55000 / mm³ OR activated partial thromboplastin time (APTT) > 2 times normal OR prothrombin time (PTT) < 50% OR international standardised ratio (INR) > 1.5)
- Sepsis (American - European Consensus Conference definitions)
- Bacteraemia / intra-abdominal infection
- Liver dysfunction with ascites
- Mechanical ventilation
- Use of positive end expiratory pressure (PEEP) or the presence of auto-PEEP
- Pneumonia
- Abdominal surgery
- Massive fluid resuscitation (> 5 liters of colloid or crystalloid / 24 hours)
- Gastroparesis / gastric distention / Ileus
- Haemoperitoneum / Pneumoperitoneum
- Major burns
- Major trauma
- High body mass index (> 30 kg/m²)
- Intra-abdominal or retroperitoneal tumours
- Prone positioning
- Massive incisional hernia repair
- Pancreatitis
- Distended abdomen
- Damage control laparotomy
WSACS algorithms

**INTRA-ABDOMINAL HYPERTENSION (IAH) ASSESSMENT ALGORITHM**

Patient meets ONE of the following criteria and has at least TWO risk factors for IAH:
1. New intensive care unit admission
2. Evidence of clinical deterioration or new organ failure

Measure patient's IAP to establish baseline pressure

Risk Factors for IAH Acute
- Abdominal wall compliance
- Altered respiratory pattern, especially with increased intra-abdominal pressure
- Abdominal surgery with primary fascial 80mmHg
- Major trauma / burns
- Proximal positioning

Increased intrathoracic contents
- Cardiopulmonary
- Thoracic
- Obesity

Increased abdominal contents
- Herniation / postoperative ileus
- Ascites / fluid accumulation

Qp/Qs > 0.8
- Arterial pH < 7.3
- Hypotension
- Hypothermia (core temperature < 33°C)
- Polyuria (>10 units of urinary 24 hours)
- C-reactive protein > 1500 ng/mL OR arterial partial pressures in brain 

IAP > 12 mmHg
- Monitor IAP
- Notify patient's doctor of abnormality
- Proceed to IAH / ACS management algorithm

**ICA Grade**
- Grade I: IAP 13-15 mmHg
- Grade II: IAP 16-20 mmHg
- Grade III: IAP 21-25 mmHg
- Grade IV: IAP > 25 mmHg

Check patient and IAP if patient deteriorates progressively

**MANAGEMENT ALGORITHM**

Perform major IAP measurements in context of warm patient's stability

Invasive monitoring
- Systolic pressure
- CVP
- ABP

Perform IAP
- Surgical operation
- Peritoneal drain
- Intermittent IAP

Invasive monitoring
- Systolic pressure
- CVP
- ABP

Post-Decompress IAP
- Surgical access
- Peritoneal drain
- IAP

Consult abdominal vascular surgeon if 12 hours of IAP

**INTRA-ABDOMINAL HYPERTENSION (IAH) / ABDOMINAL COMPARTMENT SYNDROME (ACS) MANAGEMENT ALGORITHM**

**Start with IAP**

**IAP > 12 mmHg**

- Assess IAP
- Reassess patient
- Continue treatment options to reduce IAP

**IAP < 12 mmHg**

- Perform major IAP measurements in context of warm patient's stability

**Abdominal Compartment Syndrome (ACS)**

- Abdominal peritoneal pressure plateau

**Free Download!!!**

www.wsacs.org

It is time to pay attention!
Pathophysiology

**Central Nervous System**
- Intracranial pressure ↑
- Cerebral perfusion pressure ↓
- Idiopathic intracranial hypertension (obesity)

**Cardiovascular System**
- Difficult preload assessment
- Wedge pressure ↑
- Central venous pressure ↑
- Intracranial pressure
- Cerebral perfusion pressure

**Respiratory System**
- Intrathoracic pressure ↑
- Pleural pressure ↑
- Functional residual capacity ↓
- PaO2/FiO2 ↓
- Dead-space ventilation ↑
- Intrapulmonary shunt ↑
- Lower inflection point
- Upper inflection point
- Prolonged ventilation
- Difficult weaning

**Gastro-Intestinal System**
- Celiac blood flow ↓
- Superior mesenteric artery blood flow ↓
- Blood flow to intra-abdominal organs ↓
- Mucosal blood flow ↓
- Mesenteric vein compression ↑
- Intramucosal pH ↓
- Regional CO2 ↑
- CO2-gap ↑
- Success enteral feeding ↓
- Intestinal permeability ↑
- Bacterial translocation ↑
- Multiple organ failure ↑
- Gastro-intestinal (re)bleeding ↑
- Tubular dysfunction ↑
- Glomerular filtration rate ↓
- Renal vascular resistance ↑
- Renal vein compression ↑
- Compression ureters ↑
- Anti-diuretic hormone ↑
- Adrenal blood flow =

**Hepatic System**
- Hepatic arterial flow ↓
- Portal venous blood flow ↓
- Portocollateral flow ↑
- Lactate clearance ↓
- Glucose metabolism ↓
- Mitochondrial function ↓
- Cytochrome p450 function ↓
- Hepatic arterial flow
- Portal venous blood flow
- Portocollateral flow
- Lactate clearance
- Glucose metabolism
- Mitochondrial function
- Cytochrome p450 function

**Abdominal Wall**
- Compliance ↓
- Rectus sheath blood flow ↓
- Wound complications ↑
- Incisional hernia ↑
- Compliance
- Rectus sheath blood flow
- Wound complications
- Incisional hernia


It is REAL!
It is time to pay attention to IAP/APP!


YES, It is !!!
Who will measure IAP/APP in the future?

100%
Please do the Survey

www.wsacs.org/survey.htm
Have you ever seen a society that in 2 years after it’s foundation has...
CTWG – WSACS Studies

WSACS Website – 1.000.000 hits since 2005

WORLD SOCIETY OF THE
ABDOMINAL COMPARTMENT SYNDROME

Clinical Trials / Research

The Clinical Trials Group of the World Society on Abdominal Compartment Syndrome (WSACS) solicits high quality clinical trials aimed at addressing pertinent issues in the treatment and management of intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS).

WSACS members may submit or sponsor appropriate clinical trials for posting on this page. For those interested in participating in the various trials listed, please contact the Primary Investigator listed for each trial. For those interested in posting clinical trials on this page, please email the study protocol to the WSACS webmaster.

<table>
<thead>
<tr>
<th>Trial Number</th>
<th>001</th>
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<tbody>
<tr>
<td>Date Submitted</td>
<td>16/6/06</td>
</tr>
<tr>
<td>Title</td>
<td>The Effect of Body Positioning on Intra-Abdominal Pressure Measurement: A Multicenter Analysis</td>
</tr>
<tr>
<td>Primary Investigator</td>
<td>Michael L. Cheatham MD, Jan J. DeWaele MD</td>
</tr>
<tr>
<td>Contact Email</td>
<td><a href="mailto:michael.cheatham@orhs.org">michael.cheatham@orhs.org</a></td>
</tr>
</tbody>
</table>

ECCRN
Take Home Message

- Abdominal hypertension exists!
- Always measure IAP!
- IAH is a cause of multiple organ failure
- Resuscitate towards APP and use Volumes (PiCCO-GEDVi) instead of CVP!
  > $\text{CVP}^{\text{TM}} = \text{CVPee} - \text{IAP}/2$
- Change your ventilation strategy!
  > Best PEEP = IAP
  > $\text{Pplat}^{\text{TM}} = \text{Pplat} - \text{IAP}/2$
- High morbidity and mortality
- Can be treated!

www.wsacs.org/survey.htm
It is time to pay attention