10th Annual Comprehensive Review & Update of Perioperative Echocardiography: Hemodynamics Workshop

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CASE # 1

70 yo man having CABG surgery is being monitored with an A-line, CVP, and TEE. On echo, the AV appears to be sclerosed with restricted leaflet motion and trace AR. The following measurements are made:

* Heart Rate: 80 bpm
* Systemic BP: 105/65 mm Hg
* CVP: 12 mm Hg
* Diameter LVOT: 2.0 cm
* TVI LVOT: 20 cm
* Peak Velocity LVOT: 1.2 m/sec
* TVI AV: 65 cm
* Peak Velocity AV: 3.8 m/sec
* Peak Velocity TR: 2.5 m/sec

CALCULATE:
- Stroke Volume
- Cardiac Output
- Peak Right Ventricular Systolic Pressure
- Peak Aortic Valve Area
- Peak Aortic Valve Gradient
CASE #2
48 yo man is having CABG surgery. Monitoring includes an A-line, CVP, and TEE. The LV appears to be dilated and hypococontractile. There is a central jet of MR judged to be 2+ to 3+ in severity. The following measurements are made:

- Diameter LVOT: 2.5 cm
- TVI LVOT: 15 cm
- Mitral Annular Diameter 3.7 cm
- TVI Mitral Annular Flow 12 cm
- PISA Radius 0.7 cm
- PISA Alias Velocity 45 cm/sec
- Peak Velocity MR: 445 cm/sec
- TVI MR: 180 cm

CALCULATE:
- LVOT Stroke Volume
- MV Stroke Volume
- MV Regurgitant Volume
- MV Regurgitant Fraction
- Regurgitant Orifice Area
- PISA calculations:
  - Regurgitant Flow Rate
  - Regurgitant Orifice Area
  - Regurgitant Volume
  - Regurgitant Fraction
CASE #3:

60 y.o. female s/p cardiac arrest following total hip replacement. Emergent intraoperative TEE suggests a pulmonary embolus.

Vital Signs:
• Heart Rate: 100 bpm
• Systemic BP: 90/60 mm Hg
• CVP: 20 mm Hg

TEE Data:
• Pulmonary Artery Diameter: 2.2 cm
• Pulmonary Artery TVI: 8 cm
• Aortic Valve TVI: 14 cm
• TR Peak Velocity: 3.8 m/sec

CALCULATE:
- Stroke Volume
- Cardiac Output
- Peak Right Ventricular Systolic Pressure
- Aortic Valve Area
CASE #4:

60 y.o. male with acute aortic dissection and AI.

Vital Signs:
- Heart Rate: 80 bpm
- Systemic BP: 120/60 mm Hg

TEE Data:
- LVOT Diameter: 2.0 cm
- LVOT TVI: 30 cm
- MV Diameter: 3 cm
- MV TVI: 10 cm
- AI TVI: 160 cm
- AI End-Diastolic Velocity: 3 m/sec

CALCULATE:
- LVOT Stroke Volume
- Mitral Valve Stroke Volume
- Aortic Regurgitant Volume
- Aortic Regurgitant Fraction
- Aortic Regurgitant Orifice Area
- Cardiac Output
- Left Ventricular End-Diastolic Pressure
CASE #5:

70 y.o. male with worsening dyspnea on exertion.

Vital Signs:
- Heart Rate: 70 bpm
- Systolic BP: 100/50 mm Hg
- CVP: 12 mmHg

TEE Data:
- LVOT Diameter: 2.0 cm
- LVOT TVI: 20 cm
- MV TVI: 90 cm
- MV Pressure Half Time (PHT): 360 ms
- Peak Trans-Mitral E-Velocity: 2 m/sec
- Pulmonary Insufficiency
  - End-Diastolic Velocity (EDV): 2.5 m/sec

CALCULATE:
- Mitral Valve Area by Pressure Half Time
- Mitral Valve Area by Continuity Equation
- Pulmonary Artery Diastolic Pressure
CASE #6:
54 yo man is having MV surgery. Monitoring includes an A-line, PAC, and TEE. TEE shows thickened MV leaflets with diastolic doming and restricted opening. There is 2+ MR and no AI. The following measurements are made:

**Vital Signs:**
- Heart Rate: 100 bpm
- Systemic BP: 136/80 mmHg
- Thermodilution Cardiac Output: 3.8 L/min

**TEE Data:**
- MV Pressure Half Time (PHT): 215 ms
- Peak Trans-Mitral E Velocity: 240 cm/sec
- Mean Trans-Mitral Velocity: 194 cm/sec
- TVI Mitral Inflow: 55 cm
- TVI MR: 85 cm
- MS PISA Radius: 1.4 cm
- PISA Alias Velocity: 39 cm/sec
- MV α- Angle: 120 degrees

**CALCULATE:**
- Peak Trans-Mitral Pressure Gradient
- Mitral Valve Area by Pressure Half Time
- Area of PISA
- Mitral Valve Area using PISA
- Mitral Valve Stroke Volume
- Mitral Valve Regurgitant Volume
- Mitral Valve Regurgitant Fraction
- Effective MV Regurgitant Orifice Area
CASE #7:

56 yo man presents for AV surgery.

**Vital Signs:**
- Heart Rate: 84 bpm
- Systemic BP: 90/70 mmHg
- CVP: 14 mmHg
- BSA: 1.98 m²

**TEE Data:**
- LVOT TVI: 23 cm
- LVOT Diameter: 2.2 cm
- Aortic Valve Mean Gradient: 63 mmHg
- Aortic Valve TVI: 122 cm
- TR Peak Velocity: 3.6 m/sec

**CALCULATE:**
- LVOT Stroke Volume
- Cardiac Output and Index
- Aortic Valve Area
- Pulmonary Artery Systolic Pressure
CASE #8:

78 y.o. man undergoing AAA surgery becomes hypoxic and hypotensive with cross-clamping of the abdominal aorta. TEE reveals 1-2+ MR, 1+ TR without AS or AI. The following measurements are made:

**Vital Signs:**
- Heart Rate: 110 bpm
- Systemic BP: 85/50 mmHg
- CVP: 8 mmHg

**TEE Data:**
- Aortic Valve Sides: 2.3 cm
- Aortic Valve TVI: 12 cm
- Peak Velocity MR: 3.5 m/sec
- Peak Velocity TR: 3.5 m/sec

**CALCULATE:**
- Aortic Valve Area
- Stroke Volume
- Cardiac Output
- Left Atrial Pressure
- Peak Right Ventricular Systolic Pressure
CASE #9:

81 y.o. woman develops severe dyspnea and a harsh systolic murmur 8 days after an acute myocardial infarction. She requires intubation and is transferred to the ICU. An emergent TEE is performed and reveals a VSD with left to right shunting. Aortic and mitral valves are normal. The following measurements are made:

Vital Signs:
* Heart Rate: 100 bpm
* Systemic BP: 100/60 mmHg

TEE Data:
* LVOT Diameter: 1.8 cm
* LVOT TVI: 17 cm
* PA Diameter: 2.4 cm
* PA TVI: 22 cm
* VSD Peak Velocity: 3.2 m/sec

CALCULATE:
- LVOT Stroke Volume
- Cardiac Output
- Pulmonary Artery Stroke Volume
- Pulmonary Artery Blood Flow
- Shunt Fraction (Qp/Qs)
- Peak Right Ventricular Systolic Pressure
CASE #1

\[ SV = \text{AREA}_{LVOT} \times \text{TVI}_{LVOT} \]
\[ = 0.785 \times 4 \times \text{TVI}_{LVOT} \]
\[ = 0.785 \times (2.0)^2 \times 20 \text{ cm} \]
\[ = 3.1 \text{ cm}^2 \times 20 \text{ cm} \]
\[ = 62 \text{ ml} \]

\[ CO = SV \times HR \]
\[ = 62 \text{ ml} \times 80 \text{ bpm} \]
\[ = 4960 \text{ ml/min} \]
\[ = 5.0 \text{ L/min} \]

\[ RVSP = CVP + (RVSP - CVP) \]
\[ = 22 + \Delta P_{ATP} \]
\[ = 22 + 4 \times V_{max}^2 \]
\[ = 22 + 4 \times (2.5 \text{ m/sec})^2 = 12 + 25 \]
\[ = 33 \text{ mm Hg} \]

\[ \text{Peak}_{AV} = 4 (V_{max})^2 \]
\[ = 4(3.8 \text{ m/sec})^2 \]
\[ = 58 \text{ cmHg} \]

\[ \text{AREA}_{AV} = \text{AREA}_{LVOT} \times (V_{LVOT} / V_{AV}) \]
\[ = 0.785 \times (2.0 \text{ cm})^2 \times (1.2 \text{ m/sec} / 3.8 \text{ m/sec}) \]
\[ = 1.0 \text{ cm}^2 \]

OR

\[ \text{AREA}_{AV} = \frac{SV_{AV}}{\text{TVI}_{AV}} \]
\[ = 62 \text{ cm}^3 / 65 \text{ cm} \]
\[ = 1.0 \text{ cm}^2 \]
\[ \text{SV_{LVR}} = \text{AREA}_{LVR} \times \text{TVI}_{LVR} \]
\[ = 0.785 \times \left( \text{D}_{LVR} \right)^2 \times \text{TVI}_{LVR} \]
\[ = 0.785 \times \left( 2.5 \text{ cm} \right)^2 \times 15 \text{ cm} \]
\[ = 4.9 \text{ cm}^2 \times 15 \text{ cm} \]
\[ = 74 \text{ ml} \]

\[ \text{SV}_{SV} = \text{AREA}_{SV} \times \text{TVI}_{SV} \]
\[ = 0.785 \times \left( \text{D}_{SV} \right)^2 \times \text{TVI}_{SV} \]
\[ = 0.785 \times \left( 3.0 \text{ cm} \right)^2 \times 12 \text{ cm} \]
\[ = 10.8 \text{ cm}^2 \times 12 \text{ cm} \]
\[ = 130 \text{ ml} \]

\[ \text{RV}_{SV} = \text{SV}_{SV} - \text{SV}_{LVR} \]
\[ = 130 \text{ ml} - 74 \text{ ml} \]
\[ = 56 \text{ ml} \]

\[ \text{RV}_{LVR} = \frac{\text{RV}_{SV}}{\text{SV}_{SV}} \]
\[ = \frac{56 \text{ ml}}{130 \text{ ml}} \]
\[ = 0.43 = 43\% \]

\[ \text{ERO}_{SVA} = \frac{\text{RV}_{SV}}{\text{V}_{SVA}} \]
\[ = \frac{56 \text{ ml}}{180 \text{ cm}} \]
\[ = 0.31 \text{ cm}^2 \]

\[ \text{FLOW}_{SVA} = \text{AREA}_{SVA} \times \text{V}_{SVA} \]
\[ = 3.14 \times \left( \text{D}_{SVA} \right)^2 \times \text{V}_{SVA} \]
\[ = 6.28 \times \left( 0.7 \text{ cm} \right)^2 \times 45 \text{ cm/sec} \]
\[ = 138 \text{ ml/sec} \]

\[ \text{ERO}_{SVA} = \frac{\text{FLOW}_{SVA}}{\text{V}_{SVA}} \]
\[ = \frac{138 \text{ ml/sec}}{445 \text{ cm/sec}} \]
\[ = 0.31 \text{ cm}^2 \]

\[ \text{RV}_{SVA} = \text{ERO}_{SVA} \times \text{TVI}_{SVA} \]
\[ = 0.31 \text{ cm}^2 \times 180 \text{ cm} \]
\[ = 56 \text{ ml} \]

\[ \text{BF}_{SVA} = \frac{\text{RV}_{SVA}}{\text{SV}_{SV}} \]
\[ = \frac{56 \text{ ml}}{133 \text{ ml}} \]
\[ = 0.43 = 43\% \]
CASE #3

\[ SV = \text{AREA}_{av} \times TVL_{av} \]
\[ = 0.785 \times (0.22^2 \times TVL_{av}) \]
\[ = 0.785 \times (2.2 \text{ cm})^2 \times 3 \text{ cm} \]
\[ = 5.8 \text{ cm}^2 \times 3 \text{ cm} \]
\[ = 30 \text{ ml} \]

\[ CO = SV_{av} \times HR \]
\[ = 30 \text{ ml} \times 100 \text{ bpm} \]
\[ = 3000 \text{ ml/min} \]
\[ = 50 \text{ L/min} \]

\[ RVSP = 4 \times (V_{mean})^2 + CVP \]
\[ = 4 \times (3.8)^2 + 20 \text{ mm Hg} \]
\[ = 58 + 20 \]
\[ = 78 \text{ mm Hg} \]

\[ \text{AREA}_{av} = \frac{SV}{TVL_{av}} \]
\[ = \frac{30 \text{ cm}^3}{14 \text{ cm}} \]
\[ = 2.1 \text{ cm}^2 \]
CASE #4

\[ SV_{LVOT} = \text{AREA}_{LVOT} \times TVI_{LVOT} \]
\[ = 0.785 \times (D_{LVOT})^2 \times 10 \text{ cm} \]
\[ = 0.785 \times (2 \text{ cm})^2 \times 10 \text{ cm} \]
\[ = 51.4 \text{ cm}^2 \times 10 \text{ cm} \]
\[ = 94 \text{ cm}^3 \]

\[ SV_{M V} = \text{AREA}_{MV} \times TVI_{MV} \]
\[ = 0.785 \times (D_{MV})^2 \times 10 \text{ cm} \]
\[ = 0.785 \times (3 \text{ cm})^2 \times 10 \text{ cm} \]
\[ = 7.1 \text{ cm}^2 \times 10 \text{ cm} \]
\[ = 71 \text{ cm}^3 \]

\[ RV_{AI} = LVOT_{SV} - MV_{SV} \]
\[ = 94 \text{ ml} - 71 \text{ ml} \]
\[ = 23 \text{ ml} \]

\[ RF_{AI} = \frac{RV_{AI}}{LVOT_{SV}} \]
\[ = \frac{23 \text{ ml}}{94 \text{ ml}} \]
\[ = 0.24 \]
\[ = 24\% \]

\[ ERO_{AI} = \frac{RV_{AI}}{TVI_{AI}} \]
\[ = \frac{23 \text{ cm}^3}{160 \text{ cm}} \]
\[ = 0.14 \text{ cm}^3 \]

\[ CO = SV_{SV} \times HR \]
\[ = 90 \text{ ml} \times 80 \text{ bpm} \]
\[ = 5600 \text{ ml/min} \]
\[ = 5.6 \text{ L/min} \]

\[ LVEDP = \text{Systemic Diastolic Pressure} - [4 \times (Al \text{ cm})^3] \]
\[ = 80 \text{ mmHg} - 4 \times (3)^3 \]
\[ = 80 \text{ mmHg} - 36 \]
\[ = 44 \text{ mmHg} \]
CASE #5

\[ \text{AREA}_{LV} = 220 / \text{PHT} \]
\[ = 220 / 300 \text{ cm} \]
\[ = 0.7 \text{ cm}^2 \]

\[ \text{AREA}_{MV} = 0.785 \times (D_{LVOT})^2 \times \text{TVI}_{LVOT} / \text{TVI}_{MV} \]
\[ = 0.785 \times 4 \text{ cm}^2 \times 20 \text{ cm} / 90 \text{ cm} \]
\[ = 63 \text{ cm}^2 / 90 \text{ cm} \]
\[ = 0.7 \text{ cm}^2 \]

\[ \text{PAD} = 4 \times (P_{DIA})^2 + RV_{MV} \]
\[ = 4 \times (2.3)^2 + CVP \]
\[ = 25 - 12 \]
\[ = 13 \text{ mmHg} \]

CASE #6

\[ \text{PEAK}_{LV} = 4 \times (V_{MAX})^2 \]
\[ = 4 \times (2.4)^2 \]
\[ = 23 \text{ mmHg} \]

\[ \text{AREA}_{LV} = 220 / \text{PHT} \]
\[ = 220 / 215 \]
\[ = 1.0 \text{ cm}^2 \]

\[ \text{AREA}_{LVOT} = 211 \times (R_{LVOT})^2 + 6 / 180 \]
\[ = 6.28 \times (1.4)^2 + 6 / 180 \]
\[ = 8.8 \times 0.667 \]
\[ = 5.8 \text{ cm}^2 \]

\[ \text{AREA}_{MV/LVOT} = (\text{AREA}_{LVOT} \times V_{MAX}) / V_{MAX/PEAK} \]
\[ = (5.8 \text{ cm}^2 \times 50 \text{ cm/sec}) / 240 \text{ cm/sec} \]
\[ = 246 / 240 \]
\[ = 1.0 \text{ cm}^2 \]

\[ \text{SV}_{LV} = \text{AREA}_{LV} \times \text{TVI}_{LV} \]
\[ = 1.0 \text{ cm}^2 \times 55 \text{ cm} \]
\[ = 55 \text{ ml} \]

\[ \text{RV}_{LV} = \text{SV}_{LV} - \text{SV}_{LV} - \text{SV}_{LV} - (CO/HR) \]
\[ = 55 \text{ ml} - 3000 \text{ ml/min} / 100 \text{ bpm} \]
\[ = 55 \text{ ml} - 30 \text{ ml} \]
\[ = 17 \text{ ml} \]

\[ \text{RF}_{LV} = \text{RV}_{LV} / \text{SV}_{LV} \]
\[ = 17 \text{ ml} / 55 \text{ ml} \]
\[ = 31 \% \]

\[ \text{ERG}_{LV} = \text{RV}_{LV} / \text{TVI}_{LV} \]
\[ = 17 \text{ cm}^2 / 85 \text{ cm} \]
\[ = 0.2 \text{ cm}^2 \]
CASE #7

\[ SV_{LVED} = \text{AREA}_{LVED} \times TVI_{LVED} \]
\[ = 0.745 \times (0.8)^2 \times 23 \]
\[ = 0.745 \times 22 \times 23 \]
\[ = 0.745 \times 4.84 \times 23 \]
\[ = 87 \text{ ml} \]

\[ CO = SV_{LVED} \times HR \]
\[ = 87 \text{ ml} \times 84 \text{ bpm} \]
\[ = 7368 \text{ ml/min} = 7.3 \text{ L/min} \]

\[ CI = \frac{CO}{BSA} = 7.3 \text{ L/min} / 1.88 \text{ m}^2 \]
\[ = 3.7 \text{ L/min/m}^2 \]

\[ \text{AREA}_{AV} = \frac{SV_{LVED}}{TVI_{LV}} \]
\[ = 87 \text{ cm}^3 / 122 \text{ cm} \]
\[ = 0.7 \text{ cm}^3 \]

\[ \text{PAS} = \left[4 \times (\text{V_{meanLAV}})^2 \right] + \text{RV}_{LVED} \]
\[ = \left[4 \times (3.6)^2 \right] + \text{CVP} \]
\[ = (4 \times 13) + 14 \text{ mmHg} \]
\[ = 52 + 14 \]
\[ = 66 \text{ mmHg} \]

CASE #8

\[ \text{AREA}_{AV} = 0.431 \times (\text{SIDE}_{AV})^2 \]
\[ = 0.431 \times 2.3 \text{ cm}^2 \]
\[ = 0.431 \times 5.3 \]
\[ = 2.3 \text{ cm}^2 \]

\[ SV_{AV} = \text{AREA}_{AV} \times TVI_{LV} \]
\[ = 2.3 \text{ cm}^3 \times 12 \text{ cm} \]
\[ = 28 \text{ ml} \]

\[ CO = SV_{AV} \times HR \]
\[ = 28 \text{ ml} \times 110 \text{ bpm} = 3080 \text{ ml/min} \]
\[ = 3.1 \text{ L/min} \]

\[ \text{LAP} = \text{LV Systolic Pressure} - \left[4 \times (\text{V}_{meanLAV})^2 \right] \]
\[ \text{Systemic Systolic Pressure} - \left[4 \times (3.5)^2 \right] \]
\[ = 85 \text{ mmHg} - (4 \times 12.25) \]
\[ = 85 \text{ mmHg} - 49 \]
\[ = 36 \text{ mmHg} \]

\[ \text{RVSP} = \left[4 \times (\text{V}_{meanLAV})^2 \right] + \text{CVP} \]
\[ = [4 \times (3.5)^2] + 8 \text{ mmHg} \]
\[ = (4 \times 12.25) + 8 \text{ mmHg} \]
\[ = 57 \text{ mmHg} \]
CASE 09

\[ SV_{LVOT} = \text{AREA}_{LVOT} \times TVI_{LVOT} \]
\[ = 0.785 \times (D_{LVOT})^2 \times 17 \text{ cm} \]
\[ = 0.785 \times (1.8)^2 \times 17 \]
\[ = 0.785 \times 3.24 \times 17 \]
\[ = 43 \text{ ml} \]

\[ CO = SV_{LVOT} \times HR \]
\[ = 43 \text{ ml} \times 100 \text{ bpm} \]
\[ = 4300 \text{ ml/min} \]
\[ = 4.3 \text{ L/min} \]

\[ SV_{PA} = \text{AREA}_{PA} \times TVI_{PA} \]
\[ = 0.785 \times (D_{PA})^2 \times 22 \text{ cm} \]
\[ = 0.785 \times (2.4)^2 \times 22 \]
\[ = 0.785 \times 5.76 \times 22 \]
\[ = 99 \text{ ml} \]

\[ Q_p = SV_{PA} \times HR \]
\[ = 99 \text{ ml} \times 100 \text{ bpm} \]
\[ = 9.9 \text{ L/min} \]

\[ Q_p/Q_s = \frac{9.9 \text{ L/min}}{4.3 \text{ L/min}} \]
\[ = 2.3 \]

\[ RVSP = \text{LV Systolic Pressure} - [4 \times (V_{max})^2] \]
\[ = \text{Systemic Systolic Pressure} - [4 \times (3.2)^2] \]
\[ = \text{Systemic Systolic Pressure} - (4 \times 10.24) \]
\[ = 100 \text{ mmHg} - (4 \times 10.24) \]
\[ = 59 \text{ mmHg} \]