LUMA EDUCATIONAL APPS

ECMO Made Simple

A step-by-step course for nurses and medical providers

2026 Edition | Luma Educational Apps

VV & VA Support · Circuit & Monitoring · Emergencies · Cases

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Educational resource for nurses and medical providers

Contents

Work through the modules in order the first time. After that, use the Bedside Pocket Card and the Emergencies module as quick references at the bedside.

WELCOME

How to Use This Course

This course teaches extracorporeal membrane oxygenation (ECMO) from the ground up for clinicians who care for — or will soon care for — patients on temporary mechanical circulatory and respiratory support. You will finish able to explain VV versus VA support, name the parts of the circuit, recognize common complications, and know what to do in the first minutes of an ECMO emergency.

Who this course is for

- ICU nurses (medical, surgical, cardiac, CTICU, neuro ICU) and float staff new to ECMO
- Nursing students and new graduates building critical-care foundations
- Nurse practitioners, PAs, medical students, residents, and fellows
- Respiratory therapists, perfusionists in training, and ECMO specialists
- CRNAs, SRNAs, and transport clinicians who encounter ECMO patients
- Any medical professional who wants a clear, bedside-first ECMO framework

How each module is built

- Plain-language explanation — what the concept means at the bedside
- Key numbers and terms — the vocabulary and values you must know
- Why it matters — the clinical reason the finding changes care
- What to do — the next nursing and team actions

A note on safety

This is an educational resource from Luma Educational Apps. It is not a substitute for clinical judgment, ELSO center protocols, manufacturer IFUs, prescriber orders, or accredited ECMO training. ECMO is a high-risk therapy. Always follow your facility’s competency pathway, emergency algorithms, and the guidance of the ECMO attending and specialist on duty.

MODULE 1

What ECMO Is and Why It Matters

ECMO (extracorporeal membrane oxygenation) is a form of extracorporeal life support (ECLS) in which a mechanical pump drains blood from the patient, passes it through an artificial lung (membrane oxygenator) that adds oxygen and removes carbon dioxide, and returns the blood to the body. It does not cure the underlying disease — it buys time for the lungs and/or heart to recover, or bridges the patient to transplant, durable device, or decision.

The two jobs ECMO can do

- Gas exchange — oxygenate blood and clear CO_2 when the lungs cannot
- Circulatory support — pump blood forward when the heart cannot generate adequate output (VA configurations)

The three questions ECMO answers at the bedside

- Is oxygen delivery failing despite optimized conventional care?
- Is the problem primarily respiratory (consider VV), primarily cardiac (consider VA), or both?
- Is the failure potentially reversible, or is there a clear bridge destination (recovery, VAD, transplant)?

Where ECMO sits among support options

Level	Examples	What it supports
Conventional	O_2, HFNC, NIV, ventilator, prone, iNO/epoprostenol	Lungs / gas exchange
Pharmacologic	Vasopressors, inotropes, antiarrhythmics	Blood pressure / contractility
Temporary MCS	IABP, Impella, TandemHeart, ECMO	Heart and/or lungs
Durable / destination	LVAD, transplant	Long-term cardiac replacement

When teams think about ECMO

- Severe ARDS with refractory hypoxemia or hypercapnic acidosis despite optimized ventilation and adjuncts
- Cardiogenic shock refractory to drugs and less-invasive MCS
- Massive PE with obstructive shock in selected patients
- Bridge to lung or heart transplant / decision
- Selected cardiac arrest (ECPR) in highly organized systems
- Failure to wean from cardiopulmonary bypass after cardiac surgery

Key takeaway

ECMO is temporary life support for failing lungs, failing heart, or both. Master VV versus VA first — almost every other bedside decision flows from that distinction.

MODULE 2

VV vs VA ECMO (and Hybrid Configurations)

Configuration tells you where blood is drained and where it is returned. That single fact determines whether you are supporting gas exchange only, or gas exchange plus circulation.

Venovenous (VV) ECMO — lung support

Blood is drained from a large vein and returned to a large vein. The patient's own heart still pumps blood through the body. VV ECMO replaces the gas-exchange function of the lungs but does not directly support blood pressure or cardiac output.

Drains from	Vein (e.g., femoral or IJ via dual-lumen cannula)
Returns to	Vein (toward the right heart)
Supports	Oxygenation and CO_2 removal
Does not support	Blood pressure / cardiac pump function directly
Classic use	Severe ARDS, status asthmaticus, bridge to lung transplant
Pulse	Usually remains pulsatile (native cardiac output)

Venoarterial (VA) ECMO — heart +/- lung support

Blood is drained from a vein and returned to an artery. The circuit both oxygenates blood and actively pumps it into the arterial system, unloading the heart and supporting systemic perfusion. Peripheral VA (femoral artery return) is common in adults; central VA is used especially post-cardiotomy.

Drains from	Vein (often femoral or dual-site)
Returns to	Artery (often femoral; or central aortic cannula)
Supports	Cardiac output + gas exchange
Classic use	Cardiogenic shock, post-cardiotomy shock, massive PE, ECPR
Pulse	May be reduced or absent if native output is very low
Special risk	Differential hypoxia (Harlequin / North–South syndrome), limb ischemia, LV distention

Side-by-side comparison

Feature	VV ECMO	VA ECMO
Primary goal	Gas exchange	Circulation +/- gas exchange
Return vessel	Vein	Artery
BP support	No (indirect only)	Yes
Typical patient	ARDS, hypercapnic failure	Cardiogenic / obstructive shock
Harlequin risk	No	Yes (peripheral VA)
Arterial cannula risks	N/A	Limb ischemia, bleeding, stroke risk profile differs
If heart fails on VV	May need conversion to VA or V-AV	Already supporting circulation

Hybrid and related configurations (know the names)

Name	What it means	Why it is used
V-AV	Venous drain; return split to artery + vein	Heart and lungs both need support; or VV patient develops shock
V-V-A	Two venous drains + arterial return	Improve drainage while on VA
Central VA	Right atrium drain -> ascending aorta return	Post-cardiotomy; full support; OR placement
Dual-lumen VV	Single internal jugular cannula (drain + return)	Mobility-friendly VV for selected adults
ProtekDuo / RL configurations	Specialized right-heart / oxygenator setups	Right ventricular failure +/- oxygenation needs

A simple decision frame

- Lungs failing, heart OK -> think VV
- Heart failing (+/- lungs) -> think VA
- On VV and now in shock -> escalate; may need VA or hybrid — call the ECMO team immediately
- Unclear -> echocardiography, lactate, hemodynamics, and the ECMO attending decide — not the bedside alone

Key takeaway

VV = vein-to-vein = lungs. VA = vein-to-artery = heart (+/- lungs). If you can state the configuration and why the patient is on it, you already think like an ECMO nurse.

MODULE 3

The ECMO Circuit, Explained

Think of the circuit as a loop: drain -> pump -> oxygenator -> return, plus monitoring and safety devices. Your job is to know what each part does and what failure looks like.

Core components

Component	Function	Bedside watch-outs
Drainage (access) cannula	Pulls blood from venous system	Chatter, high negative pressure, suction events
Tubing	Carries blood through the loop	Kinks, disconnects, temperature loss
Centrifugal pump	Creates flow without a large reservoir	Flow alarms, air, thrombosis, power loss
Membrane oxygenator	O_2 in, CO_2 out across a membrane	Rising transmembrane pressure, poor gases, clots
Blender / sweep gas	Sets FdO_2 and gas flow to oxygenator	Wrong gas line, empty O_2, sweep too low/high
Heat exchanger	Warms (or cools) blood	Hypothermia, overheating, water-bath issues
Return cannula	Delivers blood to vein (VV) or artery (VA)	Malposition, bleeding, limb ischemia (arterial)
Pressure transducers	Pre- and post-oxygenator pressures	Rising delta-P suggests oxygenator clot
Flow sensor	Measures circuit blood flow	Flow != ordered support if recirculation/suction
Bridge (if present)	Connects drain/return for emergencies/wean	Clamped vs open per protocol only

Two knobs that control gas exchange on the oxygenator

Blood flow (L/min)	Primary driver of oxygenation (how much blood is processed)
Sweep gas flow (L/min)	Primary driver of CO_2 removal (higher sweep -> lower $PaCO_2$)
FdO_2 / blender	Oxygen fraction delivered to the membrane (often near 1.0 initially)

This is the opposite mental model from the ventilator in some ways: on VV ECMO, turning up sweep is how you blow off CO_2; turning up blood flow (when drainage allows) is how you improve oxygenation — within the limits of cannula size, recirculation, and patient cardiac output.

Pressures you will hear about

- Venous (drainage) pressure — often negative; too negative -> collapse, chatter, hemolysis risk
- Pre-oxygenator pressure — before the membrane
- Post-oxygenator pressure — after the membrane
- Transmembrane pressure (delta-P) — post - pre (definitions vary by console); rising delta-P suggests clotting/resistance in the oxygenator

Recirculation (VV-specific concept)

Recirculation happens when returned oxygenated blood is immediately re-drained by the access cannula instead of passing through the body. Flow on the console can look high while the patient remains hypoxemic. Clues include high pre-oxygenator SO_2, cannula malposition, and low patient arterial saturation despite “adequate” circuit flow.

Safety culture around the circuit

- Know where the hand crank / emergency drive is and who is privileged to use it
- Know the clamp locations and your center’s air/emergency algorithm
- Never leave tubing vulnerable to bed rails, OR tables, or transport carts
- Coordinate every turn, bath, and travel with the ECMO specialist
- Treat the circuit like an external heart-lung — because for this patient, it is

> **Key takeaway**
>
> Memorize the loop: drain -> pump -> oxygenator -> return. Blood flow ~ oxygenation; sweep ~ CO_2 clearance. Rising oxygenator resistance and drainage chatter are two early warnings you must never ignore.

MODULE 4

Indications and Contraindications

Indication frameworks come from ELSO guidelines and center-specific pathways. Exact numeric cutoffs vary by era, trial evidence (e.g., EOLIA-informed ARDS care), and local policy. What follows is a clinical teaching map, not an order set.

Common respiratory (VV) indications

- Severe ARDS with refractory hypoxemia despite low-tidal-volume ventilation, PEEP optimization, paralysis, prone positioning, and other adjuncts
- Uncompensated hypercapnic respiratory failure with dangerous acidosis when ventilation cannot be safely increased
- Bridge to lung transplant in selected patients with end-stage lung disease
- Status asthmaticus with life-threatening hypercapnia/acidosis
- Selected inhalational injury, severe pneumonia, or aspiration with recoverable lungs

Common cardiac (VA) indications

- Refractory cardiogenic shock (MI, myocarditis, cardiomyopathy decompensation)
- Post-cardiotomy cardiogenic shock / inability to wean from bypass
- Massive pulmonary embolism with obstructive shock
- Primary graft dysfunction after heart transplant (selected)
- ECPR for refractory cardiac arrest in systems with strict inclusion criteria and rapid deployment
- Bridge to durable VAD or heart transplant decision

Contraindications — absolute vs relative (conceptual)

Few contraindications are universal. Teams weigh reversibility, neurologic prognosis, bleeding risk, and goals of care. Teaching categories:

Often prohibitive	Often relative / case-by-case
Severe irreversible neurologic injury	Advanced age alone (frailty matters more)
Terminal illness without recovery/bridge path	Immunosuppression / active infection
Unwitnessed arrest with prolonged downtime (ECPR context)	Prior anticoagulation or recent surgery
Patient/family goals inconsistent with ECMO	Obesity, pregnancy, single-organ vs multi-organ failure
Uncontrollable bleeding in some contexts	Mechanical aortic valve (VA planning issues)

The recovery question

Before cannulation, the team should be able to answer: What is the exit strategy? Recovery, bridge to device, bridge to transplant, or bridge to decision after more information. ECMO without a destination becomes prolonged organ support without a plan.

> **Key takeaway**
>
> Indications = reversible severe heart/lung failure (or clear bridge). Contraindications = no realistic recovery path, devastating irreversible injury, or goals of care that exclude this intensity of support. Always defer final decisions to the ECMO attending and center criteria.

MODULE 5

Cannulation Basics for Bedside Clinicians

Cannulation is usually performed by cardiac surgery, interventional cardiology, critical care, or a dedicated ECMO team — often with ultrasound and fluoroscopy. Bedside clinicians prepare the patient, anticipate complications, and own post-cannulation surveillance.

Common adult access patterns

Mode	Typical drainage	Typical return
VV dual-site	Femoral vein	Internal jugular vein
VV dual-lumen	IJ dual-lumen cannula (drain + return in one)	Same cannula (directed toward tricuspid)
VA peripheral	Femoral vein	Femoral artery (+/- distal perfusion catheter)
VA central	Right atrium	Ascending aorta

Distal perfusion catheter (DPC) — critical VA nursing knowledge

A large arterial return cannula in the femoral artery can obstruct flow to the leg. Many centers place a small distal perfusion catheter antegrade into the superficial femoral artery to protect the limb. Nursing checks of the cannulated limb are non-negotiable.

Pre-cannulation bedside roles

- Large-bore IV access, arterial line, central access as directed
- Type and crossmatch; blood products available per protocol
- Anticoagulation plan ready (heparin commonly; follow order)
- Airway secured; ventilator managed by RT/ICU team
- Ultrasound, sterile field, emergency meds, defibrillator
- Neurologic baseline documented; family update by lead physician

Immediate post-cannulation checks

- Confirm circuit flow, color of arterialized blood, absence of air
- Secure cannulas with center-approved method; mark positions; no tension on lines
- Limb checks q15–q60 min initially: color, temp, Doppler signals, motor/sensory if applicable
- Watch access site for hematoma, bleeding, retroperitoneal signs (femoral)
- Chest radiograph / echo per team to confirm position
- Reassess ABG, lactate, hemodynamics, urine output

> **Key takeaway**
> You may not insert the cannulas, but you own limb perfusion, site bleeding, line security, and early recognition of malposition. A cold, mottled cannulated leg is an emergency until proven otherwise.

MODULE 6

Initiation and Early Management

The first hours after cannulation set the trajectory. Goals: restore oxygen delivery, limit further lung/heart injury, control bleeding risk, and stabilize the circuit.

Typical early goals (conceptual — follow orders)

Domain	Early focus
Flow	Titrate to systemic O_2 delivery / hemodynamic targets; avoid excessive negative drainage
Sweep / FdO_2	Normalize pH and $PaCO_2$ carefully (avoid ultra-rapid CO_2 drops)
MAP / perfusion	VA: support end-organ perfusion; watch LV distention
Ventilator	Lung-protective / “rest” settings on VV per protocol
Anticoagulation	Start/maintain per center pathway once hemostasis allows
Temperature	Normothermia unless targeted temperature management ordered
Sedation	Comfort and safety; avoid unnecessary deep sedation long-term
Labs	ABG/VBG, CBC, coagulation, anti-Xa or ACT/aPTT per protocol, plasma free Hb as indicated

Avoiding secondary injury

- Lungs (VV): rest the lung — low driving pressure/tidal volume strategies per protocol; prevent atelectrauma and barotrauma
- Heart (VA): watch for LV overload; may need inotropes, IABP/Impella, atrial septostomy, or venting strategies
- Brain: avoid hypocapnia from over-sweep; monitor neuro exam; control glucose and temperature
- Kidneys: perfusion pressure and venous congestion both matter; CRRT often coexists with ECMO
- Infection: meticulous line care; early cultures when febrile or unstable

Team roles in the first hour

Role	Focus
ECMO specialist / perfusion	Circuit integrity, flows, pressures, emergency drive
ICU RN	Patient assessment, meds, bleeding, limbs, documentation, family
RT	Ventilator rest settings, airway, gases
MD/APP	Targets, echo, anticoagulation, procedures, goals of care
Pharmacy	Anticoagulation, sedation, antimicrobials, compatibility

Key takeaway

Initiation is resuscitation plus circuit stewardship. Correct hypoperfusion and hypoxemia, protect the lungs and brain, and establish the monitoring rhythm your center uses every shift.

MODULE 7

Anticoagulation and the Bleed–Clot Balance

Blood contacting foreign surfaces wants to clot. Anticoagulation protects the circuit and patient vessels — but ECMO patients also bleed (cannula sites, mucosa, lungs, brain, retroperitoneum). The entire admission is a tightrope between thrombosis and hemorrhage.

Common anticoagulant

Unfractionated heparin remains the most widely used agent because it is titratable and reversible with protamine in emergencies. Some centers use bivalirudin (especially with HIT or heparin resistance) or other protocols. Always follow your center's algorithm — do not freestyle.

Monitoring tools (center-specific)

Test	What it reflects	Teaching notes
ACT	Global clotting time at bedside	Fast; affected by many variables; still used in some pathways
aPTT	Intrinsic pathway monitor for heparin	Common inpatient titration target
Anti-Xa	Heparin activity level	Increasingly preferred for heparin effect
Viscoelastic tests (TEG/ROTEM)	Clot strength/fibrinolysis picture	Helpful in bleeding workups
Platelets, fibrinogen, PT/INR	Hemostatic reserve	Replete per protocol when bleeding
Plasma free hemoglobin	Hemolysis marker	Rising values -> investigate pump/circuit trauma
D-dimer / PF4 ELISA etc.	Context-specific	HIT workup when suspected

Bleeding — what to watch

- Oozing at cannula sites, mouth, nose, lines, chest tubes, foley
- Falling hemoglobin, rising vasopressor need, abdominal/flank pain (retroperitoneal bleed)
- Neurologic change — treat as intracranial hemorrhage until proven otherwise
- Pulmonary hemorrhage on VV (bloody ET secretions)
- Tamponade physiology post-cardiac surgery

Clotting — what to watch

- Rising transmembrane pressure / worsening post-oxygenator gases
- Visible clot in connectors (never ignore)
- Falling circuit flow with unchanged settings
- Signs of arterial emboli (VA) or DVT
- Oxygenator “looking dark” or efficiency loss — escalate early

HIT and heparin resistance

Heparin-induced thrombocytopenia is a clinical diagnosis supported by labs (4Ts score, PF4 antibody, SRA as available). Suspected HIT on ECMO is an emergency pathway: stop heparin, use an alternative anticoagulant per protocol, and involve hematology/ECMO leadership. Heparin resistance (need for very high doses) may reflect antithrombin deficiency — centers may replete AT3 per protocol.

Nursing actions when bleeding escalates

- Hold heparin only when ordered; announce bleeding to the whole team
- Local pressure/packing per protocol; do not blindly remove packing
- Prepare blood products; check last coagulation panel and fibrinogen
- Neurologic checks; lower the threshold for CT imaging when ordered
- Be ready for circuit exchange if oxygenator thrombosis is the twin problem

> **Key takeaway**
> ECMO anticoagulation is not “set and forget.” Every shift, ask: Is the circuit protected? Is the patient bleeding? What do the trends (anti-Xa/aPTT/ACT, delta-P, Hb, neuro exam) say?

MODULE 8

Daily Nursing Assessment and Monitoring

ECMO nursing is continuous surveillance of patient + circuit + cannulation sites + end-organs. Use a head-to-toe system with circuit-specific add-ons every assessment.

Shift assessment framework

System	What to assess
Neuro	GCS/pupils/focal deficits; sedation score; seizure activity; sleep
CV	MAP, HR/rhythm, lactate, mixed/central venous O_2 if available, pulse pressure (VA)
Pulm / airway	Vent settings, ETT security, secretions, SpO_2 (remember VA pitfalls)
Circuit	Flow, speeds, pressures, delta-P, sweep, FdO_2, condensate, visible clot/fibrin
Cannulas	Depth marks, securement, oozing, dressing, tubing tension

System	What to assess
Limbs (esp. VA)	Color, temp, capillary refill, Doppler, pain, compartment signs
Renal / fluid	UOP, CRRT integration, daily weight, edema
Heme	Bleeding, CBC trend, coagulation targets, transfusion response
GI	Feeding tolerance, abdominal girth, GI bleed signs
Skin	Device-related pressure injury, occipital sores, heel protection
Infection	Temp, WBC, line sites, cultures as ordered
Psych / family	Delirium, fear, goals-of-care updates, visitation

Documentation essentials every shift

- ECMO mode and cannula sites/sizes/depths
- Circuit blood flow, sweep, FdO_2, key pressures
- Anticoagulation drug + last level + bleeding score/notes
- Limb perfusion checks (VA)
- Neurologic exam
- Ventilator settings and latest ABG
- Lines, drips, and who to call for circuit emergencies

Turning, hygiene, and mobility

Turning is a two- to many-person procedure. The ECMO specialist guards the circuit while nurses guard the airway and cannulas. Early rehabilitation is increasingly emphasized in ELSO guidance for selected adults — only with a trained team and clear safety criteria.

> **Key takeaway**
> Assess the patient and the machine as one system. If something is wrong, decide quickly: is this a patient problem, a circuit problem, or both?

MODULE 9

Gas Exchange and the Ventilator on VV ECMO

On VV ECMO, the oxygenator does much of the gas exchange so the native lungs can rest and heal. Your ABG still matters — but you interpret it in light of circuit flow, sweep, recirculation, and residual lung function.

Oxygenation troubleshooting on VV

If hypoxemic, consider	Next thoughts
Inadequate circuit blood flow	Drainage limited? Chatter? Hypovolemia? Cannula size/position?
Recirculation	Cannula position, high pre-ox SO_2, echo/XR review
High cardiac output relative to ECMO flow	Sepsis, fever, agitation — ratio of ECMO flow to CO matters
Oxygenator failure	Worsening post-ox PO_2, rising delta-P, circuit age
Low FdO_2 / gas supply issue	Blender settings, wall O_2, disconnects
Shunt through native lungs	Still possible; residual lung disease

CO_2 troubleshooting on VV

- High $PaCO_2$: increase sweep (per order), check for exhaust obstruction, oxygenator efficiency, patient fever/dead space
- Low $PaCO_2$: decrease sweep; avoid cerebral vasoconstriction from over-clearance

Lung-protective "rest" ventilation — concept

While on VV ECMO, ventilator settings are often reduced to limit ventilator-induced lung injury: lower tidal volumes/driving pressures, moderate PEEP, limited plateau pressures, and FiO_2 weaned as circuit support allows. Exact targets are center- and patient-specific. Prone positioning can still be used in experienced centers.

Do not forget the native lungs

- Pulmonary hygiene and infection treatment continue
- Pneumothorax risk remains — sudden change in drainage or hemodynamics needs a wide differential
- As lungs recover, ECMO flow/sweep wean trials begin (Module 12)

> **Key takeaway**
> VV hypoxemia workup: flow, recirculation, oxygenator, oxygen supply, and patient oxygen consumption. VV hypercapnia workup: sweep first. Rest the lung while the membrane works.

MODULE 10

Hemodynamics on VA ECMO

VA ECMO supports systemic blood flow, but it changes cardiac loading conditions in ways that can harm the left ventricle if unnoticed. Bedside nurses are often the first to spot the warning signs.

What VA flow does to the heart

- Drains venous return -> decreases RV preload

- Returns blood to arterial tree -> increases LV afterload
- If the LV cannot open the aortic valve against that afterload, the LV dilates, left atrial pressure rises, and pulmonary edema / thrombosis risk climb

Pulse pressure and arterial line tracing

A pulsatile arterial waveform means the heart is still ejecting. Narrow or absent pulse pressure may mean profound LV failure, arrhythmia, or that ECMO is providing nearly all flow. Track pulse pressure trends with echo findings and lactate.

Harlequin / North–South syndrome (peripheral VA)

When the recovering or residual native heart ejects poorly oxygenated blood from failing lungs into the ascending aorta, while ECMO returns oxygenated blood up the descending aorta from the femoral artery, the upper body (brain and heart coronaries) can see blue blood while the lower body sees pink blood. Right-hand (or right-arm) arterial sampling and cerebral oximetry help detect this.

Clue	Upper body hypoxemia with lower body pink; low right radial PaO_2
Why dangerous	Brain and coronary arteries may be hypoxemic
Responses (team)	Vent optimization, increase ECMO flow, reposition, convert to V-AV / central, treat lungs

Limb ischemia

- Hourly neurovascular checks of the arterial cannulation limb
- Compare to contralateral limb
- Ensure distal perfusion catheter is functioning if present
- Escalate mottling, motor loss, severe pain, loss of Doppler signals immediately

LV distention — recognize and escalate

Sign	Why it matters
Pulmonary edema / bloody secretions	High LA pressure
Absent aortic valve opening on echo	Stasis -> root thrombus risk
Rising wedge / LA pressure (if measured)	LV overload
Ventricular arrhythmias	Strain / ischemia
Worsening lactate despite ECMO flow	Still inadequate systemic or coronary O_2 delivery

Adjuncts you may see

- Inotropes to promote LV ejection
- Vasodilators to reduce afterload (carefully)

- IABP or Impella for LV unloading (“ECPella”)
- Atrial septostomy or surgical LV vent
- Conversion to central cannulation

> **Key takeaway**
> VA ECMO saves lives and can overload the LV. Watch pulse pressure, lungs, lactate, limb perfusion, and right-arm oxygenation. Harlequin syndrome is a “think upper body oxygen” emergency.

MODULE 11

Complications and Bedside Emergencies

Memorize your center’s emergency card. The goals in any crisis are: identify, call for help, support the patient, and protect/restore the circuit.

High-frequency complications

Problem	Clues	First moves (conceptual)
Bleeding	Sites, Hb drop, instability	Team notify; hold AC if ordered; products; source control
Thrombosis / oxygenator failure	rising delta-P, poor gases, visible clot	Specialist; prepare for circuit exchange
Hemolysis	Dark urine, rising PFHb, rising K^+	Reduce suction events; investigate pump/circuit
Limb ischemia	Cold, pale, Doppler loss	Vascular/ECMO team STAT; DPC check
Stroke / ICH	Neuro change	Hold AC if ordered; imaging; neurosurgery path
Infection / sepsis	Fever, rising supports	Cultures, source hunt, antibiotics
AKI	Oliguria, rising Cr	Perfusion pressure; CRRT coordination
Harlequin syndrome	Upper body hypoxia (VA)	See Module 10
Recirculation	VV hypoxia + high pre-ox SO_2	Position/flow review with team
Air in circuit	Visible air, alarms	Emergency algorithm — clamp/isolate per training only
Pump failure / power loss	Flow to zero	Emergency drive/hand crank per privilege; call help
Accidental decannulation	Massive bleed / air / arrest	Massive hemorrhage + airway/CPR pathway

Emergency: sudden loss of ECMO flow

- Call ECMO specialist / rapid response per protocol immediately
- Look for obvious kink, clamp, disconnect, power failure, chatter/hypovolemia
- Support BP and ventilation with conventional means (pressors, vent FiO_2 1.0, fluids as ordered)
- If cardiac arrest: follow ACLS modified for ECMO configuration per center rules (VA vs VV matters)
- Do not randomly clamp or unclamp unless you are trained and it is the algorithm step

Emergency: cardiac arrest on ECMO

On VA ECMO, the circuit may already provide circulation — teams still address rhythm, reversible causes, and circuit function. On VV ECMO, there is no circulatory support from the circuit; perform ACLS and consider whether emergent conversion to VA is possible. Know your poster.

Emergency: air embolism / massive air

- Stop the source of air entrainment if identified and you are trained to do so
- Activate ECMO emergency pathway; trendelenburg/positioning per protocol
- Support ABCs; prepare for circuit interventions by specialists
- Prevention: secure all connections; de-air meticulously during any intervention

Emergency: cannula dislodgement

- Apply direct pressure; call for help; massive transfusion pathway if needed
- Do not blindly reinsert a contaminated cannula
- Support hemodynamics; emergency surgical/ECMO team to bedside

Prevention habits that save lives

- Two-person verification for any circuit intervention
- Cannula depth marks checked every assessment
- No scissors near tubing; careful dressing changes
- Travel checklist (power, O_2, clamps, hand crank, transport battery)
- Simulation practice for pump failure and air events

> **Key takeaway**
>
> In an ECMO emergency: shout for the specialist, support the patient with everything conventional medicine offers, and only perform the circuit steps you are trained and privileged to perform.

MODULE 12

Weaning, Decannulation, and Recovery

Weaning starts when the underlying disease is improving and end-organ function is stable. It is a planned team process with defined failure criteria — not a solo bedside experiment.

VV weaning — conceptual steps

- Improving lung compliance, imaging, and native gas exchange
- Sweep gas wean trials (sometimes to zero sweep / “capped” trials per protocol) while watching ABG and work of breathing
- Flow weans as tolerated
- If stable off sweep with acceptable vent settings -> plan decannulation

VA weaning — conceptual steps

- Recovering biventricular function on echo
- Falling lactate, improving urine output, lower vasoactive needs
- Flow reduction trials with careful echo and hemodynamic monitoring
- May transition to less support (Impella/IABP/inotropes) before full explant
- Decannulation often in OR or controlled ICU setting with vascular repair plan

Decannulation nursing priorities

- Blood products available; anticoagulation held per order timing
- Surgical or percutaneous removal plan clear
- Post-removal: site pressure, limb checks, bleeding surveillance for hours
- Be ready to recannulate if the patient collapses
- Psychological support — this is a milestone and also frightening

After ECMO

- ICU-acquired weakness is nearly universal after prolonged runs — PT/OT early
- PTSD, anxiety, and cognitive changes are common in survivors and families
- Wound and vascular complications may appear late
- Rehabilitation and follow-up clinics improve long-term outcome

> **Key takeaway**
> Weaning answers: Are the native lungs/heart ready? Decannulation is a procedure with a rescue plan. Recovery continues long after the circuit is gone.

MODULE 13

Special Populations and Team Care

ECPR (ECMO during CPR)

Extracorporeal CPR is VA ECMO initiated during refractory cardiac arrest. It only works in systems with rapid activation, strict selection (often witnessed arrest, short low-flow time, reversible cause), and practiced teams. Nursing roles focus on high-quality CPR until flow is established, then post-resuscitation and circuit care.

Pediatric notes (high level)

- Indications include neonatal meconium aspiration, CDH, pediatric myocarditis, and respiratory failure — center expertise matters enormously
- Circuit volumes and cannula sizes are weight-based
- Parents need structured communication; developmental care still applies

Transport on ECMO

Interfacility transport requires a mobile ECMO team, secured cannulas, continuous power and oxygen, and a dedicated emergency plan. Bedside nurses preparing a patient for transport should complete checklists, stabilize bleeding, and hand off circuit settings clearly.

Ethics and goals of care

- ECMO can prolong dying if the exit strategy disappears — revisit goals frequently
- Use time-limited trials with clear milestones when prognosis is uncertain
- Palliative care partnership is a strength, not a failure
- Support surrogates; explain configuration and daily trajectory in plain language

The ECMO team sport

High-performing programs use multidisciplinary rounds, simulation, ELSO registry participation, and clear role cards. Respect every discipline: nursing, perfusion/ECMO specialists, RT, surgery, cardiology, critical care, pharmacy, PT, and palliative care.

> **Key takeaway**
>
> Technology does not replace teamwork. The best ECMO outcomes come from practiced people, honest goals-of-care conversations, and relentless attention to basics.

MODULE 14

Practice Cases with Full Explanations

Work each case before reading the explanation. Say out loud: configuration needed, top risks, and first nursing priorities.

Case 1

Refractory ARDS

A 42-year-old with influenza ARDS remains on FiO_2 1.0, PEEP 16, deeply sedated and paralyzed, prone, with PaO_2 48 mmHg and pH 7.18 from CO_2 retention. Blood pressure is 118/70 on low-dose norepinephrine. Echo shows normal biventricular function.

Questions

- Which ECMO mode is most appropriate to discuss?
- What are the two oxygenator “knobs” you will watch after cannulation?

- Name two nursing priorities in the first hour.

Explanation

This is primarily respiratory failure with preserved heart function -> VV ECMO is the usual discussion. After cannulation, blood flow drives oxygenation and sweep gas drives CO_2 clearance. First-hour priorities: secure cannulas, prevent circuit complications, set lung-rest ventilation, trend ABGs, and watch for bleeding as anticoagulation starts. BP support is minimal — conversion to VA is not first-line here.

Case 2

Cardiogenic shock after MI

A 58-year-old post-anterior STEMI develops progressive shock: MAP 55 despite norepinephrine and dobutamine, lactate 8, cold extremities, and pulmonary edema. Impella support is insufficient. Lungs are wet but the dominant problem is pump failure.

Questions

- Which configuration supports circulation?
- What limb complication must nurses check hourly?
- Why might pulse pressure become very narrow?

Explanation

VA ECMO provides circulatory support (+/- gas exchange). With femoral arterial return, perform hourly limb ischemia checks and confirm distal perfusion catheter function. Narrow pulse pressure suggests minimal native LV ejection against ECMO-related afterload — escalate concerns for LV distention and discuss unloading strategies with the team.

Case 3

Blue hands, pink feet

A patient on peripheral VA ECMO for myocarditis begins to improve cardiac output. The nurse notices the right hand SpO_2 is 82% while the leg looks pink. The patient is still on moderate ventilator settings for wet lungs.

Questions

- What syndrome is this?
- Which organs are at risk of seeing deoxygenated blood?
- What should you do first?

Explanation

This is classic Harlequin / North–South physiology: native heart ejecting deoxygenated blood to the upper body while ECMO perfuses the lower body with oxygenated blood. Brain and coronary arteries are at risk. Notify the ECMO team immediately, sample a right-arm arterial blood gas, optimize ventilation/oxygenation, and prepare for flow or configuration changes (sometimes V-AV).

Case 4

Chatter and falling flow

On VV ECMO day 2, the pump speed is unchanged but flow falls and the drainage line “chatters.” The patient was just turned and is net negative 3 L over 24 hours.

Questions

- What is the likely mechanism?
- What patient problem often contributes?
- What are safe first responses?

Explanation

Chatter with falling flow suggests drainage insufficiency — the cannula is sucking down against vein walls. Hypovolemia, malposition after turning, abdominal hypertension, or excessive pump speed relative to available venous return are common. Call the specialist, reduce speed if protocol directs during suction events, optimize position, and address volume status per orders. Do not ignore repeated high negative pressures (hemolysis risk).

Case 5

Sudden neuro change

A VA ECMO patient on heparin becomes suddenly less responsive with a new unilateral pupil change.

Questions

- What are the top concerns?
- What anticoagulation action might be ordered?
- What nursing actions come first?

Explanation

Top concerns: intracranial hemorrhage or ischemic stroke — both occur on ECMO. ABCs, glucose, STAT team notification, hold further heparin when ordered, prepare for emergent imaging, and reverse/replete coagulopathy only as directed. Never delay airway protection for a CT. Document the last known well time and exact neuro findings.

> **Key takeaway**
>
> Cases train pattern recognition: VV for lungs, VA for pump, Harlequin for upper-body hypoxia on peripheral VA, chatter for drainage problems, sudden neuro change for ICH/stroke until proven otherwise.

QUICK REFERENCE

Bedside Pocket Card

Configuration in one line

VV	Vein -> membrane -> vein = lung support
VA	Vein -> membrane -> artery = heart +/- lung support
V-AV	Hybrid when both need support or VV patient develops shock

Oxygenator knobs

Blood flow	Improves oxygenation (if drainage allows)
Sweep gas	Lowers $PaCO_2$
FdO_2	O_2 fraction to the membrane

Every-shift must checks

- Flow / speed / sweep / FdO_2 / pressures / delta-P
- Cannula marks + securement + site bleeding
- VA limb perfusion (+/- DPC)
- Neuro exam
- Anticoagulation lab vs target + bleeding
- ABG + lactate trend
- Ventilator rest settings

Red-flag page-now list

- Pump stop / power failure / massive air
- Accidental decannulation or free hemorrhage
- Cold pulseless cannulated leg
- Sudden unresponsiveness or focal neuro deficit
- Right-arm hypoxia on peripheral VA (Harlequin)
- Unexplained cardiac arrest
- Rapidly rising delta-P with decompensating gases

VV hypoxemia quick tree

- Flow too low? -> drainage / volume / speed / cannula
- Recirculation? -> position / pre-ox SO_2
- Oxygenator failing? -> gases / delta-P / appearance
- Gas supply? -> blender / wall O_2
- High O_2 consumption? -> fever / agitation / sepsis

> **Pocket rule**
> Patient + circuit + cannulas + limbs + brain, every time. If unsure whether to call - call.

GLOSSARY

ECMO Terms You Will Hear on Rounds

ACT	Activated clotting time — bedside coagulation test used in some heparin protocols.
Anti-Xa	Assay of heparin activity; common titration target.
Bridge	Tubing connection between drain and return limbs used in specific emergency/weaning procedures.
Centrifugal pump	Non-occlusive pump commonly used to generate ECMO blood flow.
Chatter	Shaking of drainage line from excessive negative pressure / vein collapse.
delta-P (delta P)	Pressure gradient across the oxygenator; rising values may signal clotting/resistance.
Distal perfusion catheter (DPC)	Small arterial catheter preserving leg flow during femoral VA return.
ECLS	Extracorporeal life support — broader term including ECMO.
ECPR	ECMO initiated during cardiac arrest (usually VA).
ELSO	Extracorporeal Life Support Organization — guidelines and registry standards body.
FdO_2	Fraction of oxygen in gas delivered to the membrane lung.
Harlequin / North–South syndrome	Upper-body hypoxemia on peripheral VA from native cardiac ejection of deoxygenated blood.
Membrane oxygenator	Artificial lung that oxygenates blood and removes CO_2.
Plasma free hemoglobin (PFHb)	Marker of hemolysis.
Recirculation	VV phenomenon: returned oxygenated blood re-aspirated by drainage cannula.

Rest settings	Lung-protective ventilator strategy used while ECMO performs gas exchange.
Sweep gas	Gas flow through the oxygenator; primary control of CO_2 clearance.
Transmembrane pressure	See delta-P — resistance across the oxygenator.
VA ECMO	Venoarterial ECMO — cardiac +/- respiratory support.
VV ECMO	Venovenous ECMO — respiratory support.
V-AV ECMO	Hybrid configuration with arterial and venous return.
Weaning trial	Structured reduction of sweep and/or flow to test native organ recovery.

REFERENCES

Suggested Sources for Deeper Study (APA)

The following authoritative sources informed the clinical frameworks in this course. Consult them, current ELSO updates, and your facility's protocols for any clinical decision. Links are provided where publicly available.

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