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Hemodynamic instability: an echo-hemodynamic approach

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Two unstable patients

Patient #1
- 82 yo ♀ intubated in the ICU
- CABG the night before
- Unstable: lactate 14 mmol/L
- On NA 80 ug/min, vaso 4 units/h, IV milrinone + IABP
- Pericardial effusion documented on TTE

Patient #2
- 66 yo ♂ 2 days after mitral valve repair
- Found unconscious in the bathroom
- CPR started: no arterial pressure
- HR 131 irregular narrow QRS
- Pulse oximetry non detectable but < 90%
At the same time
Therefore
FOCCUS

Consequence

Approach
Venous return determinants

- $RV = \underbrace{\text{Driving pressure}}_{Pms} - \underbrace{\text{Resistance to VR}}_{Pra} = Pms - Pra$

Venous return if:

1. $\downarrow Pms$: hypovolemia, vasodilatation
2. $\uparrow Pra$: left and right ventricular systolic dysfunction
   - left and right ventricular diastolic dysfunction
   - left and right outflow tract obstruction
   - pulmonary emboli
   - hypoxia and hypercapnia
3. $\uparrow Rrv$: intrinsic or extrinsic obstruction (compartment syndrome)
   - péridical, médiastinal, thoracic, abdominal
Shock state

Hypotension
Oliguria
Cold extremities
Neurological alteration
Acidosis
Consequences

Approach

FOCCUS
Focused Cardiac Ultrasound in the Emergent Setting: A Consensus Statement of the American Society of Echocardiography and American College of Emergency Physicians

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| Table 1 Goals of the focused cardiac ultrasound in the symptomatic emergency department patient |
|==============================================================================================|
| Assessment for the presence of pericardial effusion                                          |
| Assessment of global cardiac systolic function                                               |
| Identification of marked right ventricular and left ventricular enlargement                   |
| Intravascular volume assessment                                                              |

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Transthoracic view:
Parasternal long-axis view
Transesophageal view: Mid-esophageal long-axis view
Deep Impact of Ultrasound in the Intensive Care Unit

The “ICU-sound” Protocol

Emil Paolo Manno, M.D.,* Mauro Navarra, M.D.,† Luciana Faccio, M.D.,† Mohsen Motevallian, M.D.,† Luca Bertolaccini, M.D., Ph.D.,‡ Abdou Mfochivè, M.D.,† Marco Pesce, M.D.,† Andrea Evangelista, M.S.§

• Impact: Ultrasound examination
  ➢ confirmed the admitting diagnosis in 73/125 cases (58.4%),
  ➢ modified it in 32/125 cases (25.6%)
Hypoxia and hemodynamic instability

Short history and physical exam

Simultaneous rapid diagnosis and treatment
Hypoxia and hemodynamic instability

- Short history and physical exam
- Simultaneous rapid diagnosis and treatment
  - True hypotension
    - BP measurement in all four extremities
Hypoxia and hemodynamic instability

Short history and physical exam

Simultaneous rapid diagnosis and treatment

True hypotension
- BP measurement in all four extremities

Hypoxia and signs of shock
- A: airway + antibiotics if sepsis suspected
- B: ventilation + volume (15ml/kg)
- C: vasoactive drugs (noradrenaline)
Hypoxia and hemodynamic instability

Short history and physical exam

Simultaneous rapid diagnosis and treatment

True hypotension

BP measurement in all four extremities

If true hypotension

Hypoxia and signs of shock

A: airway + antibiotics if sepsis suspected
B: ventilation + volume (15ml/kg)
C: vasoactive drugs (noradrenaline)

No response to volume

FOCCUS or TEE
Hypoxia and hemodynamic instability

Short history and physical exam

Simultaneous rapid diagnosis and treatment

True hypotension

BP measurement in all four extremities

If true hypotension

Hypoxia and signs of shock

A: airway + antibiotics if sepsis suspected
B: ventilation + volume (15 ml/kg)
C: vasoactive drugs (noradrenaline)

No response to volume

IVC or SVC collapse

FOCCUS or TEE

↓ in Pms

↑ compliance

↓ volume

Image of medical equipment displaying blood pressure readings.
Hypoxia and hemodynamic instability

Short history and physical exam

Simultaneous rapid diagnosis and treatment

True hypotension

BP measurement in all four extremities

If true hypotension

Hypoxia and signs of shock

A: airway + antibiotics if sepsis suspected
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No response to volume

IVC or SVC collapse

FOCCUS or TEE

↓ in Pms

↑ compliance

Non-septic
Anaphylaxis
Anesthesia
Addison
Hypothyroid
Intoxication

Septic
Pneumonia
Empyema
Peritonitis
Abcess
Cholecystitis

↓ volume

Hemothorax
Peritoneal bleeding
GI bleed
Retroperitoneal bleeding
Normal or ↓ Pms
Patient # 2
Focused Transesophageal Echocardiography
Extracardiac views
Anatomical description
Patient #1
Reduced Pms: why?

Hemothorax

Pneumonia

Peritonitis

Acute cholecystitis
Patient # 1
Patient # 2

Right lung
Hypoxia and hemodynamic instability

Short history and physical exam

Simultaneous rapid diagnosis and treatment

True hypotension

BP measurement in all four extremities

If true hypotension

Hypoxia and signs of shock

A: airway + antibiotics if sepsis suspected
B: ventilation + volume (15ml/kg)
C: vasoactive drugs (noradrenaline)

No response to volume

FOCCUS or TEE

↑ in Pra

RV

LV
FOCUS or TEE

↑ in Pra

RV

LV

Hypoxia and hypercapnia
Systolic dysfunction
Diastolic dysfunction
Outflow tract obstruction
Pulmonary emboli

Others:
congenital, tumor, CMP, arrhythmias
Patient #2

Left lung
Par 126/81 99
ETCO2 30
VM 3.6
Na 25ug/min

PAT T: 37.0°C
TEE T: 38.6°C

98 bpm
FOCUS or TEE

↑ in Pra

RV
LV

Hypoxia and hypercapnia
Systolic dysfunction
Diastolic dysfunction
Outflow tract obstruction
Pulmonary emboli

Others:
congenital, tumor, CMP, arrhythmias
Transesophageal echocardiography

Transgastric mid-papillary view

18
Patient #1
Myocardial 2D strain

Valeur normale > 44
Patient #2
FOCUS or TEE

▲ in Pra

RV

LV

Hypoxia and hypercapnia
Systolic dysfunction
Diastolic dysfunction
Outflow tract obstruction
Pulmonary emboli

Others:
congenital, tumor, CMP, arrhythmias
Transesophageal echocardiography
Mid-esophageal four-chamber view
Patient #1
Patient #2

Par 126/81  99
ETCO2 30
VM 3.6
Na 25ug/min
FOCUS or TEE

↑ in Pra

RV  LV

Hypoxia and hypercapnia
Systolic dysfunction
Diastolic dysfunction
Outflow tract obstruction
Pulmonary emboli

Others:
congenital, tumor, CMP, arrhythmias
Always consider left ventricular outflow tract obstruction in hemodynamically unstable patients

Antoine G. Rochon, MD • Philippe L. L’Allier, MD • André Y. Denault, MD
Focused Transesophageal Echocardiography
Mid-esophageal long-axis view
Anatomical description
Patient #1

[Images of medical scans]
Hypoxia and hemodynamic instability

Short history and physical exam

Simultaneous rapid diagnosis and treatment

True hypotension
- BP measurement in all four extremities

If true hypotension
- No response to volume

Hypoxia and signs of shock
- A: airway + antibiotics if sepsis suspected
- B: ventilation + volume (15ml/kg)
- C: vasoactive drugs (noradrenaline)

FOCCUS or TEE
- Elevated pleural or IAB pressure measurement

↑ in Rvr
- Extrinsic obstruction
- Intrinsic obstruction
↑ in Rvr

Extrinsic obstruction

Intrinsic obstruction

Pericardial tamponade
Pleural compression: air or fluid
Mediastinal compression
Abdominal compression
Patient #1
Transthoracic echocardiographic examination in the ICU
Subcostal area
Four-chamber plane
Patient #2
Patient #1

Intrinsic

↑Rrv ➔ Obstructive shock

Hypovolemic shock

↓Pms ➔ Distributive shock

Non blood losses

Hypotension
Oliguria
Cold extremities
Neurological alteration
Acidosis

Shock state

Cardiogenic shock

↑Pra ➔ Diastolic

Septic
Non-septic
Patient #2

Shock state

Obstructive shock

Hypovolemic shock

Distributive shock

Cardiogenic shock

- Obstructive
- Diastolic
- Non-septic

- Intrinsic
- Hypotension
- Oliguria
- Cold extremities
- Neurological alteration
- Acidosis

↑Rrv

↓Pms
After cardioversion, drainage + milrinone 5 mg
In summary
Intrinsic

Obstructive shock

↓Rrv

Hypovolemic shock

Non blood losses

↓Pms

Distributive shock

↑Pra

Cardiogenic shock

Obstructive

Diastolic

Hypotension
Oliguria
Cold extremities
Neurological alteration
Acidosis

Shock state

Non-septic
Conclusion

- Hemodynamic instability is rarely the result of a single mechanism
- The etiology might be rapidly changing and iatrogenic
- Hemodynamic monitoring alone is insufficient to determine the multiple etiologies of hemodynamic instability of the critically ill patient
Thanks

Denis Babin
MSc Inh, RT
Research assistant
Normal right ventricle
Pre-op RV dysfunction: ventricular septal defect

Hepatic venous flow

Robitaille JTCVA 2006
RV dysfunction

Hepatic venous flow
Right ventricular failure
Severe RV dysfunction

Diastolic equalisation

RV Pulsus tardus and ↓ pulse pressure
53 year old man: AVR, mitral and tricuspid repair

After induction of anesthesia

Cardiac index: 1.3 L/m²
PVRI: 429 dynes.s.cm⁻⁵m⁻²

15 minutes after inhaled milrinone + PGI₂

Cardiac index: 1.79 L/m²
PVRI: 178 dynes.s.cm⁻⁵m⁻²
Post-CPB

Unstable

Inhaled milrinone