Universitair Medisch Centrum Groningen
Afdeling Anesthesiologie

university of groningen

Anesthesia for Cardiovascular Surgery

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ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Basic monitoring:

- ECG
  - ≥2 leads (II and V_5)
  - Baseline print of all leads
  - ST-segment analysis
- Pulse oxymetry
- Backup manual or automatic blood pressure cuff

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ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Venous Access:

- Two large-bore (16-gauge or larger) peripheral IV catheters
- One central venous line, usually IJV
- Measurement of central venous pressure (?)
- PA-catheters: on indication
    - Low EF, pulm. Hypertension, complex procedures

Arterial cannulation

- Insert before induction of anesthesia
- Non-dominant hand (caveat: radial art. harvesting)
- Direct and continuous measurement of arterial blood pressure

ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Other:

- Indwelling urinary catheter
  - Urine output, bladder temperature
- Temperature probes
  - Esophageal, nasopharyngeal, skin, bladder, tympanic, blood
- Cross-matched blood available
  - Especially if patient has already had a midline sternotomy
- Consider thoracic epidural anesthesia (only Europe)
  - Problem: epidural hematoma formation following heparinization

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ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Induction of Anesthesia:

•Goal: hemodynamic stability

•Selection of induction agents:

- High-dose opiates
- ± Benzodiazepine
- Modest dose propofol
- Muscle relaxant, endotracheal intubation
- Vasopressor if blood pressure falls >20%

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ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Maintenance of anesthesia:

- Selection of anesthetic technique/agents:
    - TIVA with short acting agents, covers whole procedure
    - Volatile anesthetic agents
        - Cardioprotection
        - Difficult to use during CPB
    - Avoid N_2O! (expansion of intravascular air bubbles, pneumothorax)
    - High-dose opiates
    - Muscle relaxants
    - Vasopressor if blood pressure falls >20%
    - Goal: early extubation (1–6 h postop.), fast track?

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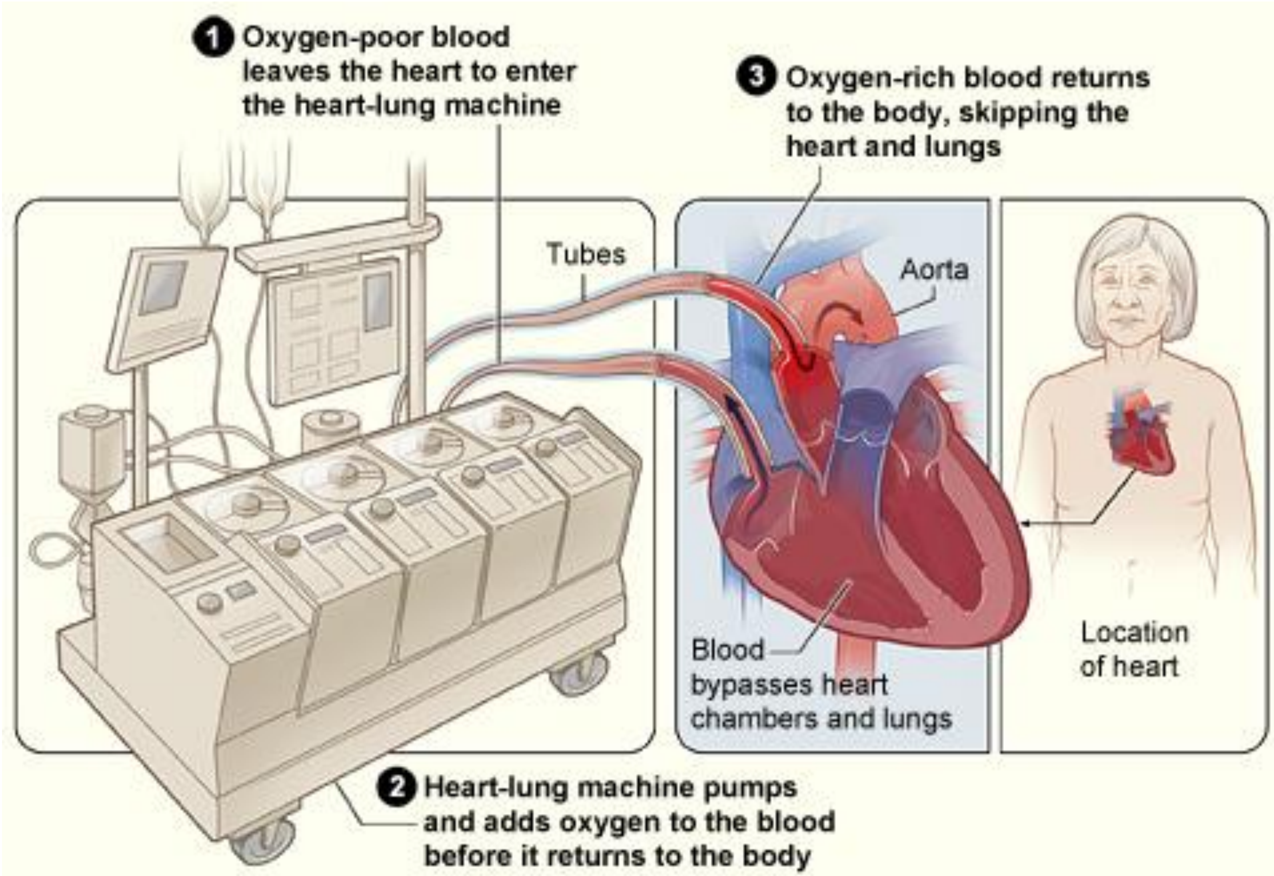
CARDIOPULMONARY BYPASS



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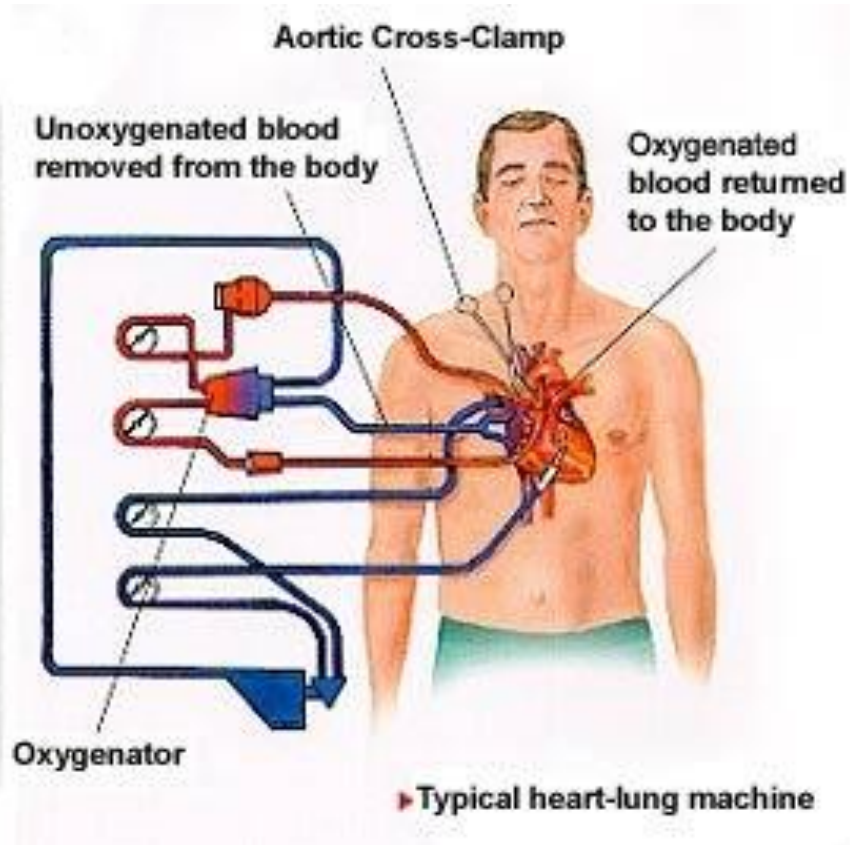
CARDIOPULMONARY BYPASS



The CPB machine has five basic components:

1. venous reservoir,
2. oxygenator,
3. heat exchanger,
4. main pump (roller pumps of centrifugal pumps), and
5. arterial filter (air, thrombi, fat globules, calcium, tissue debris)

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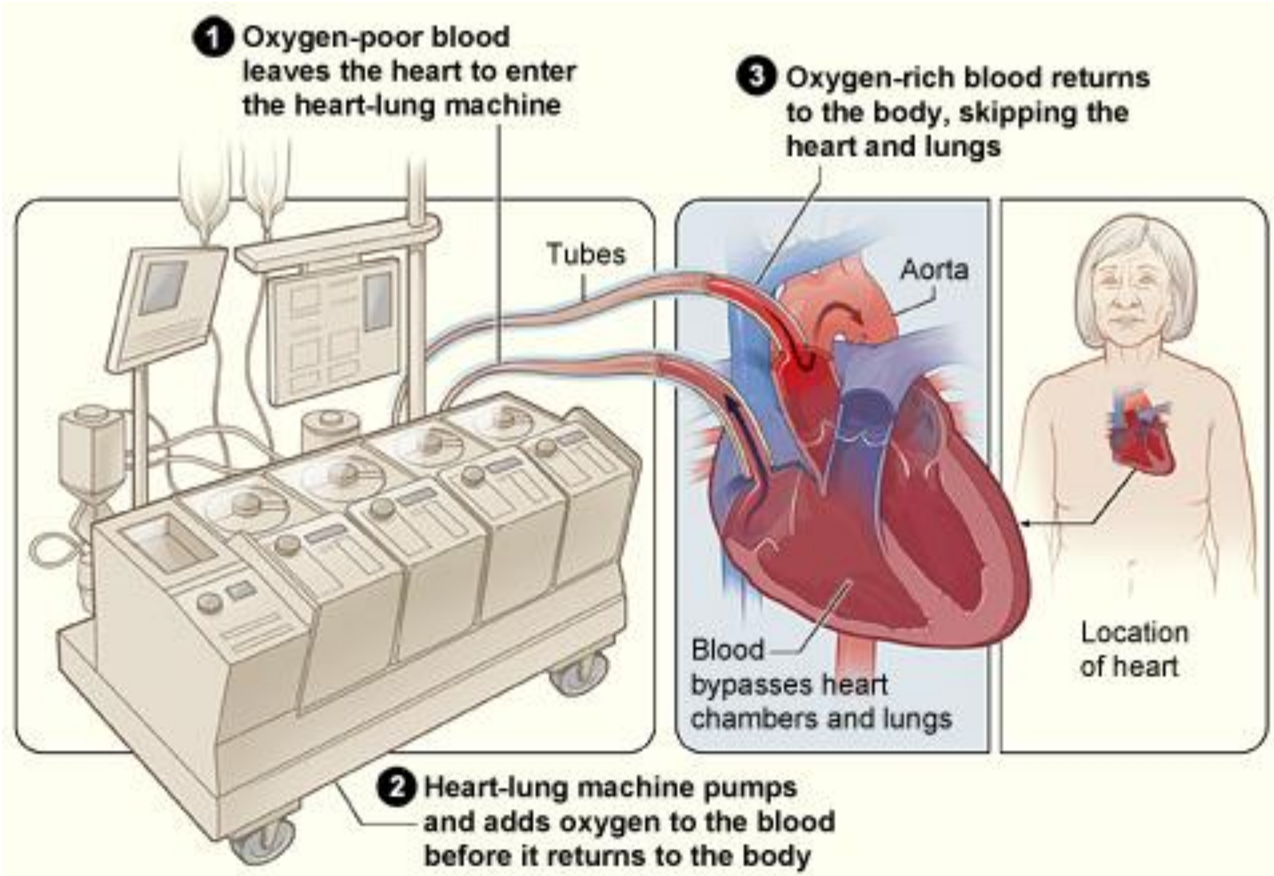
CARDIOPULMONARY BYPASS



CPB diverts venous blood away from the heart, adds oxygen, removes CO_2, and returns the blood to a large artery. As a result, most blood flow through the heart and most of the flow through the lungs cease.

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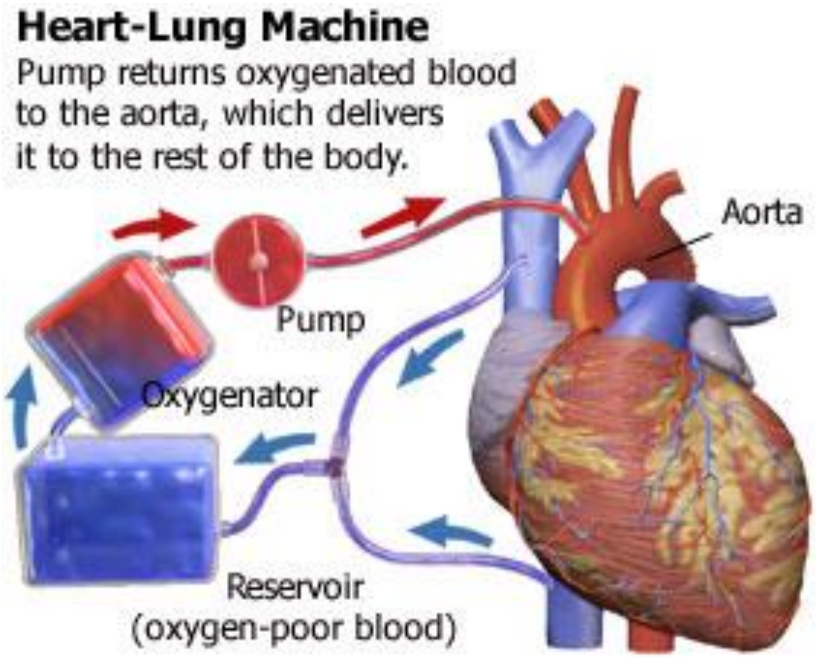
CARDIOPULMONARY BYPASS



Perfusionist

Flow = non-pulsatile

Organ protection:

- Hypothermia
- Cardioplegia
  - (cold, K^+-rich, blood or crystalloids, ante- and retrograde, repeat every 30 min)

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PHYSIOLOGICAL EFFECTS OF CARDIOPULMONARY BYPASS

Initiation of CPB is associated with:

- a marked increase in stress hormones
- a variable systemic inflammatory response (sepsis-like)
    - Generation of oxygen-derived free radicals
- Activation of multiple humoral systems, including complement, coagulation, fibrinolysis, and the kallikrein system
- Mechanical trauma alters platelets and activates leukocytes
    - Depletion of glycoprotein receptors on the surface of platelets
    - Increased perioperative bleeding

PHYSIOLOGICAL EFFECTS OF CARDIOPULMONARY BYPASS

Potential methods to prevent complications (experimental):

- Glucocorticoids?
- Cyclokapron acid?
- Leukocyte depletion?
- Intraoperative hemofiltration?
- Antioxidants (Vit. C, E, Mannitol)?
- cyclooxygenase-2 inhibitors?
- Pentoxifylline?

ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Going on-pump

- Confirm adequate anticoagulation (ACT) before cannulation
- Venous cannulation
- Aortic cannulation
  - Reduce systemic arterial pressure (to 90–100 mm Hg systolic)
  - Complications: Aortic dissection, Cerebral embolism (plaque, air)
- Start CPB, pump flow gradually increased to 2–2.5 L/min/m^2
- Cold blood cardioplegia
- Continue ventilation until heart stops ejecting blood
- Maintain MAP 50 - 80 mmHg (organ perfusion)
- Hemodilution due to CPB priming
  - Keep hematocrit between 20% and 25%

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ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Intraoperative laboratory monitoring:

- Blood gas analysis (point of care):
  - Hematocrit
  - Serum potassium
  - Ionized calcium
  - Glucose
- Activated clotting time (ACT)
  - Activators: celite, kaolin, glass
  - Reference value ranges between 70-180 sec
  - During CPB the desired range is >400-500 sec
  - During OPCAB procedures usually >300-400 sec
- Thrombelastography (TEG)?

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ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Anticoagulation:

•must be established prior to CPB

•must be confirmed with determination of the ACT

•Heparin: 3 mg/kg (OPCAB: 2 mg/kg)

- Problem: resistance to heparin (AT III deficiency)
  - Solution: infuse FFP (2 units) or AT III
- Problem: heparin-induced thrombocytopenia (HIT)
  - Solution: consider alternative anticoagulants (hirudin, bivalirudin, argatroban)
- Problem: previous administration of glycoprotein IIb/IIIa inhibitors (abciximab [RheoPro] or tirofiban [Aggrastat]) or ADP receptor antagonist clopidogrel (Plavix)
  - Solution: aminocaproic acid (5–10 g followed by 1 g/h) or tranexamic acid (10 mg/kg followed by 1 mg/kg/h)

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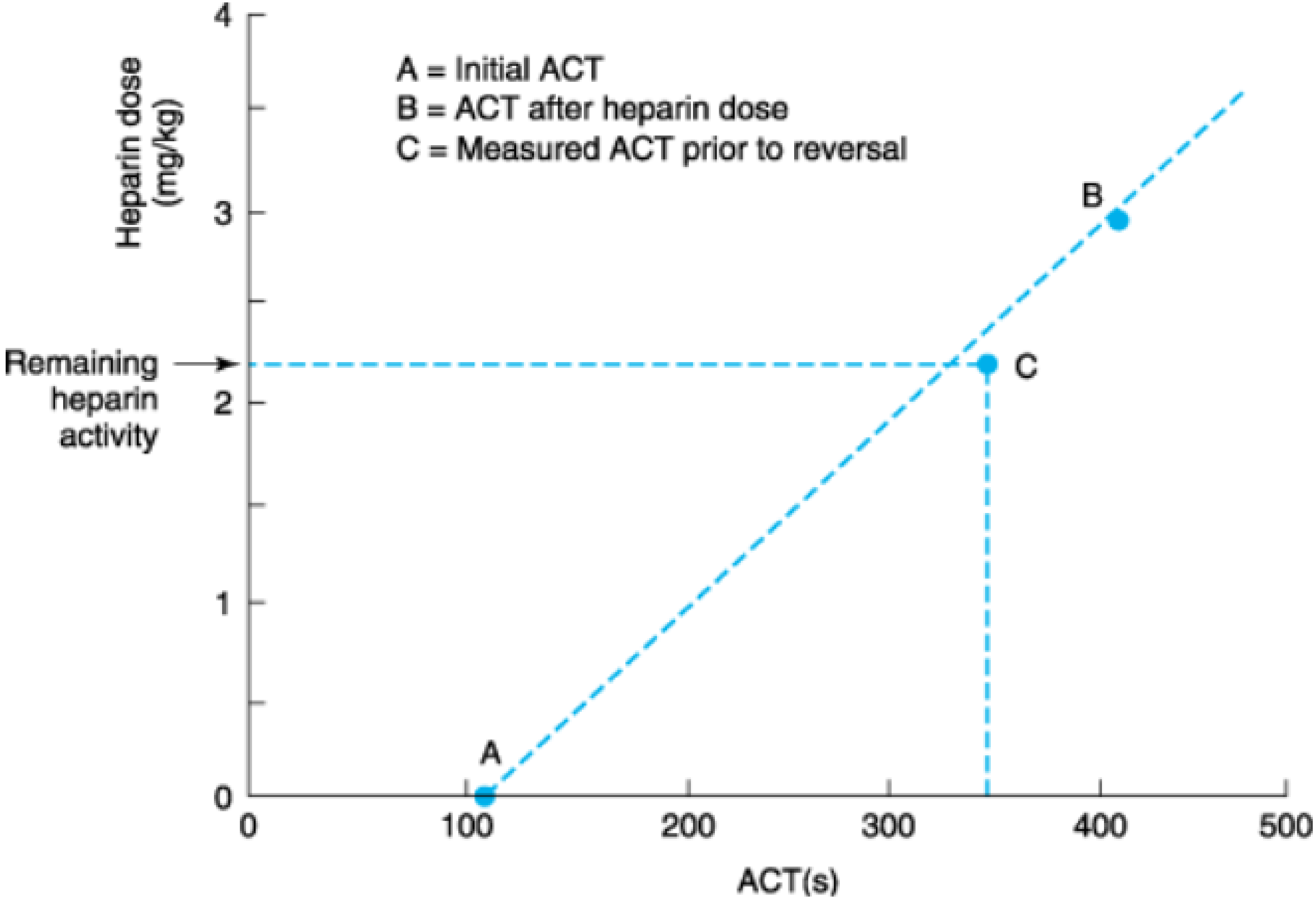
ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Anticoagulation:



ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Management of Respiratory Gases

- Problem: the solubility of a gas increases with hypothermia
  - As a result, the partial pressure of the gas will decrease
  - most significant for $PaCO_2$ (effect on cerebral blood flow)
- *Example: Blood with $PaCO_2$ of 5 kPa and a pH of 7.40 at 37°C, when cooled to 25°C, will have a $PaCO_2$ of about 2.6 kPa and a pH of 7.60*

ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Management of Respiratory Gases

- Problem: blood samples are heated to 37°C in blood gas analyzers

- Solution 1: pH-stat management
  - Temperature correcting gas tensions and maintaining a "normal" $PaCO_2$ of 40 mm Hg and a pH of 7.40 during hypothermia
  - May require adding CO_2 to the oxygenator
  - Increases total blood CO_2-content
  - Impairs cerebral blood flow autoregulation

- Solution 2: α-stat management (more common)
  - Use of uncorrected gas tensions during hypothermia
  - Preserves cerebral autoregulation of blood flow

ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Troubleshooting during CPB

- Problem: after start of CPB, venous reservoir empties (air enters pump circuit)
- Solution: check venous return:
  - forgotten clamps?
  - Cannula malposition?
  - Kinking?

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ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Troubleshooting during CPB

- Heart does not empty
  - Solution: aortic regurgitation? Malpositioning of the venous cannula?

- MAP decreases <30 mmHg
  - Solution: search for unrecognized aortic dissection, recannulate aorta (distal)

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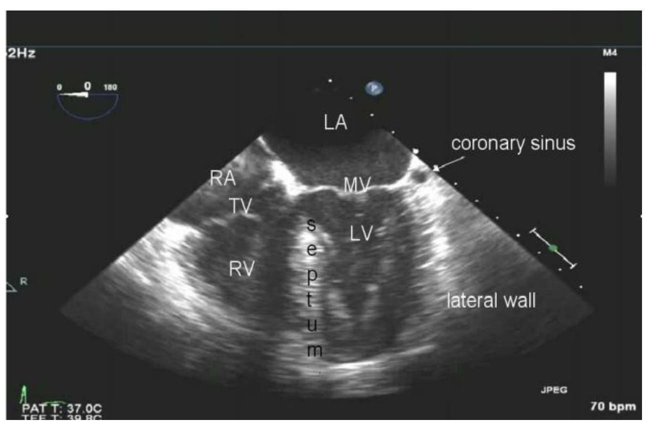
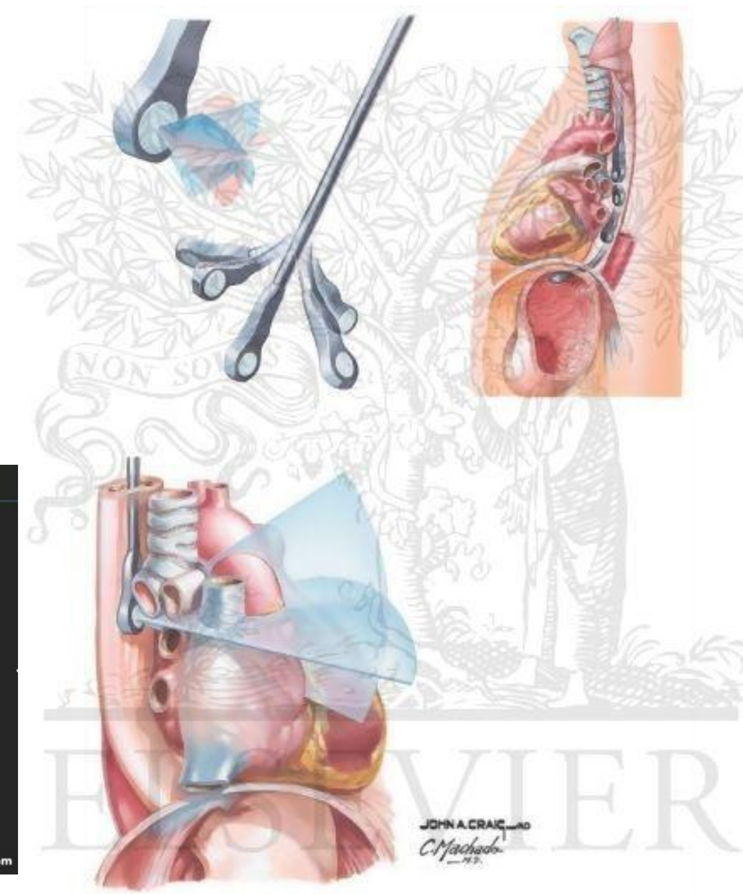
Monitoring: Transesophageal Echocardiography (TEE)

TEE provides extremely valuable information about

- Cardiac anatomy and
- Cardiac function during surgery (valvular function, pump function, ischemia, hypovolemia)
- Surgical result, need for re-intervention





Monitoring: Transesophageal Echocardiography (TEE)

Future: 3D echo

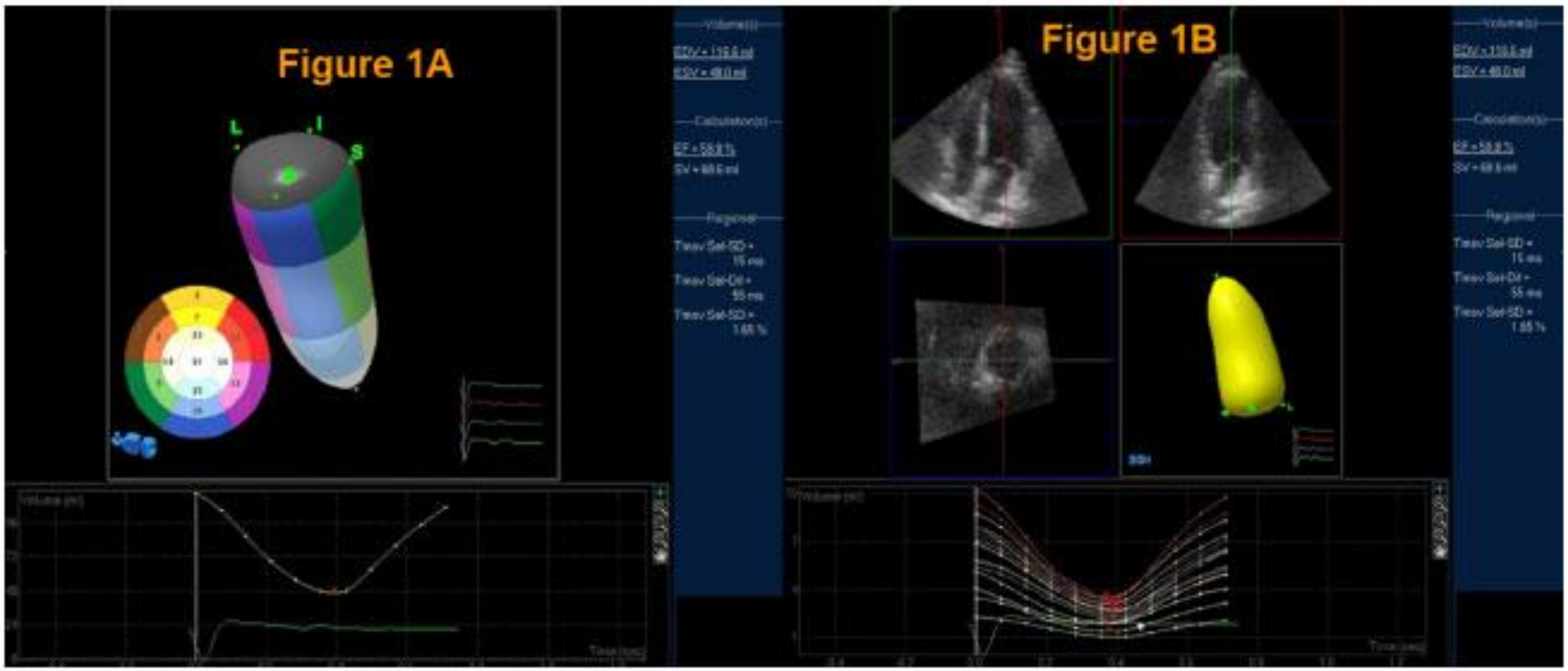


Figure 1 - Three-dimensional echocardiographic image of the left ventricle (17-segment model, Figure 1A), with measurements of ventricular ejection fraction and volumes. Volume and ejection fraction measurements were derived from the two-dimensional echocardiography (Figure 1B) as analyzed in multiple observation planes.

CARDIOPULMONARY BYPASS

Weaning from CPB (preparation):

- A "hot shot" or warm blood cardioplegia can be administered
  - To wash out byproducts
  - Replenish metabolic substrates
- Optimise physiological conditions
  - Acidosis and hypoxia should be corrected
  - Lung ventilation must be resumed
  - Normothermia (≥36°C) should be achieved
  - Normovolemia should be achieved
  - Hb should be kept ≥5 mmol/L

Weaning from CPB (preparation):

- Surgeon unclamps the aorta
  - Washes out cardioplegia (heart re-starts)
- Re-start pulmonary ventilation
- Continue CPB additional 5 – 10 mins after heart re-start
  - Keep heart in empty and beating state
  - Stabilizes heart, minimal metabolic requirements
- A stable rhythm (preferably sinus) must be present
  - Atrioventricular pacing may be necessary (80–100 bpm)
- TEE monitoring (chamber vols, contractility, valvular function)

CARDIOPULMONARY BYPASS

Weaning problems:

•Problem: residual air (TEE, ECG)?

•Solution:

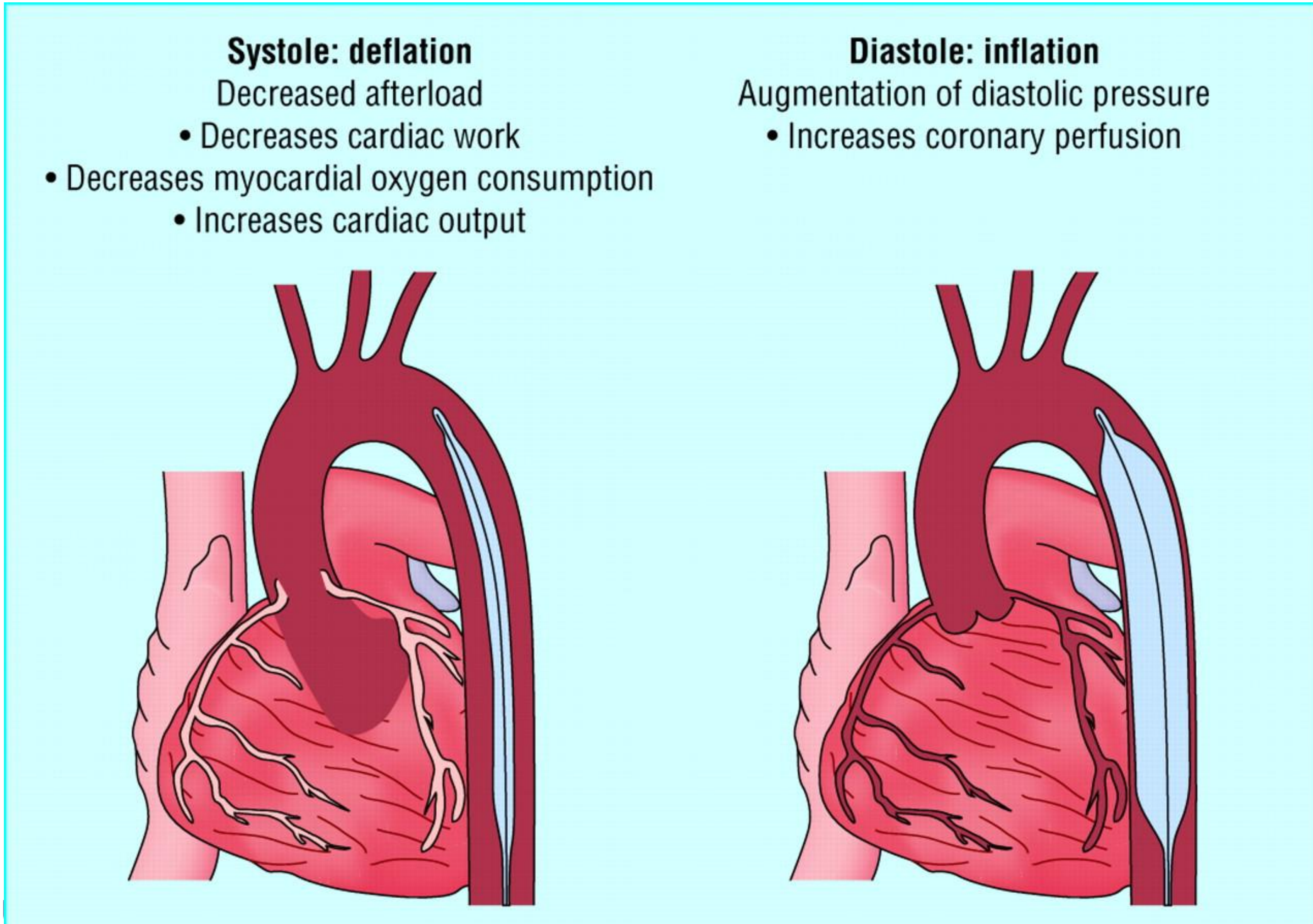
- Evacuate air from the heart and any bypass grafts
- increase perfusion pressure (norepinephrine)

CARDIOPULMONARY BYPASS

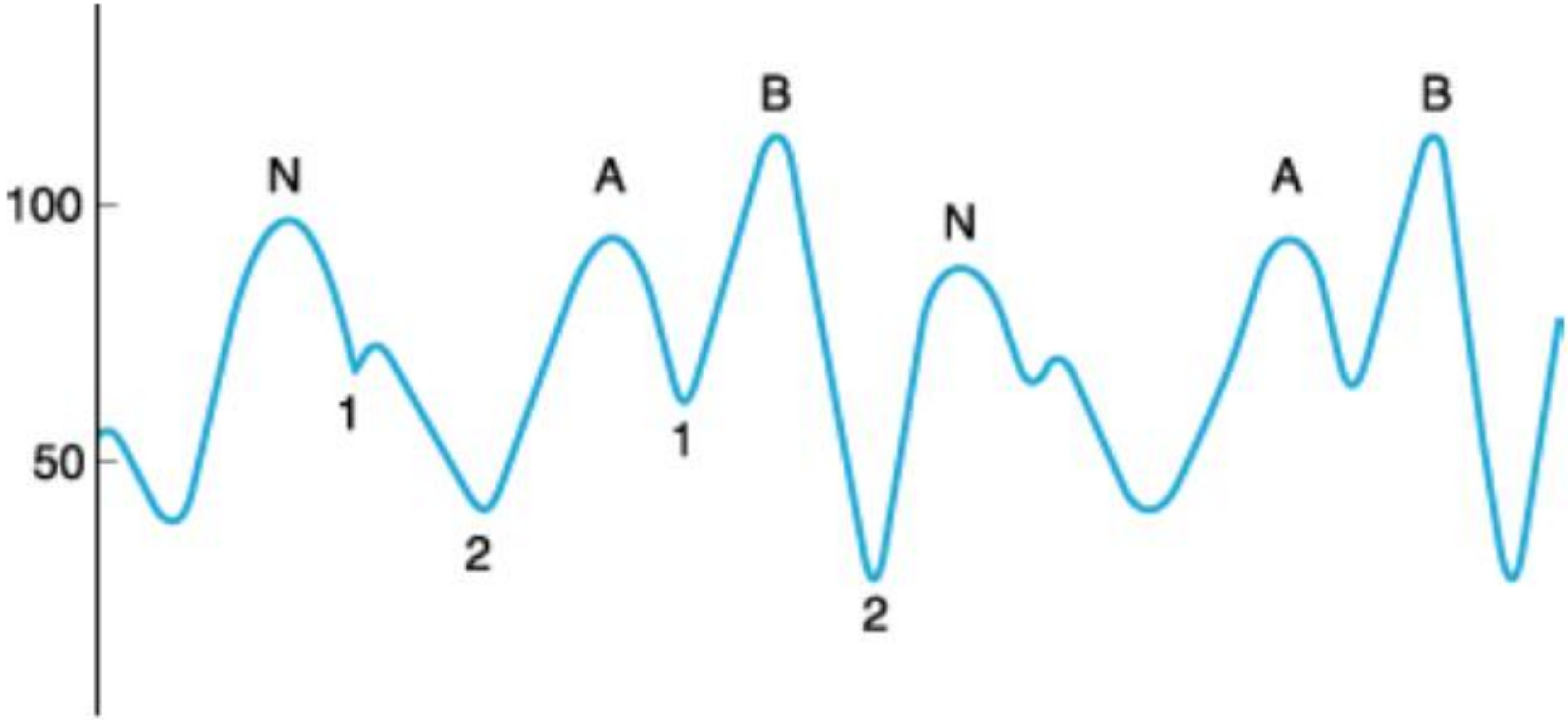
Weaning problems:

- Poor cardiac function
  - Consider inotropic support:
    - dobutamine (1st choice)
    - milrinone (esp. right ventricular failure)
    - Norepinephrine
    - (epinephrine, dopamine)
    - Levosimendan (not approved in NL)
  - Consider reperfusion
  - Consider afterload reduction (nitroprusside, milrinone)
  - Consider intraaortic balloon pump (IABP)
  - Consider left or right ventricular assist device

Intraaortic balloon pump



Intraaortic balloon pump



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ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Reversal of anticoagulation:

- Protamine binds and effectively inactivates heparin
- Dose: 1 mg of protamine per mg of (initial) heparin
- Infuse slowly
    - Hemodynamic side-effects
        - Hypotension (vasodilation)
        - myocardial depression
        - pulmonary hypertension
        - Allergic reactions
- Check effect with ACT
- Consider supplemental protamine (50–100 mg) after administration of CPB blood

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PATHOLOGICAL EFFECTS OF CARDIOPULMONARY BYPASS

- **Underlying problems**
  - Age
  - Comorbidities
  - Procedural complexity
  - Equipment issues
- **Postoperative problems**
  - Stroke, incidence 1-3%, higher in aortic surgery
  - Delirium, incidence 10-60%
  - POCD, incidence 24-53%
  - Longer hospital LOS
  - Higher costs

PATHOLOGICAL EFFECTS OF CARDIOPULMONARY BYPASS

Intra- and Postoperative Predictors of Stroke After Coronary Artery Bypass Grafting

Donald S. Likosky, PhD, Bruce J. Leavitt, MD, Charles A. S. Marrin, MB, BS, David J. Malenka, MD, Alexander G. Reeves, MD, Ronald M. Weintraub, MD, Louis R. Caplan, MD, Yvon R. Baribeau, MD, David C. Charlesworth, MD, Cathy S. Ross, MS, John H. Braxton, MD, Felix Hernandez, Jr, MD, and Gerald T. O'Connor, DSc, PhD, for the Northern New England Cardiovascular Disease Study Group

(Ann Thorac Surg 2003;76:428–35)

- 11,825 CABG Patients, 1.5% Incidence of Stroke
- 75% of strokes occurred among low or medium preoperative risk patients
  - Many of these strokes may be preventable
  - Traditional pre-op risk assessment is unreliable
  - Additional intraoperative monitoring (e.g. NIRS) may be of value

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Cerebral Oxymetry

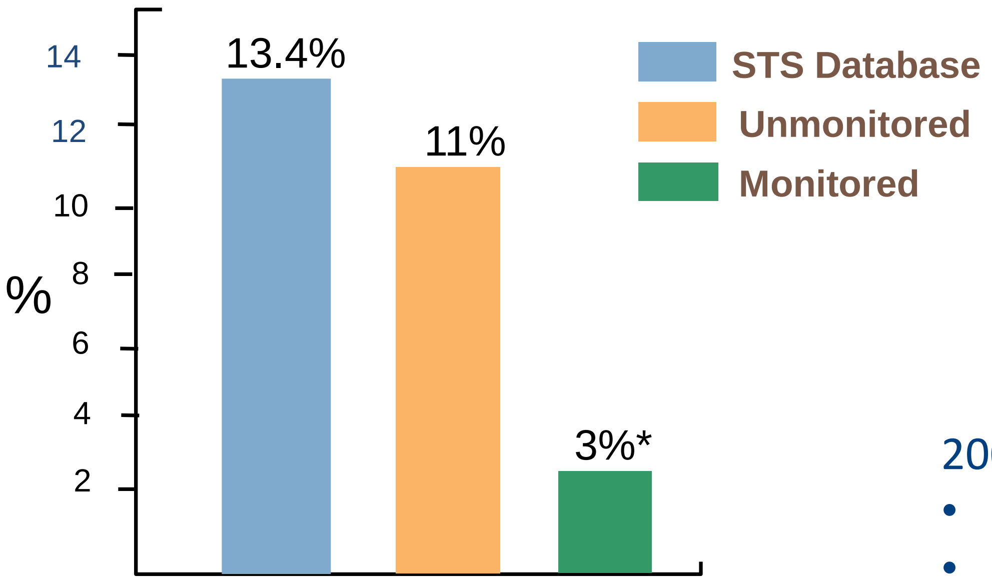
Changes in INVOS values are influenced by the critical balance between arterial oxygen delivery and cerebral consumption.

Imbalances are identified by changes in rSO_2.

Cerebral Oxymetry: Results

Monitoring Brain Oxygen Saturation During Coronary Bypass Surgery: A Randomized, Prospective Study

Murkin JM, et al. Anesth Analg. 2007 Jan;104(1):51-8.



Morbidity (p <0.048)

200 CABG patients;

- 100 blinded rSO_2 monitoring
- 100 intervention protocol

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PATHOLOGICAL EFFECTS OF CARDIOPULMONARY BYPASS

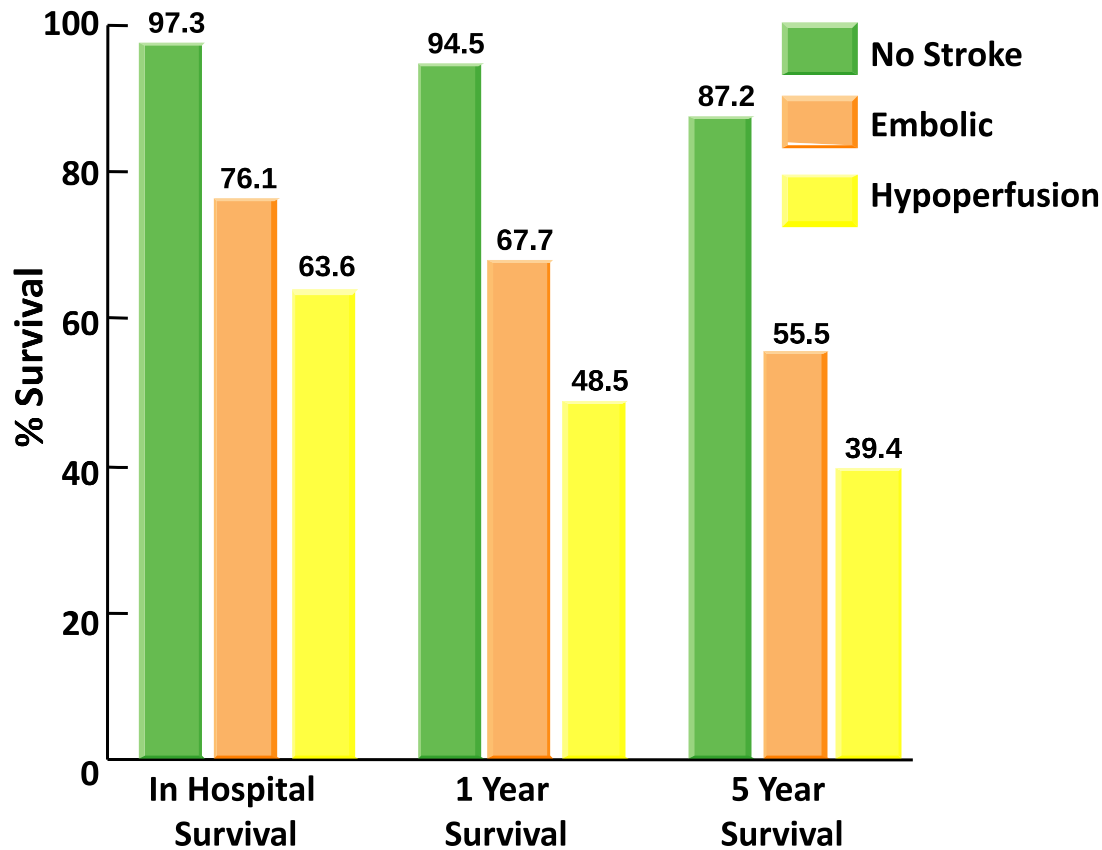
Perioperative Stroke and Long-Term Survival After Coronary Bypass Graft Surgery (Ann Thorac Surg 2005;79:532–7)

Lawrence J. Dacey, MD, Donald S. Likosky, PhD, Bruce J. Leavitt, MD, Stephen J. Lahey, MD, Reed D. Quinn, MD, Felix Hernandez, Jr, MD, Hebe B. Quinton, MS, Joseph P. Desimone, MD, Cathy S. Ross, MS and Gerald T. O'Connor, DSc, PhD, for the Northern New England Cardiovascular Disease Study Group

35,733 CABG patients

Stroke incidence 1.61%

"Patients who had perioperative stroke were at a significantly increased risk for death…Survival at each time point was lowest among patients who had hypoperfusion strokes."



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Any questions?

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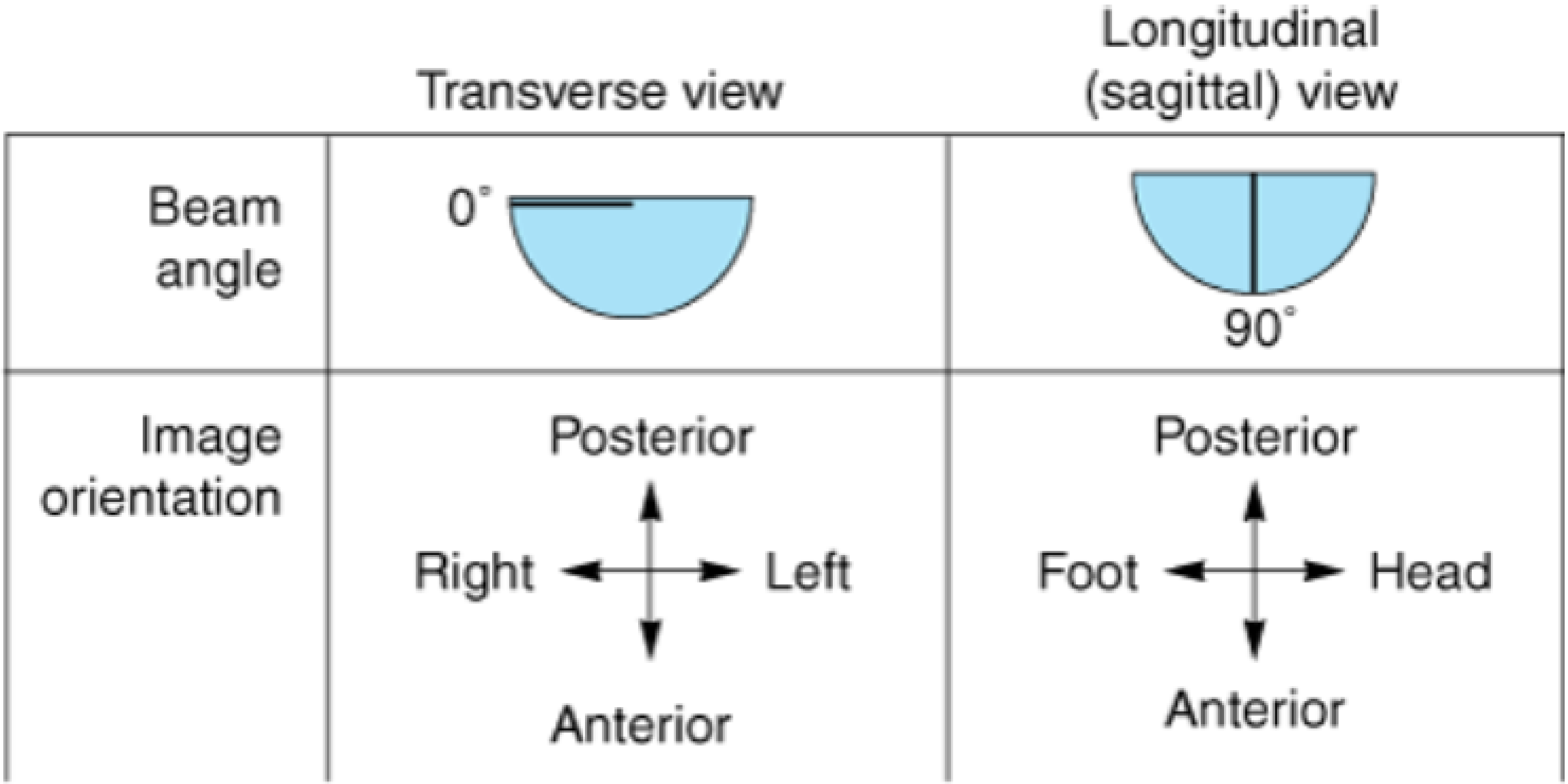
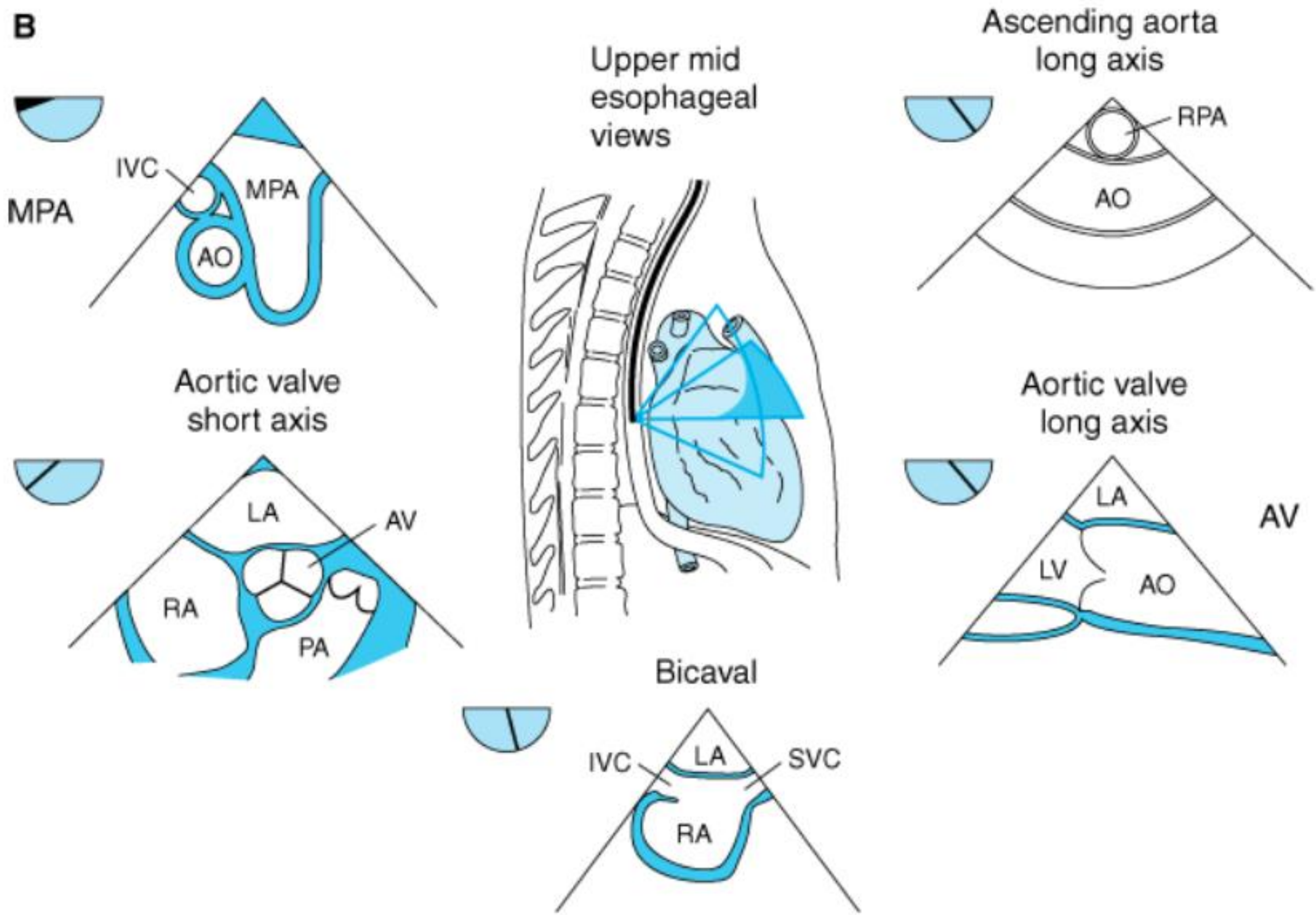
Monitoring: Transesophageal Echocardiography (TEE)



Twodimensional, multiplane TEE: nomenclature

Monitoring: Transesophageal Echocardiography (TEE)



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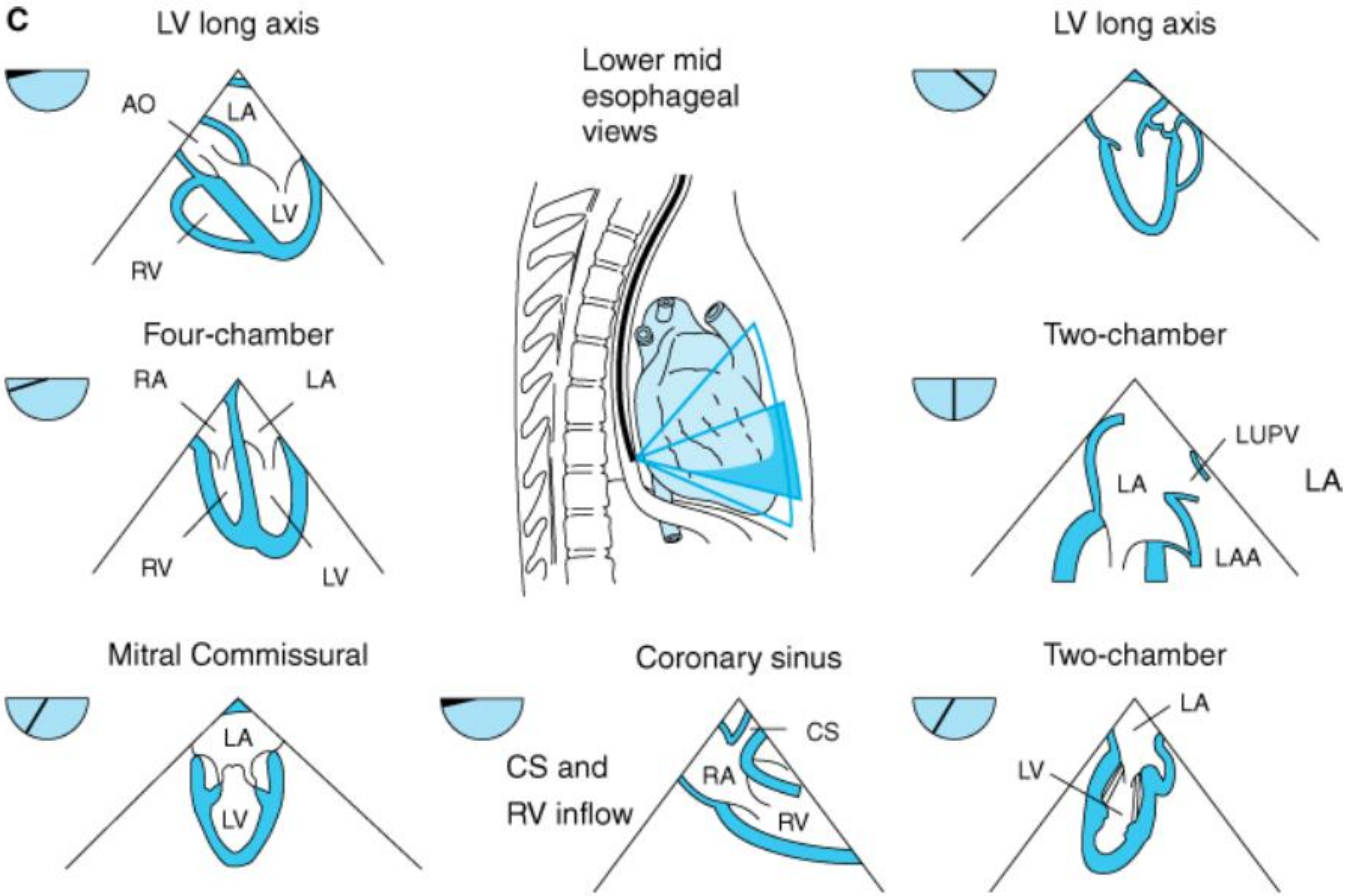

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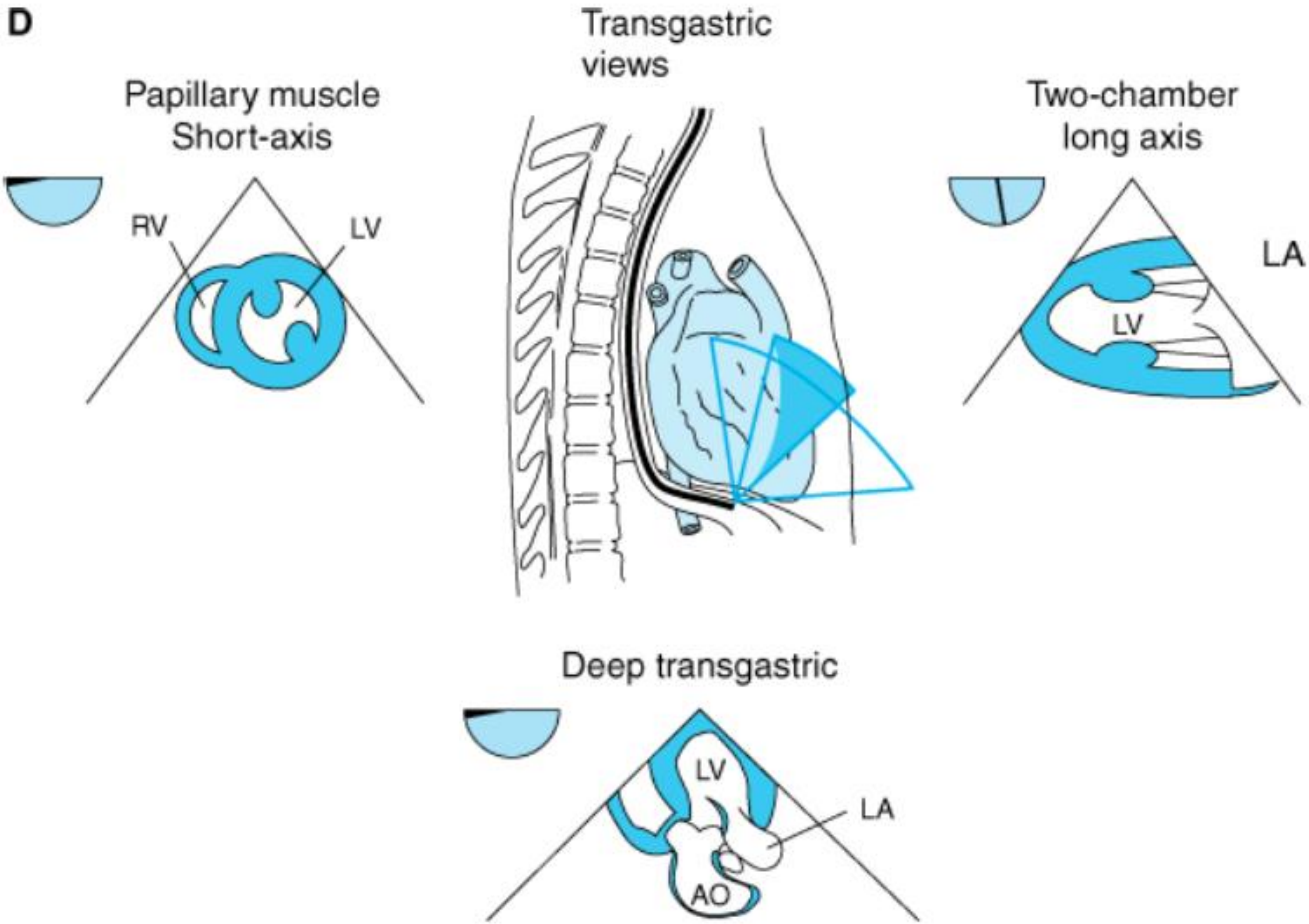

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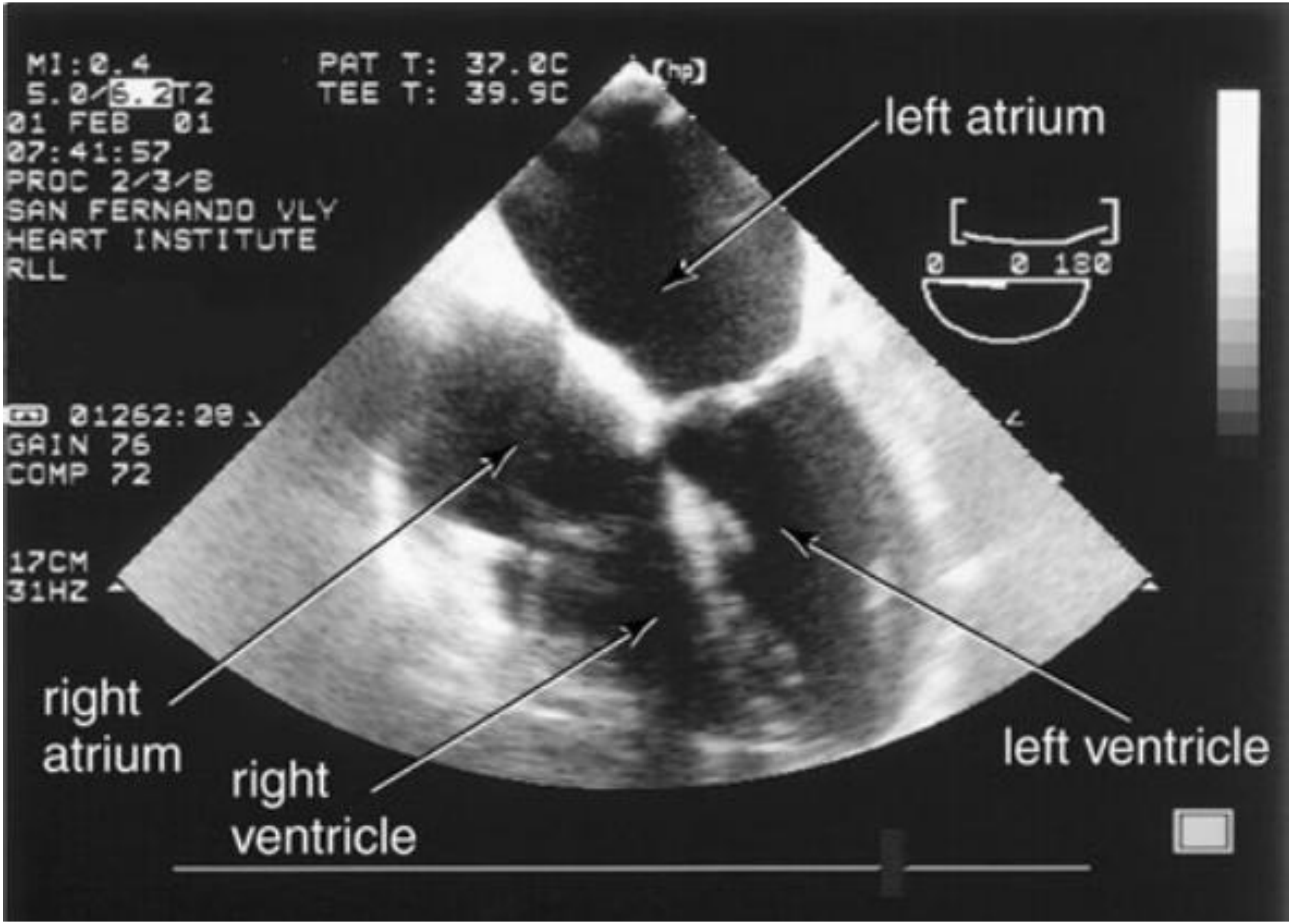

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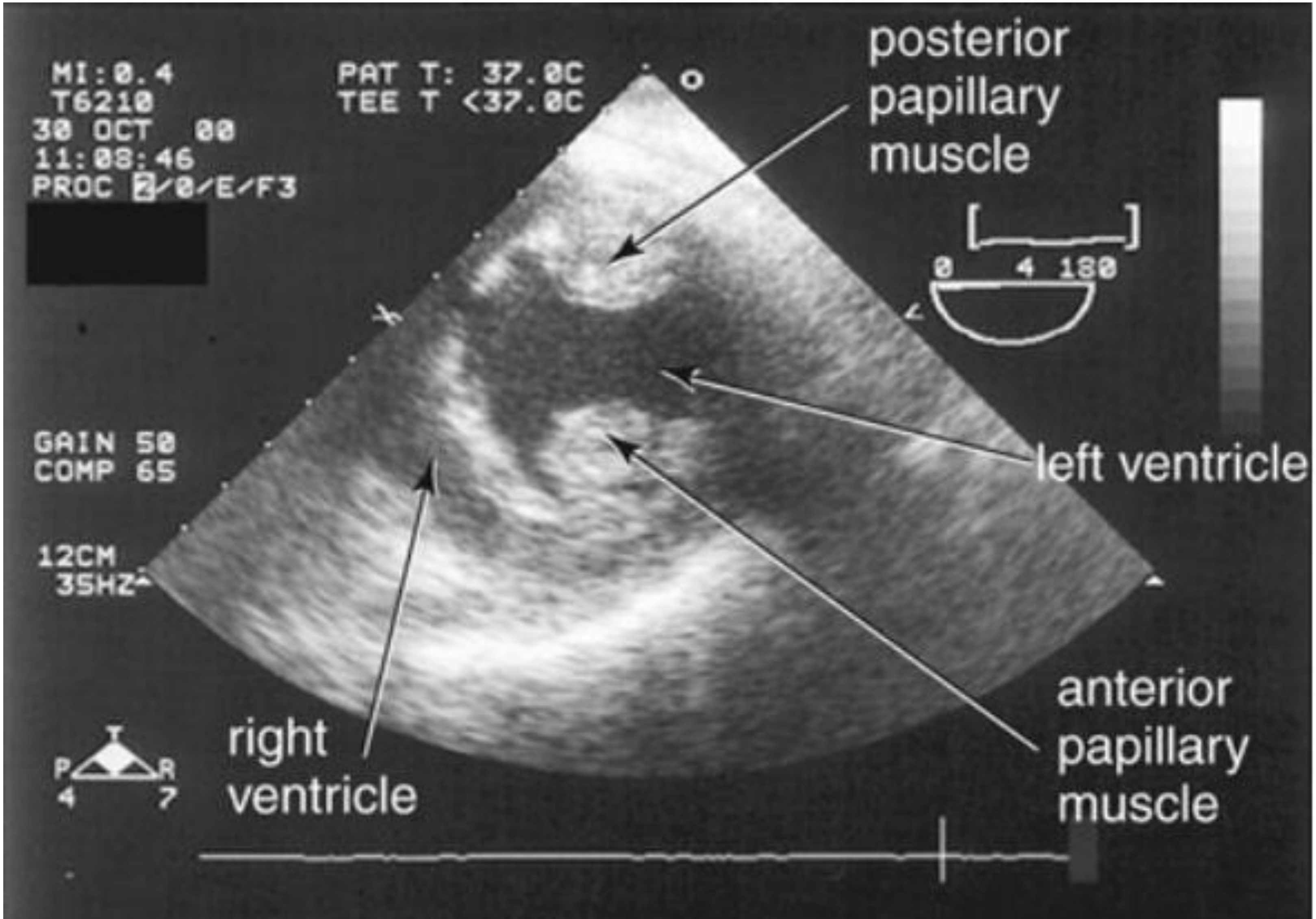

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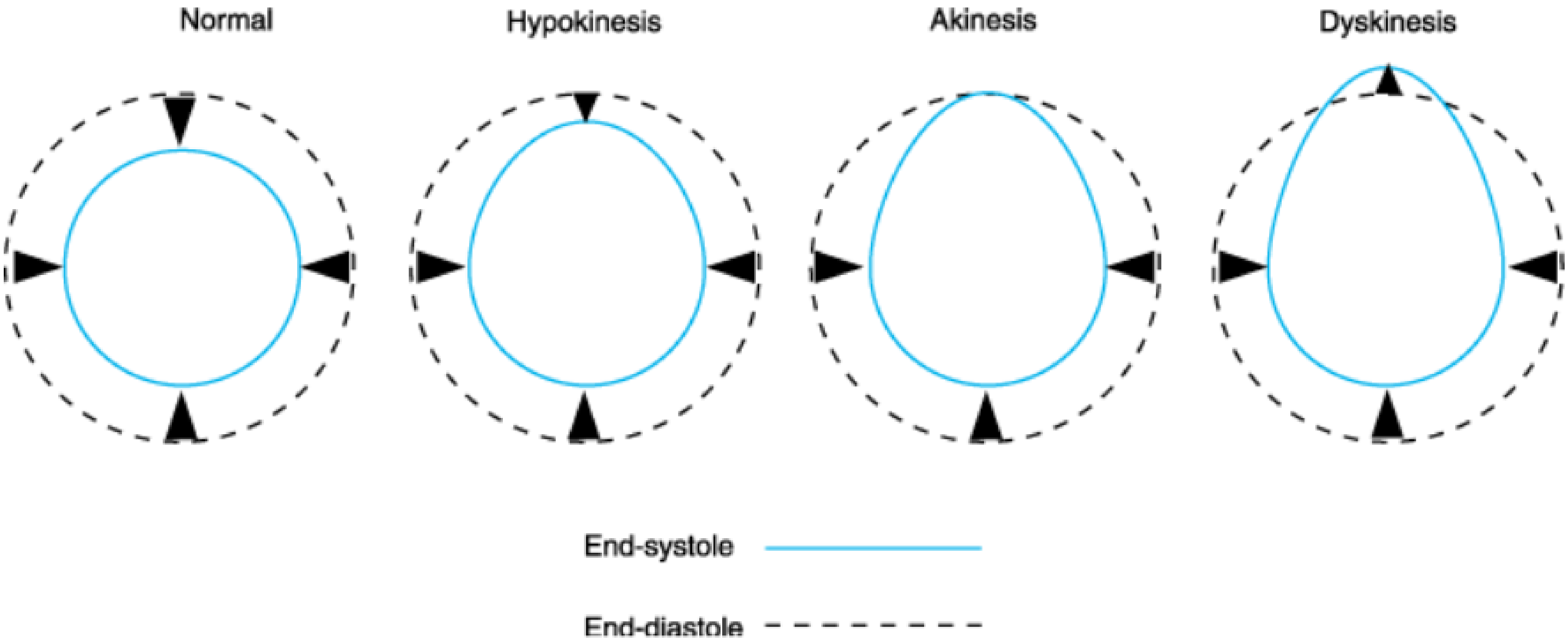
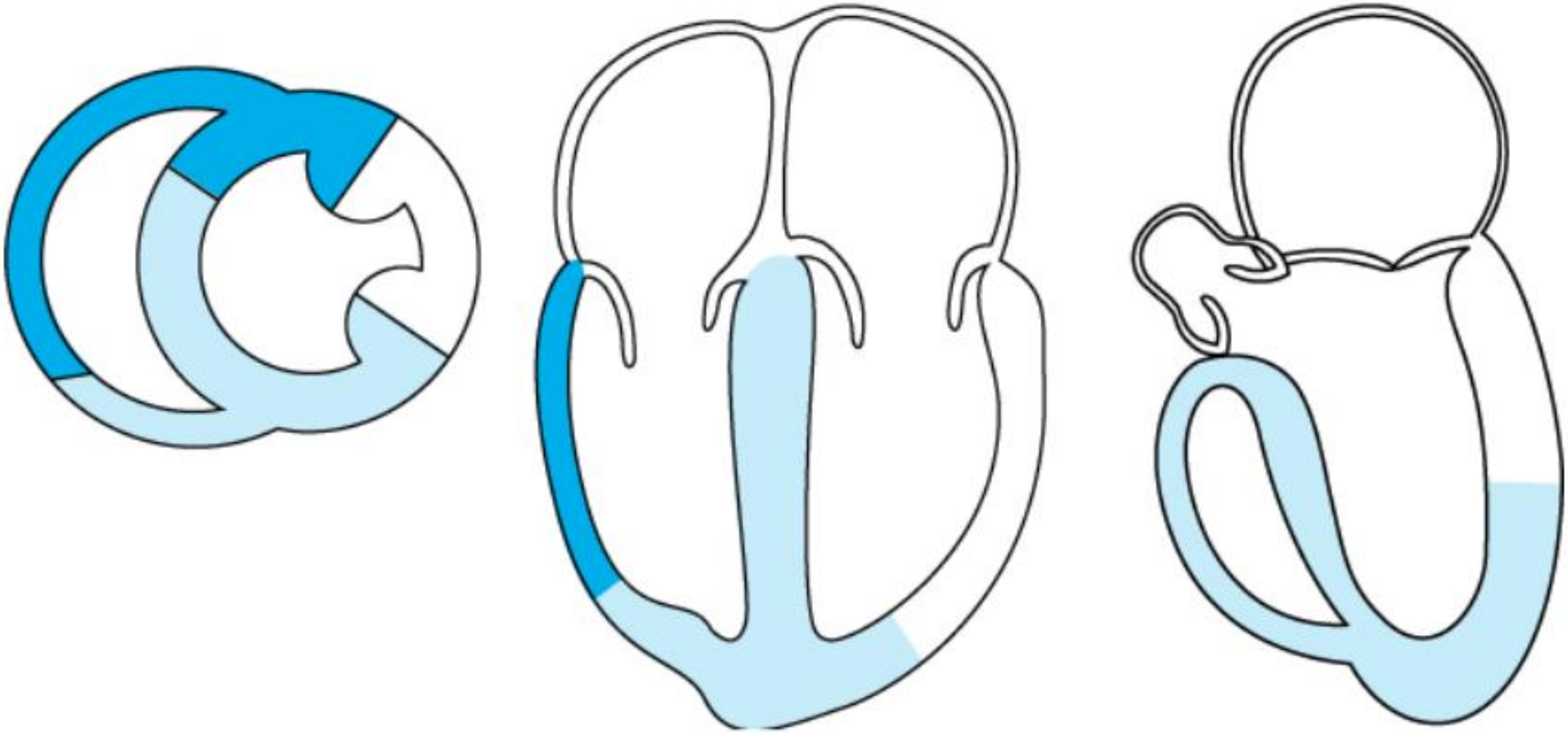
Monitoring: Transesophageal Echocardiography (TEE)

Assessing Ventricular Function



Monitoring: Transesophageal Echocardiography (TEE)

Coronary artery supply of the left and right ventricles



Dark blue, RCA; light blue, LAD; white, CX.

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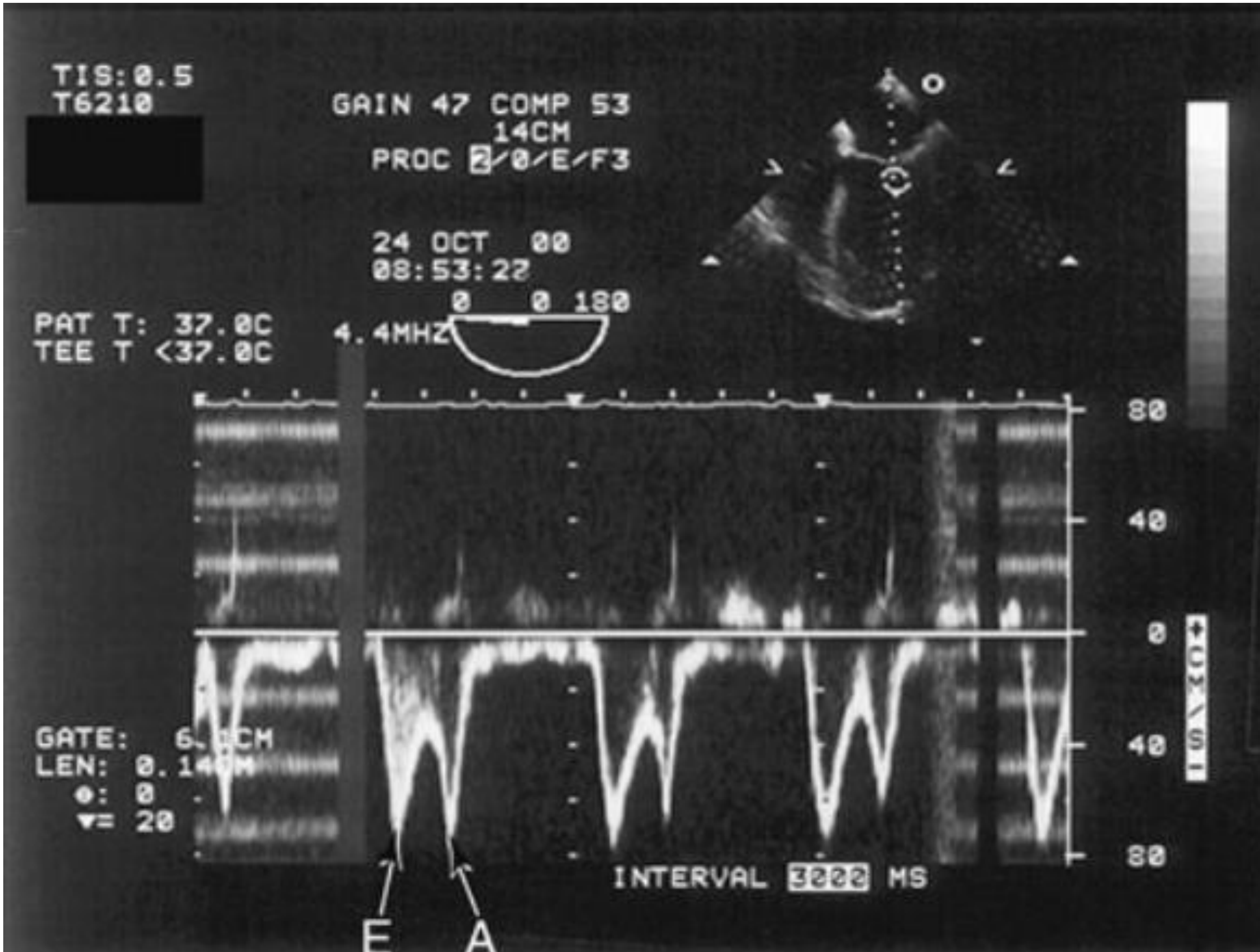
Monitoring: Transesophageal Echocardiography (TEE)

Assessing Valvular Function: MV



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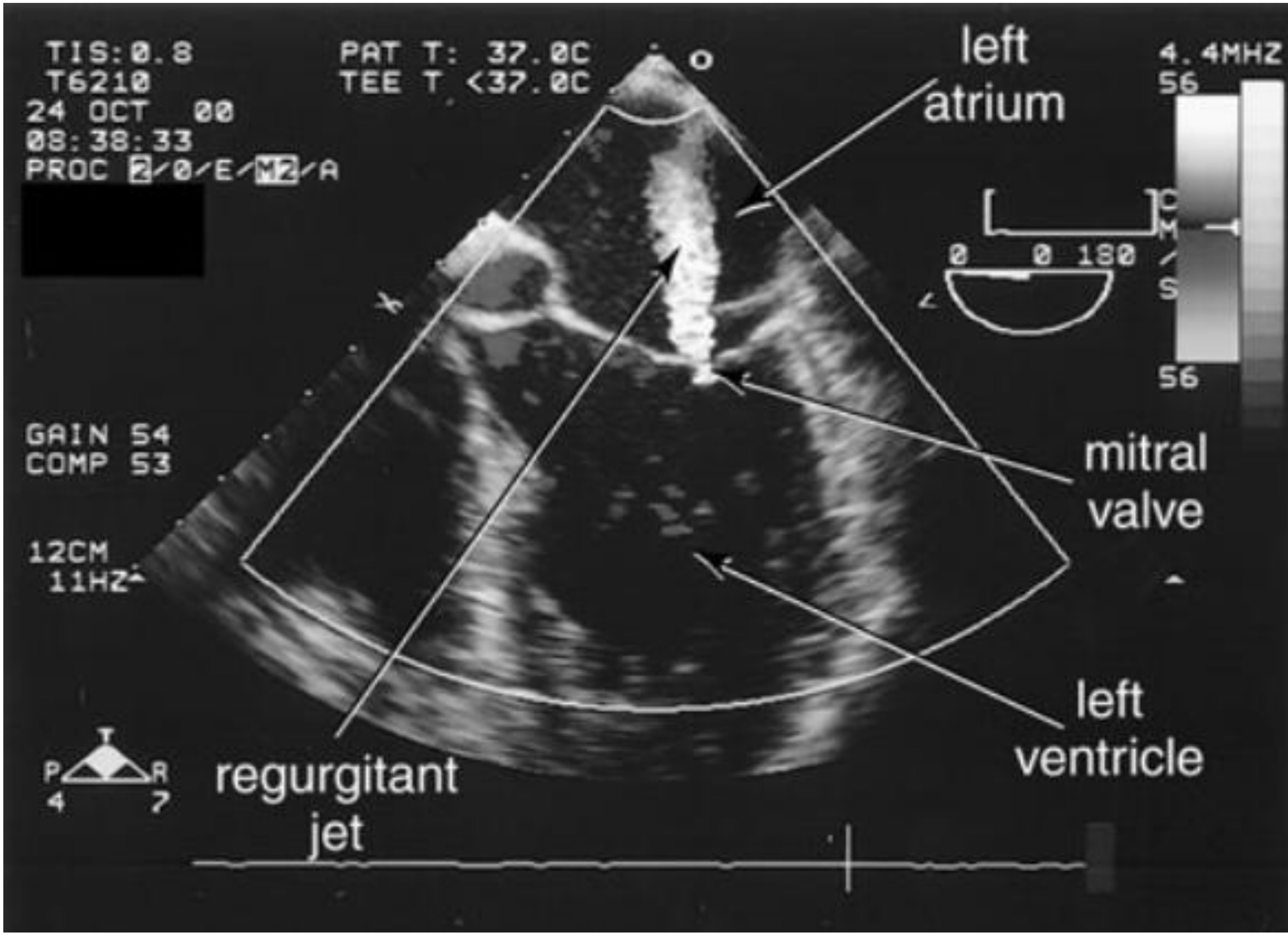
Monitoring: Transesophageal Echocardiography (TEE)

Assessing Valvular Function: MV



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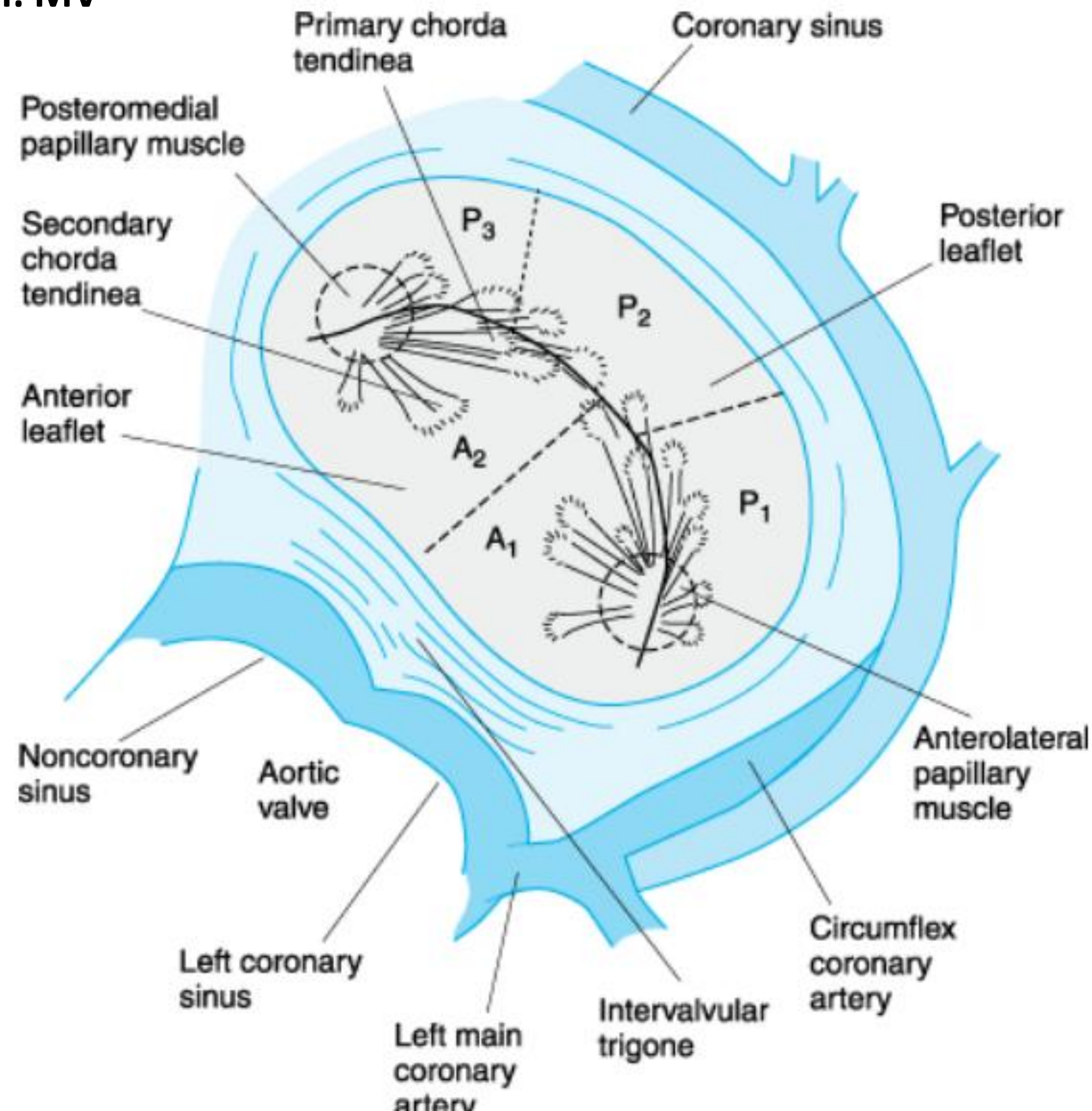

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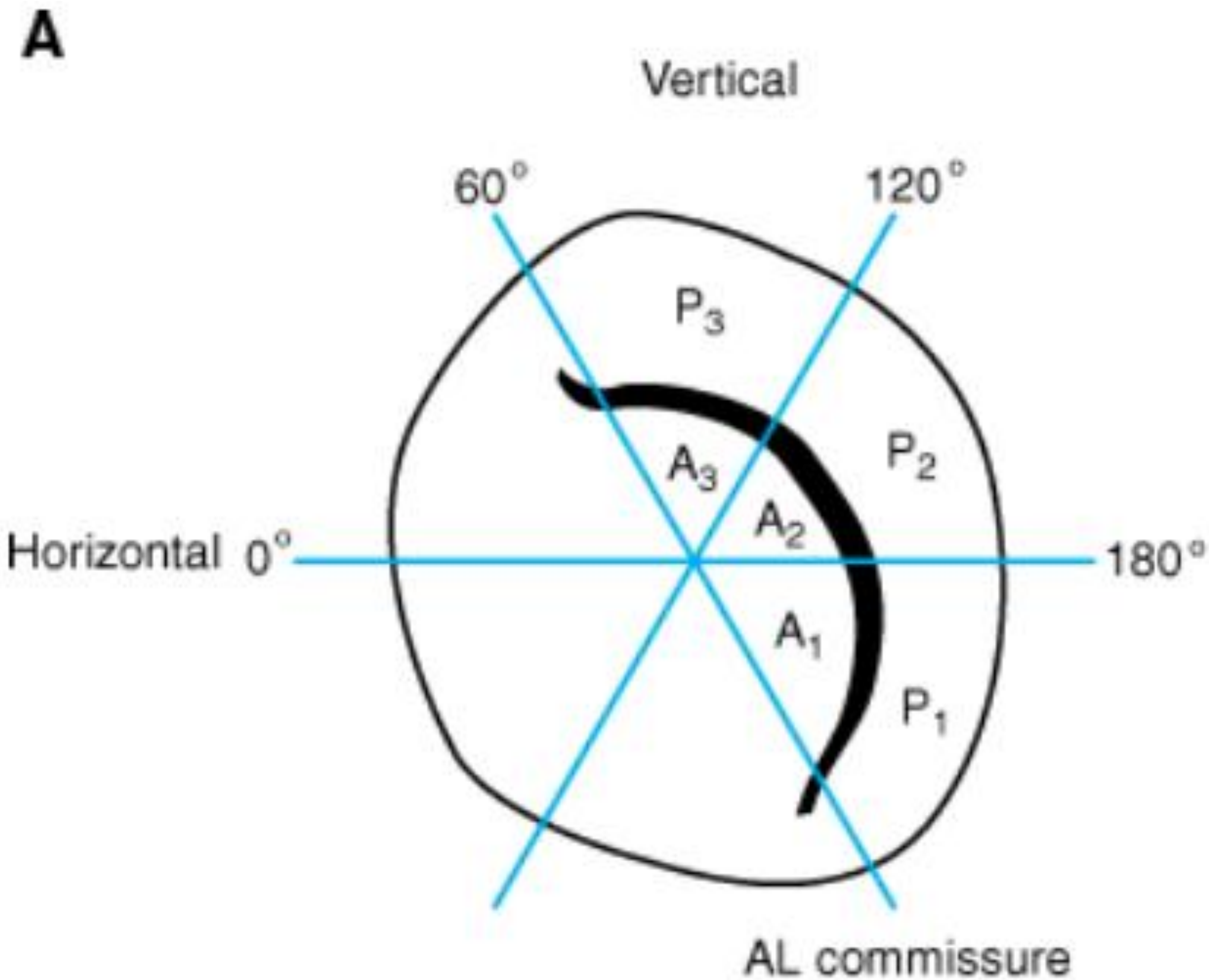

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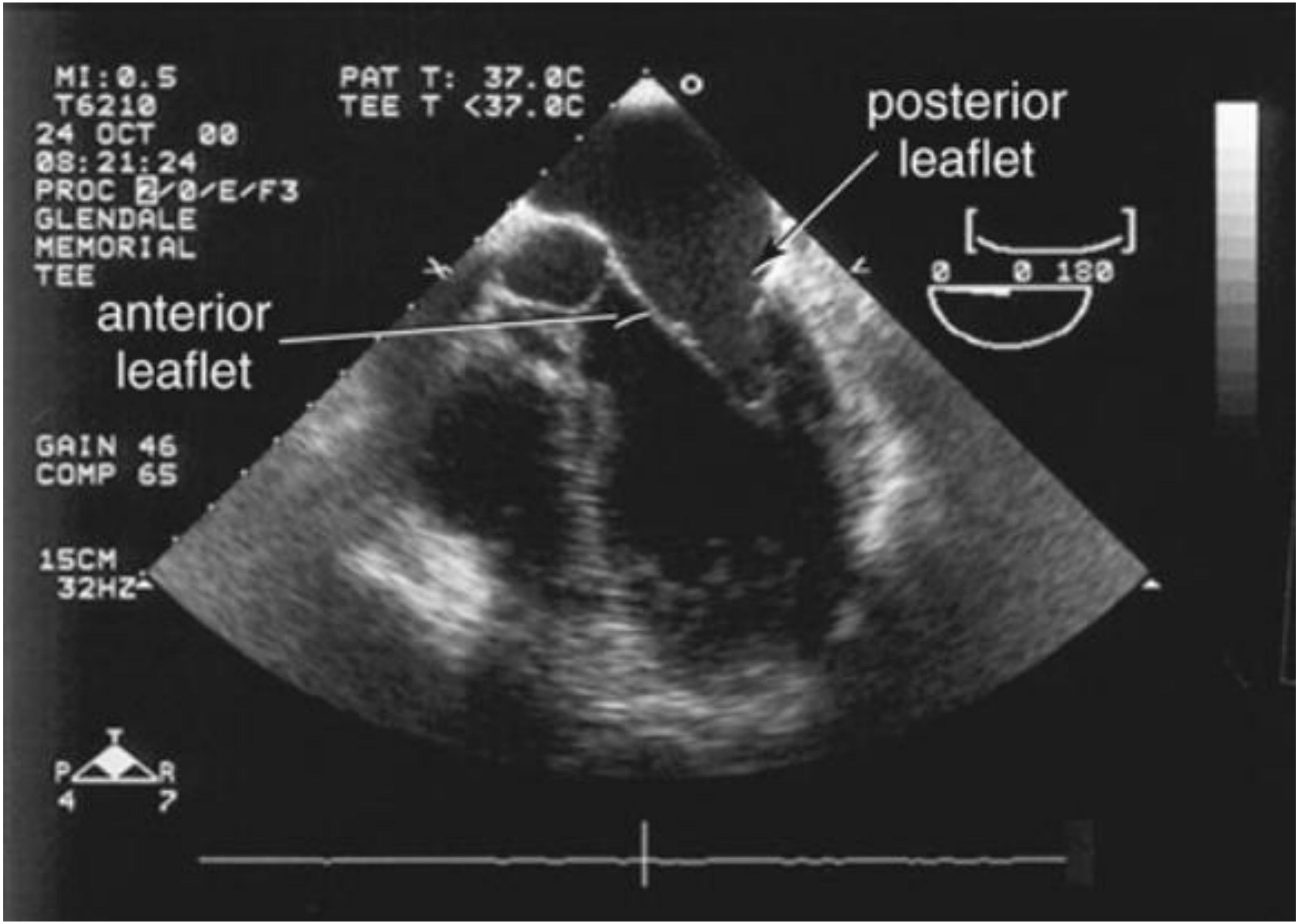

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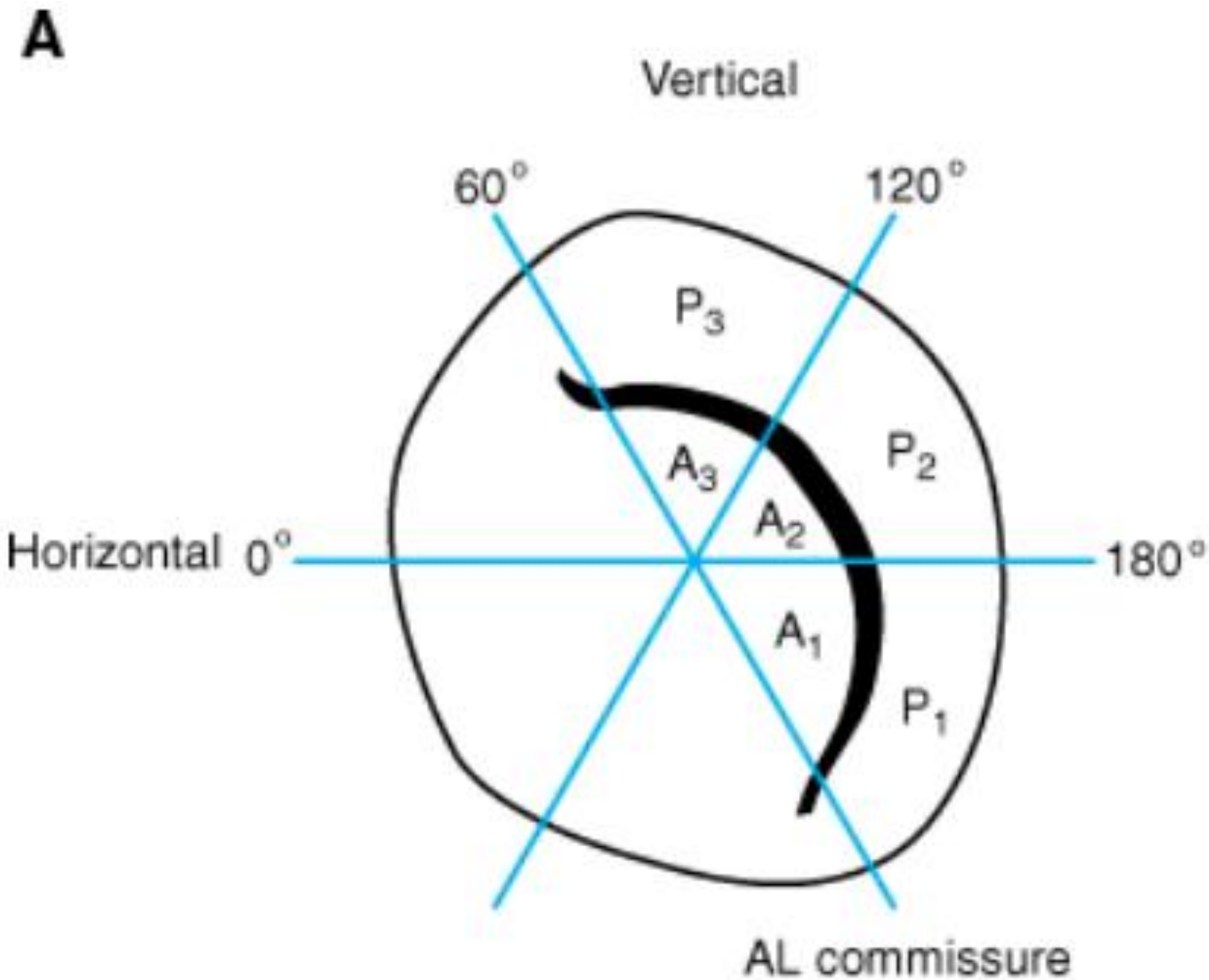

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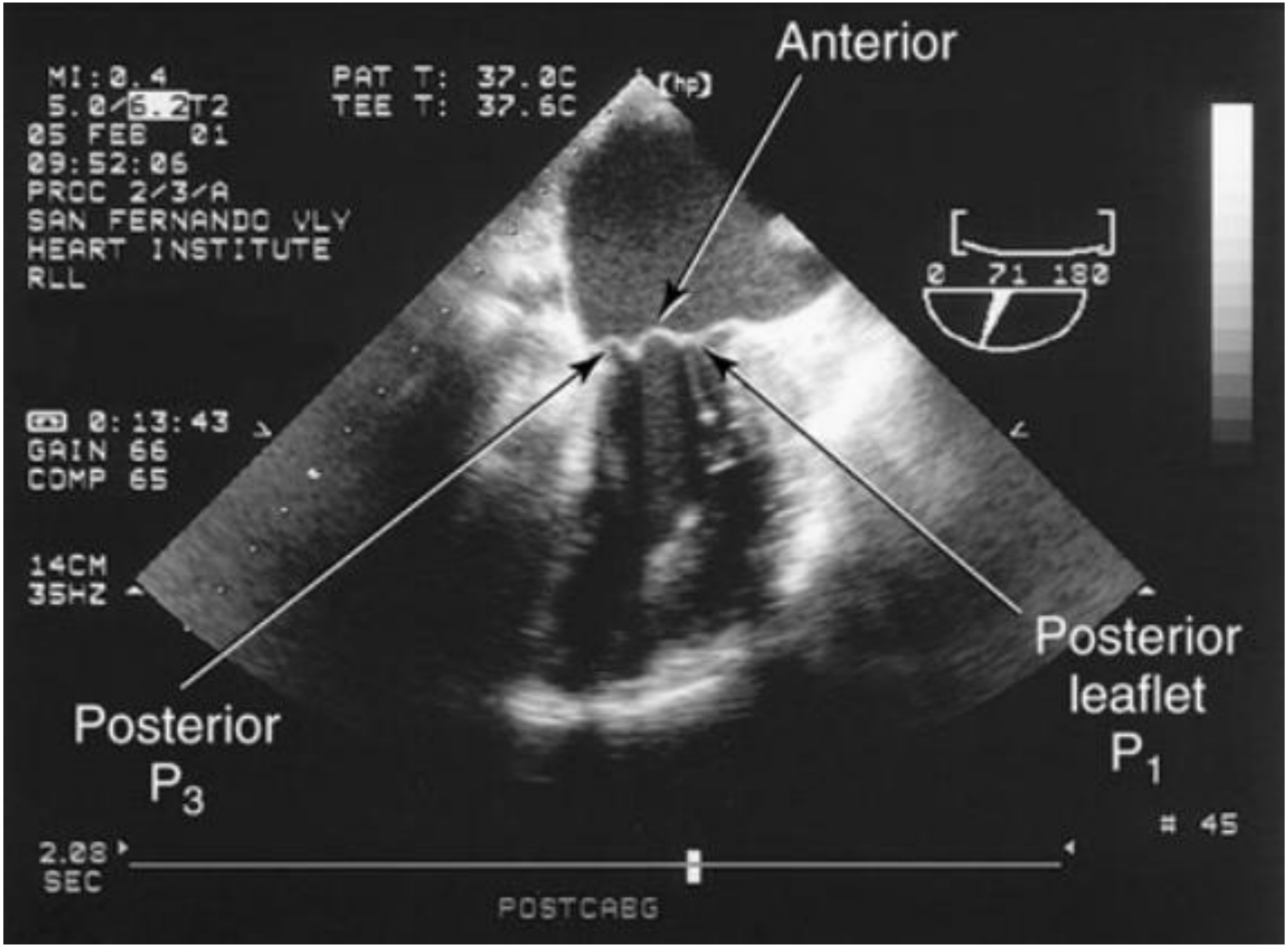
Assessing Valvular Function: MV



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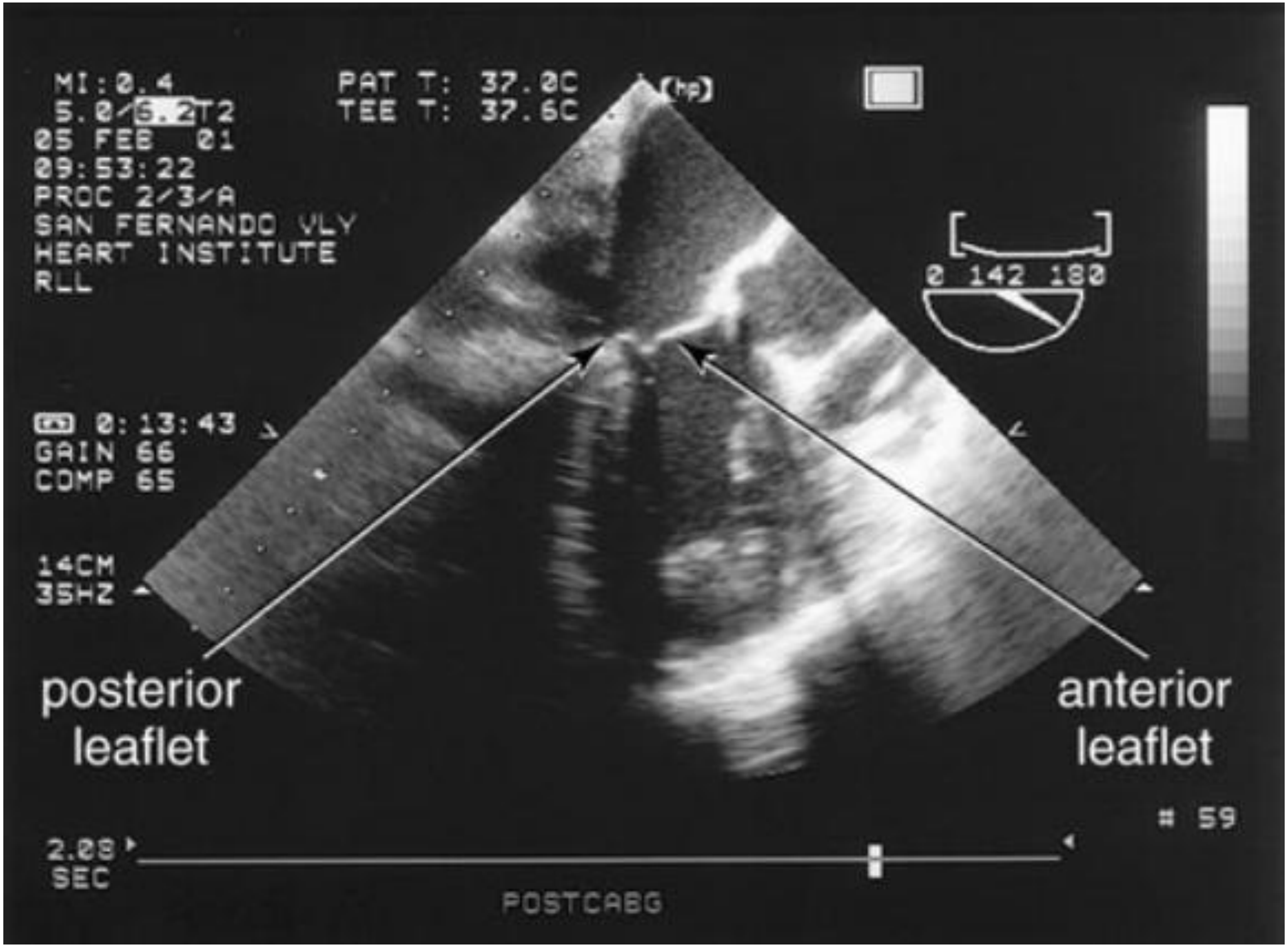
Monitoring: Transesophageal Echocardiography (TEE)

Assessing Valvular Function: MV



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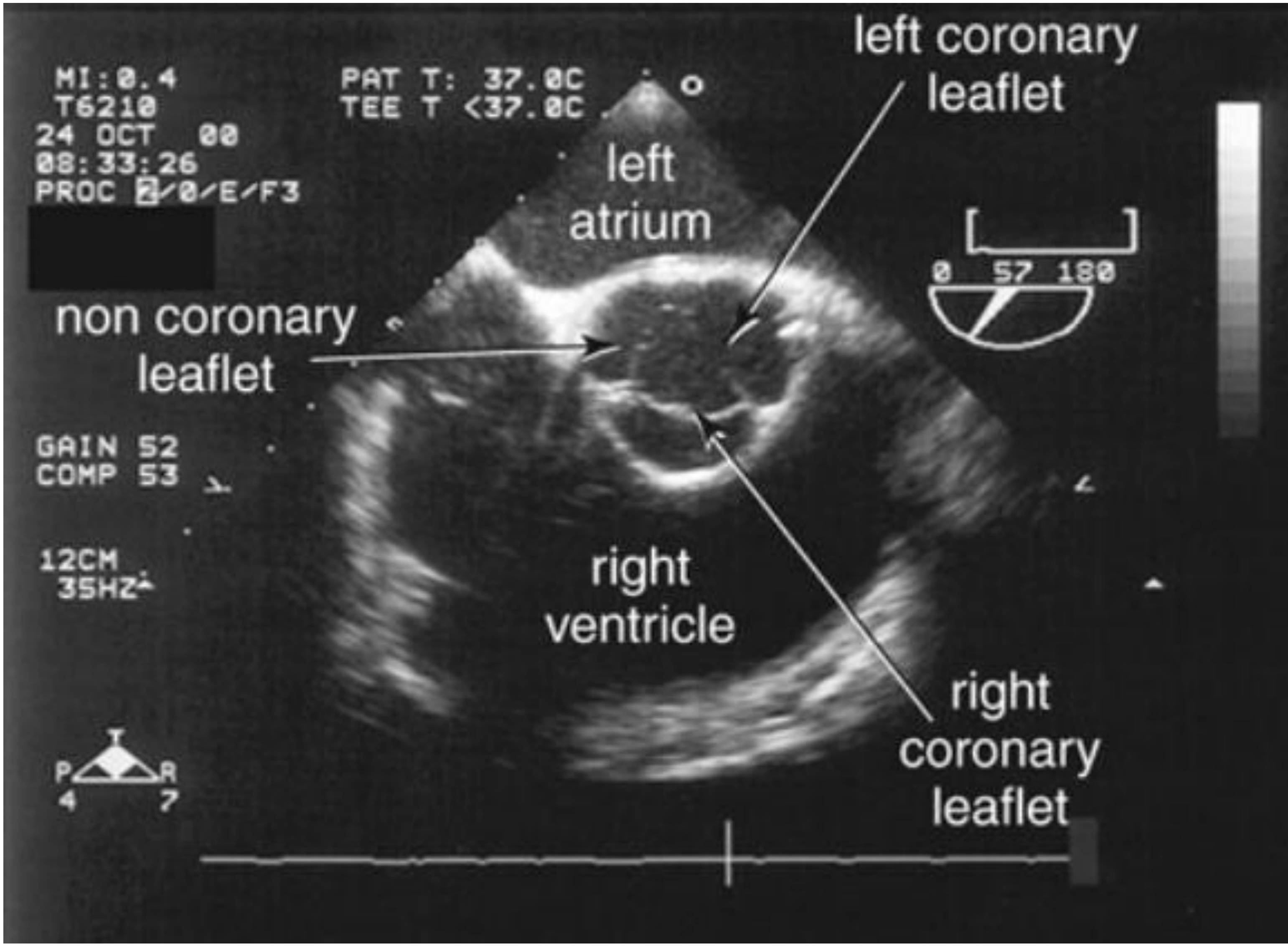
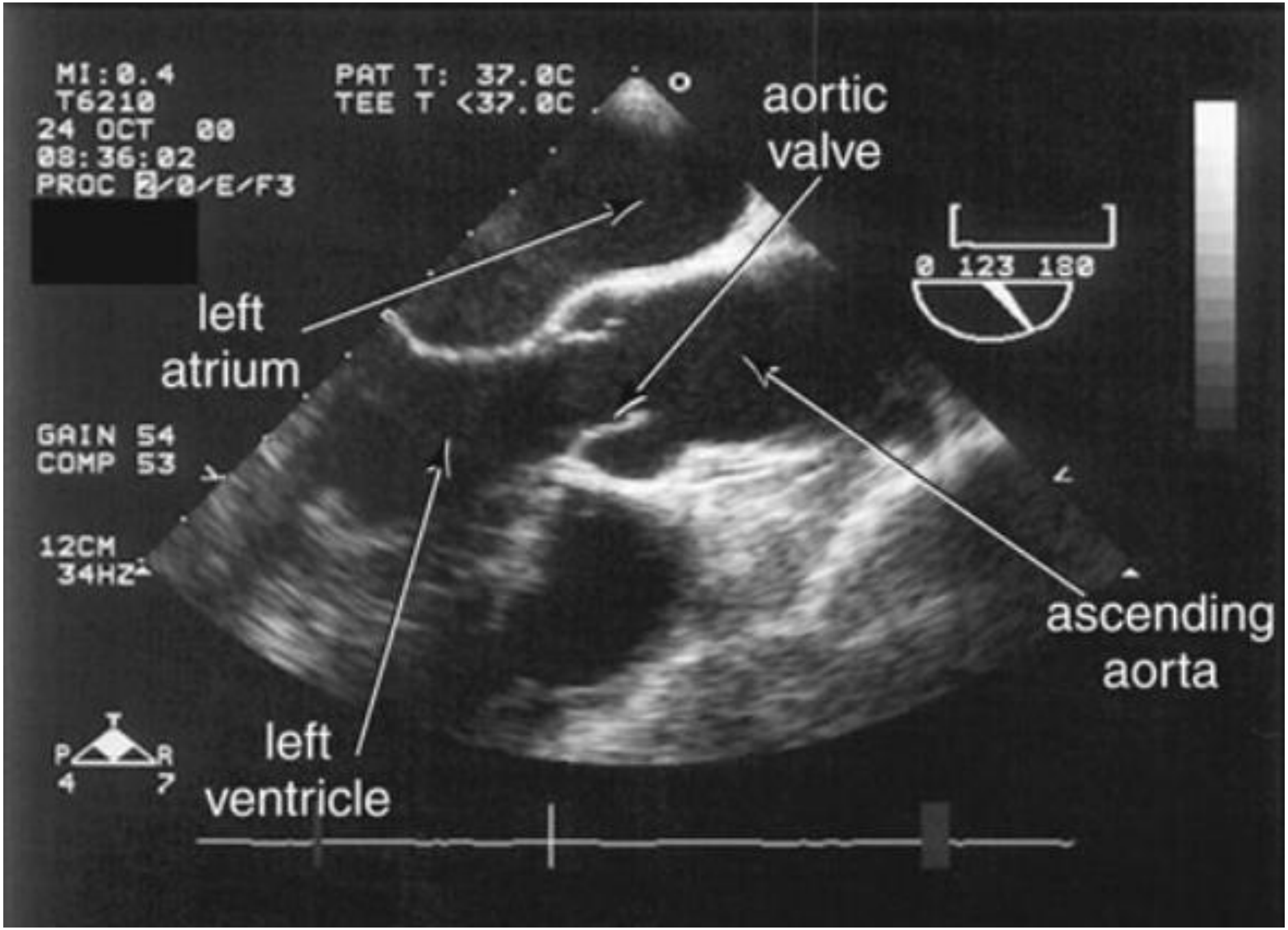
Monitoring: Transesophageal Echocardiography (TEE)

Assessing Valvular Function: AV



Monitoring: Transesophageal Echocardiography (TEE)

Assessing Valvular Function: AV



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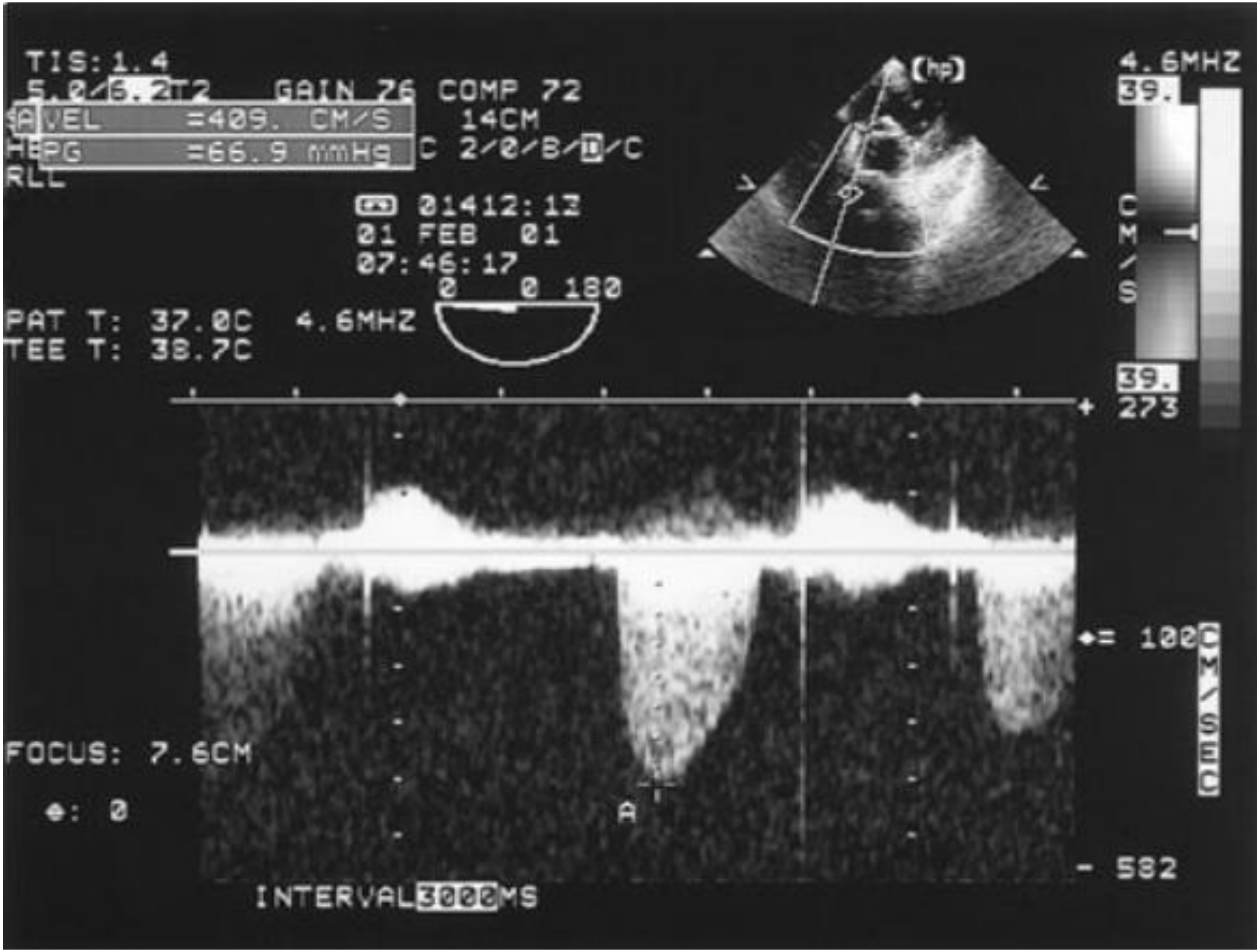
Assessing Valvular Function: AV



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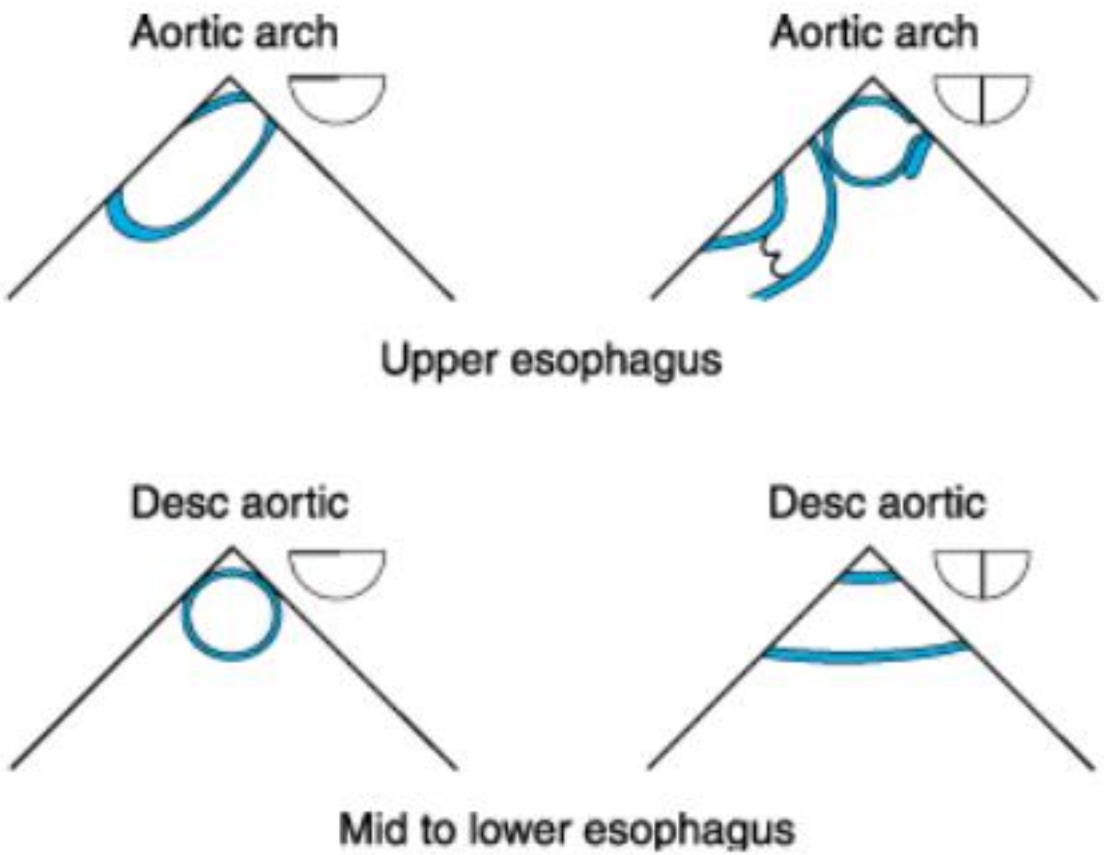
Monitoring: Transesophageal Echocardiography (TEE)

Views of the aortic arch and descending aorta



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