Physiology of the Pneumoperitoneum

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Resident Rounds 18/08/06
Case:

• 34 y.o. female undergoing elective laparoscopic cholecystectomy
• PMH: nil, obese
• Medx: nil
• Allg: nil
Case:

- Intra-op:
  - 17 mm Hg pneumoperitoneum
  - Reverse Trendellenberg
  - Dissection of GB
  - Bleeding from liver bed noted
  - Sudden ↓ sBP to 70/40 mm Hg, HR 120
  - Sats 68 %, ↓ ET CO₂
  - What next?

.....
Case:

• Abdomen desufflated
• BP still 60 / 40
• ? “Millwheel” Murmur heard
• ??
Outline:

• Background

• Physiologic effects
  – Cardiovascular
  – Pulmonary
  – Gastrointestinal
  – Renal
  – Peripheral vascular
Background:

• “Pneumoperitoneum”:
  – Gas in the peritoneal cavity
  – Induced in laparoscopic surgery to elevate abdominal wall
  – Gases used: CO$_2$, N$_2$O, He
Background:

- 1901 – 1\textsuperscript{st} laparoscopic pneumoperitoneum established (George Kelling)
Background:

- 1901 – 1st laparoscopic pneumoperitoneum established (George Kelling)
- 1900-1970 mainly diagnostic use
- 1970s – 1st therapeutic applications in gynecology
- 1990s – 1st application in cholecystectomy
- 2000s
  - bowel resection, nephrectomy, splenectomy, gastrectomy, hernia repair, etc, etc…
Physiologic Effects:

- Cardiovascular
- Pulmonary
- Renal
- Gastrointestinal
- Peripheral vascular
Physiologic Effects:

- Mechanical Effects
- AND
- Metabolic Effects
Cardiovascular Effects:

↑ IAP → ↑ CVP → ↓ VR → ↓ Preload → ↓ SV → ↓ CO

↑ PCWP → ↓ LVEDV

↑ SVR → ↑ MAP

↓ CO × ↓ HR → ↓ SV

Peritoneal Stretch

Vasovagal response
Cardiovascular Effects:

- ↑ IAP
- ↑ CVP
  - ↓ VR
  - ↓ LVEDV
- ↑ PCWP
- ↑ SVR
- ↑ MAP
- ↑ Afterload
- ↓ SV
  - x HR
  - = ↓ CO
- ↑ CO₂
- ↑ Vasopressin & Catecholamines
Cardiovascular Effects:

- ↑ IAP
- ↑ CVP
- ↑ PCWP
- ↑ MAP
- ↑ SVR
- ↓ VR
- ↓ MC
- ↑ CO₂
- ↓ CO₂
- ↓ SV
- x HR
- = ↓ CO

Afterload ↑ → MAP ↑ → SVR ↑ → CO₂ ↑

Vasopressin & Catecholamines ↑ → MC ↓ → SV ↓ → CO ↓
Cardiovascular Effects:

• Cardiac Output
  – Variation between studies
  – < 30% decrease when observed
  – On insufflation; $\infty \uparrow$ in I.A.P; transient
    • generally noted in:
      – ASA Class III/IV
      – hypovolemic patients
      – PP > 15 mm Hg
      – reverse Trendellenberg position
Respiratory Effects:

- ↑ IAP
  - ↓ FRC
  - ↑ Ve & work of breathing
  - ↑ RR
  - ↑ PARP
  - ↓ chest wall compliance
  - ↓ TV
  - ↑ ITP
  - ↑ cephalad shift diaphragm
  - paradoxic diaphragm motion
  - ↑ CO₂
  - Hypercapnia
  - ↑ Ve & work of breathing
  - ↑ RR

↑ ITP
↓ chest wall compliance
↓ TV
↑ Ve & work of breathing
↑ RR
Respiratory Effects:

- ↑ respiratory acidosis, $V_e$ req’ts in ASA III / IV patients
  - Pre-op FEV < 70 % predictive
- ↓ FRC, TV more marked in obese / compromised patients
- Post-op FEV, FVC, FRC lower with PP
- No long term change in PaCO$_2$
Respiratory Complications:

- Pneumothorax / Pneumomediastinum / Pneumopericardium
  - 2° to diffusion of gas from pneumoperitoneum
    - Accidental diaphragm injury / pre-existing diaphragmatic defect
  - 2° to rupture of blebs with ↑ PAWP

- Gas Embolism
  - 2° to vascular injury
    - trocar / needle insertion on insufflation / intra-op vessel injury
Back to Case:

- Peritoneum desufflated
- “Millwheel” Murmur heard
- Durant position
  - Steep Trendellenberg, Left Lateral Decubitus
- 100% $O_2$, hyperventilation to excrete $CO_2$
- Insertion of CVL $\rightarrow$ aspirate air bubbles
Gastrointestinal effects:

- ↑ I.A.P.
  - ↓ Mesenteric & celiac flow
    - ↓ perfusion intestines & stomach
      - ↓ intestinal & gastric pH
  - ↓ Portal flow
  - ↓ hepatic artery flow
    - ↓ hepatic perfusion
      - ↑ LFTs
Renal Effects:

↑ CO₂

↑ I.A.P.

↓ GFR

↓ U/O

↓ ERPF

RAAS
Renal Effects:

- U/O return to baseline within hours
- No long-term change in GFR
- No change in Cr, BUN
Peripheral Vascular Effects:

\[ \uparrow \text{I.A.P.} \]

\[ \downarrow \]

\[ \downarrow \text{VR} \]

\[ \rightarrow \text{Venous stasis} \]

\[ \rightarrow \text{Reverse Trendellenberg} \]

\[ \uparrow \text{Risk DVT?} \]
Peripheral Vascular Effects:

• Incidence of DVT, PE generally lower post laparoscopic procedures
  – Secondary to improved prophylaxis?
  – Risk increased with longer procedures and reverse Trendellenberg
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• Cardiovascular:
  – ASA I/II
    • Hemodynamic effects of 12 - 14 mmHg capnoperitoneum rarely clinically relevant (grade A)
  – ASA III/IV
    • Invasive BP/ volume measurement should be considered (grade A)
    • Adequate pre-op volume loading +/- B-blockers recommended (grade A)

*EAES International Congress 2002
E.A.E.S. Clinical Practice Guidelines on Pneumoperitoneum for Laparoscopic Surgery

• Cardiovascular:
  – ASA III/IV
    • Gasless or low-pressure laparoscopy may be alternative for patients with limited cardiac function (grade B)
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- **Respiratory:**
  - CO$_2$ pneumoperitoneum causes hypercapnia and respiratory acidosis
  - ETCO$_2$ monitoring is mandatory and $V_e$ should be increased to maintain normocapnia (grade A)
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• Respiratory:
  – In patients with normal lung function, effects not relevant (grade A)
  – In patients with limited pulmonary reserves:
    • Laparoscopic surgery preserves post-op pulmonary function better than open surgery (grade A)
      BUT:
    • Intra- and post-op ABG monitoring recommended (grade A)
    • ↓ IAP and controlling hyperventilation reduce respiratory acidosis (grade A)
    • Gasless laparoscopy, low-pressure PP may be alternatives (grade B)
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• G.I:
  – ASA I-II:
    • changes in liver perfusion (grade A) and splanchnic perfusion (grade D) 2° IAP of 12-14 mmHg have no clinically relevant effects on organ function
  – Patients with impaired hepatic function:
    • IAP should be as low as possible to reduce microcirculatory disturbances (grade B)
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• Renal:
  – ASA I-II:
    • Changes in kidney perfusion 2° IAP of 12-14 mmHg have no clinically relevant effects on organ function
  – Patients with impaired renal function:
    • Adequate volume loading before and during elevated IAP (grade A)
    • IAP should be as low as possible to reduce microcirculatory disturbances (grade B)
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• Peripheral Vascular:
  – Head-up position and elevated intra-abdominal pressure independently ↓VR from lower extremities (grade A)
  – Thromboprophylaxis mandatory
  – Sequential intermittent pneumatic compression of lower extremities reduces venous stasis and is recommended for all prolonged laparoscopic procedures (grade A/B)
References: