Compartment Syndromes

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Disclosures: None
Learning Objectives

- Describe the pathophysiology of compartment syndrome
- List the common causes
- Apply methods of assessment to reach a diagnosis
- Describe the treatment of compartment syndrome
Introduction: Abdominal Compartment Syndrome

- Definitions
- History
- Classification
- Pathogenesis
- Measurement
- Pathophysiology
- (ACS in AAA patients)
- Clinical management
Compartment Syndrome

- "a condition in which increased tissue pressure in a confined anatomic space, causes decreased blood flow leading to ischaemia and dysfunction"

- "may lead to permanent impairment of function"
Compartment Syndrome - What is it & what happens?

- Blood flow requires a pressure gradient
Blood flow / Perfusion

Arterial pressure (MAP) HIGH

Pressure gradient

FLOW

Venous capillary pressure LOW
Blood flow / Perfusion

Arterial pressure (MAP) HIGH

Pressure gradient
Flow

Venous capillary pressure INCREASED
Blood flow / Perfusion

Arterial pressure (MAP) HIGH

Venous capillary pressure HIGH

No Flow = No perfusion = ISCHEMIA
Intra-abdominal pressure & hypertension

“Normal” in critically ill: IAP = 5 – 7 mmHg

Consensus definitions:

IAH:
Sustained or repeated pathologic elevation in IAP \( \geq 12 \text{mmHg} \)

ACS:
Sustained IAP\(>20 \text{mmHg with new onset end-organ dysfunction}\)
Abdominal Compartment Syndrome

Definition

Abdominal pressure $>20$mmHg with new organ dysfunction

- Clinical syndrome of increased IAP, increased airway pressure, hypoxia & oliguria
Abdominal Perfusion Pressure

- Same concept as cerebral perf. press.
- APP = MAP – IAP
- APP is possibly a better resus. end point than pH, base deficit, lactate & even UO.
- APP ≥ 60mmHg improves survival from IAH & ACS
1890: ↑IAP → death due to ↓ respiratory function

1911: ↑IAP → ↓VR → cardiac failure

1947: ↑IAP → ↓ UO due to ↓ GFR

1940: Ogilvie advised against abdo closure under tension, advocating impregnated canvas.
1984: Kron coins the term ACS following observation of AAA patients

Early ↑IAP → renal impairment independent of BP or CO

Described use of urinary catheter as a method of measuring IAP
Increasingly recognized cause of:

- Decreased C.O.
- Decreased U.O.
- Increased airway pressure
- Metabolic acidosis
Frequency of ACS

- Trauma: 0.5 – 36%
- Burns: 1 – 20%
- Surgery: 4 – 8%
- Pancreatitis: 36%
- Mortality: 25 – 75%
Classification & Pathogenesis
ACS

Chronic
Ascites
Obesity

Acute
Secondary
(extra - abdominal)
Extrinsic pressure
– tight closure
Burns
Shock suits
Sepsis
Capillary leak

Primary
Intraperitoneal
- Common
Trauma
Post op bleeding
Bowel Obstruction
Peritonitis
Visceral oedema
Large incisional
hernia closure
AAA

Retroperitoneal
-less common
Pancreatitis
Trauma
Pelvic bleeding
Sepsis
AAA

Multifactorial
Ischaemia-reperfusion injury
Fluid resus & ECF volume
Capillary leak
Oxygen free radicals

Recurrent
ACS redevelops after management of primary or secondary ACS
Risk Factors for ACS

1. Reduced Abdo wall compliance
2. Increased intra-luminal contents
3. Abdominal collections
4. Cap. leak & Fluid resus
   Many ICU patients
1. Reduced Abdo wall compliance

Obesity
Abdominal surgery
Prone positioning
Rectus sheath hematoma
Burns with abdominal eschars
Mechanical ventilation with high positive end-expiratory pressure
Ventilator dyssynchrony
2. Increased intra-luminal contents

Gastric distention
Gastroparesis
Colonic pseudo-obstruction
Volvulus
Abdominal tumor
Intra-abdominal or retroperitoneal tumor
Damage control laparotomy
Enteral feeding
2. Increased intra-luminal contents

Gastric distention
Gastroparesis
Colonic pseudo-obstruction
Volvulus
Abdominal tumor
Intra-abdominal or retroperitoneal tumor
Damage control laparotomy
Enteral feeding
3. Intra-abdominal collections

Ascites
Hemoperitoneum
Pneumoperitoneum
Major trauma
Laparoscopy with excessive inflation pressures
Peritoneal dialysis
Abdominal inflammation-peritonitis, pancreatitis
Abdominal abscess
3. Intra-abdominal collections

- Ascites
- Hemoperitoneum
- Pneumoperitoneum
- Major trauma
- Laparoscopy with excessive inflation pressures
- Peritoneal dialysis
- Abdominal inflammation-peritonitis, pancreatitis
- Abdominal abscess
4. Capillary leak & fluid resuscitation

- Acidosis
- Hypothermia
- Coagulopathy
- Massive transfusion
- Trauma
- Sepsis
- Large volume fluid resuscitation
- Major burns
4. Capillary leak & fluid resuscitation

Acidosis
Hypothermia
Coagulopathy
Massive transfusion
Trauma
Sepsis
Large volume fluid resuscitation
Major burns
Measurement of IAP

Direct
- Catheter placed at laparotomy/laparoscopy
- Highly accurate
- Potential for infection
- Not all patients need one at time of surgery

Indirect
- **Intra-vesical**
- Intra-gastric
- Rectal catheter
- Femoral vein catheter
- Less invasive
- Less infection risk
- Can be placed at any time post op
Intravesical Catheter

- Bladder is a passive diaphragm when volume is 25ml
- Standard urinary catheter
- Empty bladder filled with 25ml saline
- Catheter clamped
- Needle connected to pressure transducer inserted into aspiration port
- Accurate to within 3mmHg (range 5 to 50mmHg)
- Dedicated catheter kit now in use in ITU
Standards

- mmHg (1 mmHg = 1.36 mmH₂O)
- End expiration
- Supine
- Zeroed at MAL
-Measured 30 – 60 secs after instillation
Equipment to measure Intra-abdominal (bladder) pressure:

- Sterile saline on infusion set tubing
- 30 mL instillation syringe
- Disposable pressure transducer
- Cable to bedside monitor
- Stopcocks
- Pressure tubing
- Foley catheter
- Urine sampling port (Luer lock)
- Clamp here when measuring pressure
- Urine drainage tubing & collection bag
Pathophysiology of ↑ IAP

- CVS
- Renal
- Respiratory
- GI
- (CNS)
Cardiovascular System

- ↓CO due to ↓pre- & ↑after-load
- Mainly ↓venous return due to increased resistance in IVC / portal circulation
- ↑IAP transmitted to thorax → ↑ITP = ↑CVP → ↑resistance in SVC and cardiac tamponade
- Caused by pressures as low as 15mmHg
- Exacerbated by hypovolaemia
- ↓Cellular O₂ delivery, anaerobic metabolism, ischaemia, endothelial damage and capillary leakage.
Renal System

- Multifactorial – pre-renal & renal
- Pre-renal - ↓CO → ↓renal perfusion
- Renal:
  - Oliguria at 15mmHg, anuria >30mmHg

- Compression of RV
- ↑ Renal vasc resistance
- ↓ Renal perfusion

- ↑ IAP

- ↓ GFR
- ↑ Renin
- ↑ Aldosterone
- ↑ ADH
Respiratory System

- ↑IAP → ↓intra-thoracic volume → ↓lung capacity & compliance → resp. failure

- ↑Peak airway pressure → Alveolar volutrauma

- Compliance → V/Q mismatch

- Also ↑Pulm. Vasc. Resistance

- Effects at pressures as low as 15mmHg
GI System

- ↑IAP ➔ ↓blood flow in mesenteric & hepatic arteries

- ↓blood flow to intestinal mucosa

- Bowel tissue oxygenation drops at 15mmHg

- Effects potentiated by hypovolaemia

- Organ ischaemia & bacterial translocation
CNS

- ↑IAP → ↓Lumbar venous plexus & Central venous drainage

- ↑PaCO₂ → ↑cerebral arterial inflow

- Altered CNS function
Summary of effects

Overall

- IAP > 20mmHg can have profound effects on all the above systems

- Up to 93% improvement in organ function following decompression
ACS in AAA Patients

- All ACS studies small
- Majority in trauma patients
- Few & small studies in AAA surgery
- Mostly retrospective
- More common in RAAA
  - Multi-organ failure common cause of death - ? Due to ACS
Studies to date:

- Fietsam: 4% incidence of ACS in RAAA
  American Surgeon 1989 (55).

- IAP >18mmHg significant risk factor for renal impairment
  ANZ J Surgery 1990 (60).

- Rasmussen: improved survival with early mesh closure in at risk patients
Prospective Study

- Papavassiliou et al. Eur J Vasc Endovasc Surg 2003

- IAP significantly higher at closure of RAAA than elective AAA

- At risk of ACS if IAP > 15mmHg
Management of ACS - Prevention

- Recognition of at risk patients:
  - Hb < 100g/l
  - Pre-op arrest
  - SBP < 90mmHg for > 18min
  - > 3.5l fluid resus per hour of surgery
  - T < 33°C
  - Base deficit > 13

- Benefit from open abdomen strategy?
Diagnosis / Work up

- Measure IAP
- U&Es, FBC, Coag, Amylase, lactate, ABG.
- ECG
- CXR - ?perf
- CT abdo: “Round belly sign”
  - IVC collapse
  - Thickened bowel wall
  - Bilat. ing. Hernias
  - AAA
Management

1. Serial monitoring of IAP
2. Optimize systemic perfusion & organ function
3. Specific medical Rx to reduce IAP
4. Surgical decompression
2. Optimize perfusion

- Adequate but judicious fluid resus.
  *(avoid overload)*

- Vasopressors / inotropes
3. Medical Rx to reduce IAP

- Improve abdo wall compliance
  - Sedation & analgesia
  - NMB
  - Positioning

- Evac. Intra-luminal contents
  - NGT/Rectal tube

- Evac. Abdo fluid collections
  - Percutaneous

- Correct +ve fluid balance
  - Early CVVH/diuretics
4. Surgical decompression

- Refractory ACS
- Life-saving
- “presumptive decompression” in at risk cases
- Bogota bag
- VAC dressing
Patient has IAP ≥ 12 mmHg
Begin medical management to reduce IAP (GRADE 1C)

Measure IAP at least every 4-6 hours or continuously. Titrate therapy to maintain IAP ≤ 15 mmHg (GRADE 1C)

Evacuate intraluminal contents
- Insert nasogastric and/or rectal tube
- Initiate gastro-colonoprostokinetic agents (GRADE 2D)

Evacuate intra-abdominal space occupying lesions
- Abdominal ultrasound to identify lesions
- Percutaneous catheter drainage (GRADE 2D)
- Consider coelioscopic decompression (GRADE 1D)

Improve abdominal wall compliance
- Abdominal computed tomography to identify lesions
- Consider surgical evacuation of lesions (GRADE 1D)
- Consider neuromuscular blockade (GRADE 1D)

Optimize fluid administration
- Ensure adequate sedation & analgesia (GRADE 1D)
- Remove constrictive dressings, abdominal eschars
- Consider reverse Trendelenberg position
- Consider hemodialysis/ultrafiltration

Optimize systemic/regional perfusion
- Avoid excessive fluid resuscitation (GRADE 2C)
- Aim for zero to negative fluid balance by day 3 (GRADE 2C)
- Resuscitate using hypertonic fluids, colloids
- Fluid removal through judicious diuresis once stable

Step 1

Step 2

Step 3

Step 4

If IAP > 20 mmHg and new organ dysfunction/failure is present, patient's IAH / ACS is refractory to medical management. Strongly consider surgical abdominal decompression (GRADE 1D).

Adapted from Intensive Care Med 2013 7:1190-1206
Finally

“ACS without expedient decompression is uniformly fatal”

From a vascular surgeon’s perspective:

“there is often a delicate balance between effective tamponade of bleeding and the untoward physiological effects of ACS”

An aortic graft in an open abdomen is very risky
Limb Compartment Syndrome

Why does it matter?

- Muscle and nerve ischemia
- Untreated progresses to necrosis
- Permanent disability
- Limb loss
Compartment Syndrome - What is it & what happens?

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NO gradient
NO Flow

No Flow = No perfusion = ISCHEMIA
Lower leg compartments

- Deep fascia -
  - enveloping entire leg
  - separating the 4 compartments

- Fixed volume
- Little capacity for expansion

Image courtesy of "fastbleep.com"
Increased compartment volume
  
  cell swelling, interstitial fluid,
  blood, venous occlusion

  
  Increased compartment pressure

  
  Increased venous capillary pressure

  
  Decreased gradient

  
  Decreased flow / perfusion

  
  ISCHEMIA
Compartment Syndrome - What causes it?

- Ischemia / reperfusion injury - ALI
- Trauma - crush, fracture
- Severe DVT - Phlegmasia
- Intra-compartment hemorrhage
Assessment & Diagnosis - History

- At risk patient - relevant injury
- High index of suspicion

- Pain
  - Out of proportion
  - Unresponsive to immobilization
  - Increased with passive movement
  - Little response to opiates

- Neurological dysfunction - paraesthesia
Assessment & Diagnosis - Examination

- Swollen, tender & tense compartments
- Neurological dysfunction
- Pulselessness - LATE sign
- Compartment pressures
From a vascular surgeon’s perspective:

“if you think it, do it!”

“no-one should regret doing a fasciotomy. Plenty have regretted not doing one”
Compartment Pressures - Measurement

- Stryker compartment monitor (emerg / ward)
- Arterial line + needle (OR / ICU)
- Normal < 10 - 12mmHg
Intra-Compartmental Pressure Monitor System

Unique Design with Unique Benefits

Image courtesy of stryker.com
Compartment Pressures - Interpretation

- MAP - ICP < 40mmHg
- DP - ICP < 10mmHg

= Compartment Syndrome
Treatment

- **Fasciotomy** - emergency

- Medical **interim** management
  - Keep BP up
  - Keep Hgb up
  - Oxygenate
  - Loosen dressings / split cast etc
Fasciotomy - lower leg

- 4 compartments

Images courtesy of "fastbleep.com"
Wound care

- Non-adherent absorbent dressings
- Transfuse as required
- Delayed primary closure
- VAC
- Split skin graft
Fasciotomy -
long term complications

- Neurological dysfunction
- Chronic swelling / CVI
- Scars
Other compartments

- Thigh
- Buttock
- Forearm
- Abdomen

All managed with the same basic principles
Summary - compartment syndrome

- SURGICAL EMERGENCY!
- Limb threatening condition
- Clinical diagnosis
- High index of suspicion
- Requires 4 compartment fasciotomy