Dr. Erin Plaza, Kansas University Medical

Background:

Hemodynamically significant venous air embolisms (VAEs) are likely rare events, though their actual incidence is unknown. VAEs may present themselves in a variety of clinical scenarios and most episodes are preventable. Traditionally VAEs are associated with posterior fossa surgery in the sitting position but may occur where gas is entrained under pressure in the peritoneal cavity or via vascular access. An anesthesiologist must know how to immediately recognize and treat a VAE while commanding the attention of the surgeon. In order to do this, one must know the pathophysiology of VAEs, be well versed in their prevention, diagnosis and treatment. Due to the seriousness of this clinical scenario and its relative infrequency, a simulated scenario is the perfect way to recreate and practice this emergency, its diagnosis, treatment and communication with the surgical team during the stress of a simulated crisis.

Objectives:

1. Recognize venous air embolism in an anesthetized patient using standard anesthetic monitors, exam findings along with precordial Doppler and/or transesophageal echo findings.
2. Explain clearly and calmly to the surgeon that air is being entrained.
3. Execute the steps to treating a VAE in a timely manner, including calling for help and maintaining communication with the surgical team.

Format:

1. Huddle to confirm set-up, rolls and scenario progression
2. Learners given Pre-Brief, patient information and anesthesia pre-procedure evaluation.
3. Simulation Scenario follows case progression
4. Debrief following scenario

PATIENT DATA and MANIKIN SETUP										
Patient Data										
Patient Name	John Doe									
Patient Gender	Male									
Patient Age	45 yo									
Patient Date of Birth	11/24/19xx									
Patient Weight	87 kg									
Code Status	Full code									
Primary DX/Problem	Right accoustic neuroma									
Past Medical History	Hypertension, hyperlipidemia, current smoker (½ pack per day), sleep apnea									
Home Medications	Lisinopril-HCTZ, lipitor, fish oil, multivitamin									
Allergies	No known allergies									
Laboratory Data	**ABG**			**BMP**			**CBC**			
x Yes	pH	7.39		Na	139	mmol/L	WBC	9.1	mmol/L	
No	pCO2	39	mmHg	K	4.2	mmol/L	Hemoglobin	12.1	mmol/L	
	PO2	99	mmHg	CL	103	mmol/L	Hematocrit	36.4	mmol/L	
	BEecf	-1	mmol/L	CO2	27	mmol/L	Platelet	248	mmol/L	
	HCO3	23	mmol/L	BUN	16	mg/D				
	TCO2	36	%	Creatine	0.8	mmol/L				
	sO2	99	%	Glucose	99	mg/D				
Other Labs to be included	Type and cross- awaiting second confirmation test, tube sent									
How is laboratory data provided to learners?	Labs, H&P, Anesthesia pre-procedure evaluation printed and handed out to learners									
Radiology Data *Provide files for display if applicable*	*Video of TEE during sitting craniotomy *Sound loop of precordial doppler sounds for debrief									
Integrate EHR		Yes		x	No					
	EHR Computer setup (e.g. opened, logged on, in room):									
Need paper chart	**x**	**Yes: -surgical consent form, anesthesia consent form, anesthesia pre-procedure eval. Form on clipboard at nurse station**			No					
In-room handouts/aids	**x**	**Yes: -Emergency Manual in top drawer of the Anesthesia machine -Surgery Time Out board filled in**		**X**	**Update OR Board with Info: Patient name: John Doe Procedure: right suboccipital semi-sitting craniotomy Allergies: NKDA**					

Manikin(s) and Accessories on Manikin							
Manikin(s)		**Manikin Type (options)**		**Manikin Skin Tone** (Not all manikins are available in every skin tone. Only use if crucial to simulation learning objectives.)		**Pt ID band(s**	
x	**Adult**	**-NEW SimMan 3G- for use with ASL 5000**				**x**	**Name Band**
	Birthing Adult	**-ASL 5000 Lung Simulator -VitalsBridge**					Allergy
	5-year old	**Manikin Sex**				x	Fall Risk
	1-year-old	x	Male		Light Skin	**x**	**Other: orange sleep apnea band**
	Newborn		**Female**		Medium Skin		Other:
	Other:		Other:		Dark Skin		Other:
Attire		**Wigs/Props**		**IV Access**		**Moulage/Wounds/Dressings**	
x	**Hospital Gown**		Blonde Wig	x	Left arm 18g PIV **Right radial art line Right triple lumen central line**		
	Male Clothes		Brunette Wig		Saline Lock	x	Wounds: right suboccipital crani incision
	Female Clothes		Gray Wig	**x**	**Peripheral IV with 1 L NS or LR**		Dressings:
x	Yellow (Fall Risk) socks		Glasses		Ability for learner to start IV		Surgical drain:
	Other:		**Other: OR bouffant hat**	**x**	**Other: second IV fluid bag on R IJ**	**X**	**Other: SCDs on manikins legs**
Bed			**Other: female wig**		Other:	**X**	Other: **? IONM wires on patient?**
	ICU Bed	**Patient Position**		**Oxygen on Manikin at Sim Start**		**Other Manikin Information**	
	Med Surg Bed		Sitting up in bed		**None**	x	Foley catheter
	ED Gurney Bed		**Lying flat in bed**		On at ___L/min	x	Other: precordial doppler
x	**OR Table**	x	Other- semi-sitting position with head in Mayfield, head turned to left		Nasal Cannula	x	Other:
	Birthing Bed				NRB Mask	x	Other: TEE probe in mouth with bite block/TEE holder fixed to bed and ?echo machine
	Crib			x	Other: intubated with regular oral ETT	x	Other: lower body bear hugger
	Other:						

MEDICAL EQUIPMENT, ROOM SETUP AND MEDICATIONS

Medical Equipment and Room Setup Supplies

Monitor(s)- Use VitalsBridge monitor		**Monitor Display**			
	None	**X**	**Monitor on at sim start**		Monitor put on during sim
	Simulated Computer Monitor	**x**	**Primary ECG (Waveform)**		Secondary ECG
	Clinical Wall Mounted Monitor	**x**	**NIBP**	x	ABP
	Clinical Portable Monitor	**x**	**Pulse**	**X**	**CO2**
	Defibrillator	**x**	**SPO2**	**x**	**Other: Video TEE playing on echo monitor**
X	**Other: Philips MP70 on anesthesia machine.**	**x**	**RR**	x	Other:
	Other:	**x**	**Nasopharyngeal temp**		Other:

Supply Carts		**Location**	**O2/Airway**		**Location**	**Other Devices**		**Location**
	Nursing Supply Cart			Nasal Cannula			EKG Machine	
x	**Adult Code Cart**	**Outside OR**		O2 mask			Ultrasound	
	Pediatric Code Cart			High Flow NC			Ventilator	
	Rapid Response			NRB Mask			Glidescope	
x	Anesthesia Cart		x	Ambu Bag / BVM	**Hanging on side of anesthesia machine (in usual location**	**x**	**Other: Anesthesia machine**	
	Intubation Tower			Nebulizer mask		**x**	**Other: Upper body bear hugger**	**Available in OR on metal OR cart**
	Other:		x	Suction available			Other:	
	Other:		**x**	**Other: Anesthesia machine**			Other:	

Standard Hospital Kits		**IV Setup**		**# needed**	**Pump Profile**	
	Intubation Med kit	**x**	**IV Pump**	**1**	**x**	Critical Care
	Adult Code Blue Tray	**X**	**Infusion Module**	**3 channels**		Med Surg
	Pediatric Code Blue Tray		PCA Module			Heme Onc
	NICU Code Blue Tray	x	Syringe Module	1 channel		Telemetry
	Red Emergency box	**x**	**Arterial line**			Other (specify):
	Blue Emergency box	**Infusion at Sim Start: Info Below**			**Consumable Supplies**	
x	**OR Standard tray**	**Infusion: LR bag and IV tubing hanging and dripping in slowly**		Rate:		
x	**OR Emergency tray**					
	OR LDR tray					
	Malignant Hyperthermia kit	PCA Module				Bedside table
	Anaphylaxis kit	Syringe Module				Observer chairs: (#)
	Other:	**Infusion at Sim Start: Info Below**				Bedside chair

	Other:	Infusion:	Rate:		
	Other:			**x**	Other: Standard OR setup

MEDICATION LIST –							
Where are medications stored during the simulation: For example- anesthesia workstation? Omnicell?							
Qty.	**Available In Formulary**	**Generic Medication Name**	**Trade Name**	**Volume**	**Concentration**	**Form**	**Physical Appearance**
Examples							
10	Yes	Levofloxacin inj in 5% Dextrose	Levaquin	150mL	750mg/100mL D5W	IV bag	pale yellow liquid in bag
10	Yes	Ceftriaxone Inj	Rocephin	10mL	1g	Vial	white powder in vial
5	Yes	Epinephrine 1:10,000 Inj		10mL	1mg/10mL (0.1mg/ml)	syringe in box	auto-injector syringe in box
Medications at start of simulation – **Are medications already drawn up for learners? YES**							
1	Yes	Lidocaine 2%		10 ml	200mg/10ml	syringe	Clear liquid in 10 ml syringe
1	Yes	Fentanyl		5 ml	250mcg/5ml	syringe	Clear liquid in 5 ml
1	Yes	Propofol		20 ml	200mg/20ml	syringe	White liquid in 20 ml syringe
1	Yes	Rocuronium		10 ml	100mg/10ml	syringe	Clear liquid in 10 ml syringe
1	Yes	Succinylcholine		10 ml	200mg/10ml	syringe	Clear liquid in 10 ml syringe
2	Yes	Cefazolin	Ancef	10 ml	1Gram/10ml	syringe	Clear liquid in 10 ml syringe
1	Yes	Propofol infusion		50 or 100 ml	10 mg/ml	vial	On alaris pump, running at 125 mcg/kg/min
1	Yes	Remifentanil infusion		20 mL syringe	50 mcg/mL	Syringe	On alaris syringe pump running at 0.1 mcg/kg/min
1	Yes	Phenylephrine infusion		250 ml	40 mcg/mL	IV Bag	On alaris pump, running at 0.2 mcg/kg/min
Medications to have available to deliver during simulation							
1	Yes	Norepinephrine		250 ml	16 mcg/mL	IV bag	Clear liquid in 250 ml IV bag
5	Yes	Epinephrine 1:10,000 Inj		10mL	1mg/10mL (0.1mg/ml)	syringe in box	auto-injector syringe in box

Event Day

<u>Instructor, Educator, Technician Huddle -</u> All simulation event team must arrive 15 minutes prior to learner start time.
• Verify setup checklist: manikin, equipment, and supplies are staged as requested.
• Confirm instructor roles and responsibilities:
  ○ patient voice (n/a)
  ○ answering the phone
  ○ Scenario director
  ○ Lead debriefer
  ○ Co-debriefer
  ○ ESPs
• Simulation progression understood by entire team

Pre-Brief Plan	
Time Allotted	20 minutes
Plan (Suggested outline below): Instructors will show the pre-brief power point	

Case Overview for Instructors/Facilitators
Pre-anesthesia evaluation in separate document will be presented to the learners. The participants will begin the scenario following the pre-brief by entering the OR during the beginning part of the surgery, after positioning and after incision has been made but before the microscope has been brought in. One participant will be assigned to monitor the TEE for air and the other participant will be monitoring/managing all other aspects of the anesthetic. The circulator will say that the lab called and they lost the confirmation blood sample in the tube system. Immediately after, the surgeon will state that there is some bleeding and ask if there is any blood available and to make sure it is in the room because they expect more blood loss, the patient has complicated anatomy and is oozing. Within a minute, the surgeon announces bleeding, one hears blood being suctioned and the blood pressure drops. After about 90 seconds there will be a significant venous air embolism and the air will appear on the TEE screen. The surgeon will announce proudly that the bleeding has stopped, but the monitors show suddenly low end-tidal CO2, oxygen desaturation and severe hypotension/low blood pressure. Participants will identify the problem, the cause and manage the treatment with an emphasis on communication with the entire OR team.
Case Summary in Lay Language: John Doe is a 45 yo male undergoing a right semi-sitting craniotomy. His pre-procedure evaluation is on a separate document that will be presented to the learners. The participants will begin the scenario following the pre-brief by entering the OR during the beginning part of the surgery, after positioning and after incision has been made but before the microscope has been brought in. One participant will be assigned to monitor the TEE for air and the other participant will be monitoring/managing all other aspects of the anesthetic. The circulator will say that the lab called and they lost the confirmation blood sample in the tube system. Immediately after, the surgeon will state

that there is some bleeding and ask if there is any blood available and to make sure it is in the room because they expect more blood loss, the patient has complicated anatomy and is oozing. Within a minute, the surgeon announces bleeding, one hears blood being suctioned and the blood pressure drops. After about 90 seconds there will be a significant venous air embolism and the air will appear on the TEE screen. The surgeon will announce proudly that the bleeding has stopped, but the monitors show suddenly low end-tidal CO2, oxygen desaturation and severe hypotension/low blood pressure. Participants will identify the problem, the cause and manage the treatment with an emphasis on communication with the entire OR team.

Information for Patient Voice

N/A- pt already anesthetized in this scenario

Information for Embedded Simulation Persons

Please provide the information the ESP should be prepared to provide to learners if queried. Consider: Recent history, apparent symptoms, physical exam findings that may need to be provided (eg: capillary refill)…

Role: **Surgeon-**
Instruction: **The surgeon will be gowned, gloved and operating. Surgeon will state that there is some bleeding and ask if there is any blood available and to make sure it is in the room because they expect more blood loss, the patient has complicated anatomy and is oozing.**
Shortly after, surgeon will suction and about 90 seconds later, the patient's blood pressure will drop. This is when you proudly announce you have stopped the bleeding and immediately after, signs of VAE will appear. During the scenario follow whatever instructions the anesthesia team gives you. They may ask you to flood the field with saline and apply bone wax while (make sure to ask them to hold some pressure on the bilateral jugular veins after you apply bone wax and announce you don't see any bleeding, you think the bone wax worked). If they say that air is still being entrained, say there is nothing more you can do, you don't see any bleeding. Surgeon should let the anesthesiologists try to diagnose, treat and manage the problem without prompting or leading but if they haven't addressed the problem with you ask, "Do you need me to stop?" "Can I keep going?" "What do you recommend we do post-op?"
Role: **Circulator-**
Instruction: **In the beginning within a minute of start of session, the circulator will say that the lab called and they lost the confirmation blood sample in the tube system. Once the surgeon asks if blood is available, ask the anesthesiologist if they have the confirmation tube yet. Ask a few more times as a distractor. If the anesthesiologists don't call for help, ask if they need you to call for help.**

Case Stem for Learners

An anesthesia pre-procedure evaluation form will be handed out and discussed with the learners after the OR orientation and before the scenario begins.

CASE PROGRESSION

Minute 0 - 3

State 1 Descriptor: Baseline

Temp	HR	BP	RR	O2%	Eyes	Vent Settings
36.2 C	68	120/80	14	99	closed	14 x 500, FiO2 50%, PEEP 5, EtCO2 32

Expected Learner Actions	Manikin/Response	Prompts/Script (For ESP, Voice…)
Acknowledge circulator, surgeon re: blood, communicate they are drawing another sample to be sent to lab	**n/a**	Circulator says blood bank called, 2nd sample lost for type and cross. Need to resend to lab. Surgeon says it is a good idea to get blood up to the core because the patient is oozing and he has complicated anatomy

Critical action or time to transition to next state: once blood sample in pink top tube handed to nurse can proceed to next state

Minute 3 - 6

State 2 Descriptor: Hypotension

Temp	HR	BP	RR	O2%	Eyes	EtCO2
36.2 C	88	74/42	Same settings/FiO2 as above	88	closed	30

Expected Learner Actions	Manikin/Response	Prompts/Script (For ESP, Voice…)
Learner #1: Identify and treat hypotension	**→ BP/CO2 rise to baseline once treated but BP CO2 fall again**	Surgeon: announces that he has control of bleeding/bleeding stopped; start suctioning blood again shortly after Surgeon: states they'll put some more bone wax on
Learner #2: Continue to monitor for VAE	**→ Notice and communicate that some air is being entrained**	
Learner #1: Identify and treat hypotension	**→ BP/CO2 do not return to baseline, pt now hypotensive and ETCO2 14 and SpO2 82%, →**	

Critical action or time to transition to next state: increase in air entrainment, vital signs do not improve

Minute 6 - 10						
State 3 Descriptor: VAE						
Temp	**HR**	**BP**	**RR**	**SpO2%**	**Eyes**	**ASL 5000 Settings**
36.2 C	**120**	**64/38**	**Same settings as above**	**82%**	**closed**	**50% FiO2, same settings as above**

Expected Learner Actions *Actions to be video tagged	**Manikin/Response**	**Prompts/Script (For ESP, Voice…)**
Learner #1/2- alert surgeon to VAE Learner #2- apply jugular pressure Learner #1- place patient on 100% FiO2, ask surgeon to flood field with saline and apply more bone wax, possibly aspirate central line, call for help	**→ mild improvement in BP to 88/68, SpO2 89%, HR 94, sinus rhythm** **→ ETCO2 remains 16**	Surgeon agrees to flood field, apply more bone wax, asks for bilateral jugular venous pressure; emphasizes that they're doing everything they can and do not see any source of VAE; If not addressed ask "Can I keep going? Do you need me to stop?" Suggest taking the patient out of sitting/putting them in Trendelenburg if not mentioned
Critical action or time to transition to next state: One of the learners states or agrees with surgeon that need to put patient in Trendelenburg in order to continue then can proceed to next state		

Minute 10 -20						
State 4 Descriptor: Recovery/Resolution						
Temp	**HR**	**BP**	**RR**	**O2%**	**Eyes**	**Lung Sounds: ETCO2:**
	94	**88/68**	**Same as above**	**SpO2 89%**		**Mild wheeze**

Expected Learner Actions *Actions to be video tagged	**Manikin/Response**	**Prompts/Script (For ESP, Voice…)**
Learner #1 Puts patient in Trendelenburg Learner #2 Monitors TEE and notes decrease in air entrainment	→ Vital signs improve to baseline with change in position	*Decrease in air on TEE once in Trendelenburg *Need to make sure learner puts patient in Trendelenburg and does not press "level" (due to position of head in Mayfield frame)- can surgeon or circulator prompt?
If no interventions, patient continues to deteriorate, and code called	**BP=50/28, HR=141, SPO2=75 EtCO2 10**	

Critical action or time to transition to next state: either patient improves, or code is called		