

Supplementary Appendix

This appendix has been provided by the authors to give readers additional information about their work.

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Supplementary Appendix for manuscript: Surgical Crisis Checklists: A Simulation-Based Randomized Controlled Trial

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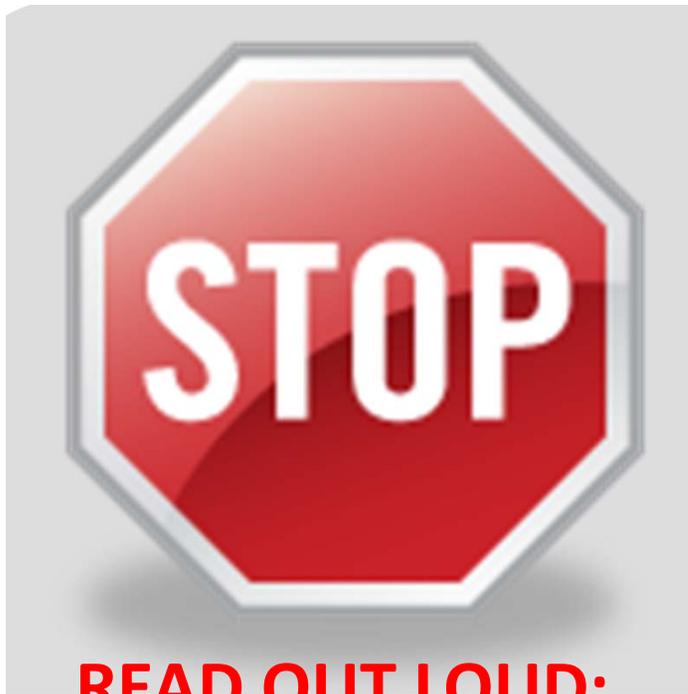
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Copy of the Crisis Checklists Used for the Study:

A copy of the Crisis Checklists used for this study is attached below. As noted in the manuscript, future work in this field should include determining the best user interface (e.g. paper, electronic, tablet versions), a method to update the checklists as evidence evolves, and the ideal mechanisms for training and implementation. Those implementing must review and customize to their institution. In an effort to keep the checklists updated, the authors of this work have assembled a team to periodically review the content and modify the checklists as evidence evolves. Further information, including a link to the most up-to-date version of the crisis checklists, can be found at <http://www.projectcheck.org/crisis>.

OR Critical Event Checklists



READ OUT LOUD:

Has somebody called for help?

Who is going to be the team leader?

Air Embolism

1

Anaphylaxis

2

Bradycardia - Unstable

3

Cardiac Arrest - Asystole/PEA

4

Cardiac Arrest - VF/VT

5

Failed Airway

6

Fire

7

Hemorrhage

8

Hypotension

9

Hypoxia

10

Malignant Hyperthermia

11

Tachycardia - Unstable

12

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1: Air Embolism

Condition: Suspected air embolism (decreased end-tidal CO₂ and oxygen saturation).

Objective: Restore normal oxygen saturation and hemodynamic stability and stop source of air entry.

- **Call for help.**
- **FiO₂ increased** to 100%?
- **Nitrous oxide** anesthetic stopped?
- **Source of air entry stopped?**
 - **Surgical site** lowered below level of heart, if possible?
 - **Wound** filled with irrigation?
 - **Entry point** searched for (including open venous lines)?
 - **Intermittent jugular venous compression** considered if head or cranial case?
- **Transesophageal echocardiography** called for (if available)?

Have we considered:

- **Left side down** once source controlled?
- **Aspiration of air** from a central line?
- **Vasopressors** (e.g. dobutamine, norepinephrine)?
- **Chest compressions** (100/min; to force air through lock, even if not in cardiac arrest)?

Reference:

- **If cardiac arrest:**
Give 1 mg epinephrine IV, begin ACLS and **GO TO:** Cardiac Arrest – Asystole/PEA Checklist or Cardiac Arrest – VF/VT Checklist.

1

2: Anaphylaxis

Condition: Suspected anaphylaxis (consistent history, urticaria, hypotension, bronchospasm).

Objective: Restore hemodynamic stability, abort reaction.

- **Call for help.**
- **Potential causative agents** removed?
- **FiO₂** increased to 100%?
- **Epinephrine** given?
(Epinephrine dose may be repeated every 1-2 minutes as clinically indicated).
- **Airway** established/secured?
- **IV access** adequate?
- **IV fluids opened** and/or **fluid bolus** given at high rate?
- **If no response: begin IV epinephrine infusion** (rate: 1-4 micrograms/minute).

Have we considered:

- **Termination of the procedure** to focus on resuscitation?
- **Vasopressin?** (40 Units IV; for patients with continued hypotension)
- **Albuterol?** (if bronchospasm a prominent feature)
- **Diphenhydramine** (25-50mg IV)?
- **H₂ blockers** (e.g. ranitidine 50mg IM/IV; cimetidine 300mg IM/IV)?
- **Glucagon?** (1-5mg administered IV over 5 minutes, in patients taking beta blockers)
- **Hydrocortisone** (100-200mg IV)?
- **Tryptase level?** (useful to guide future management)

Common causative agents:

Neuromuscular blocking agents, latex products (gloves, blood pressure cuff, Foley catheter), chlorhexidine, IV colloids.

Drug Doses:

- **Epinephrine doses:**
1 to 5 mL (0.1-0.5 mg) IV, depending on severity, diluted 1:10,000 before bolus.
- 0.3 mL (0.3 mg) IM if no IV access (diluted 1:1,000).
- **If cardiac arrest:** give 1 mg epinephrine IV, begin ACLS and **GO TO:** Cardiac Arrest – Asystole/PEA Checklist or Cardiac Arrest – VF/VT Checklist.

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3: Bradycardia - Unstable

Condition: Hemodynamic instability, persistent bradycardia with pulses.

Objective: Restore hemodynamic stability, adequate perfusion.

- **Call for help.**
- **Get transcutaneous pacer.**
- Give **Atropine** (0.5mg IV; may repeat to 3mg total).
- Stop **surgical stimulation** (If laparoscopy, desufflate).
- **If myocardial infarction suspected** (e.g. ECG changes), treat accordingly. (e.g. oxygen, nitrates, consider terminating procedure)
- **Assess for drug induced causes** (e.g., beta blockers, calcium channel blockers, digoxin).
- **If persistent bradycardia, begin pacing:**
 1. **Place electrodes on chest** from the transcutaneous pacer.
 2. **Place pacing pads on chest** per package instructions.
 2. **Turn monitor/defibrillator ON**, set to **PACER** mode.
 3. **Set PACER RATE (ppm) to 60/min**. (Can be adjusted up or down based on clinical response once pacing is established).
 4. **Increase the milliamperes (mA) of PACER OUTPUT until electrical capture** (pacer spikes aligned with QRS complex; threshold normally 65-100mA). Set final milliamperes to 10mA above this level.
 5. **Confirm pulse present.****
- **If pacing ineffective (or while awaiting pacer):**
 - **Consider Epinephrine** (2 to 10 micrograms/min) or **Dopamine** (2 to 10 micrograms/kg/min).
- Consider **expert consultation**.

During Resuscitation:

- **Airway** (assess and secure)
- **Breathing** (100% FiO₂)
- **Circulation** (confirm adequate IV or IO access)
 - Consider IV fluids wide open.
 - Consider 12-lead ECG.

Overdose Treatments:

Beta-blocker overdose:

- Glucagon (2-4mg IV push).

Calcium channel blocker overdose:

- Calcium chloride (1g IV).

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**** If PEA develops, GO TO: Cardiac Arrest – Asystole/PEA Checklist**

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4: Cardiac Arrest – Asystole/PEA

Condition: Non-shockable pulseless cardiac arrest.

Objective: Restore pulse, hemodynamic stability.

- **Call for help.**
- **CPR** (100 chest compressions/min and 8 breaths per minute)*
 - Ensure full chest recoil with minimal interruptions.
- **Epinephrine (or Vasopressin).**
- **Check pulse & rhythm** (after every 2 minutes of CPR):
 - If **no pulse and shockable** (VF/VT): **GO TO: Cardiac Arrest - VF/VT Checklist**
 - If **no pulse and NOT shockable** (asystole/PEA):
 - Resume CPR.
 - Read out potential causes (H&Ts).
 - Restart checklist.
 - If **pulse:**
 - Begin post-resuscitation care.
 - Read out potential causes (H &Ts).

Potential Causes (H&Ts):

- Hypovolemia
- Hypoxia
- Hydrogen ion (acidosis)
- Hypo-/hyperkalemia
- Hypothermia
- Tension Pneumothorax
- Tamponade (Cardiac)
- Toxins (narcotic, local anesthetic, beta blocker, channel blocker)
- Thrombosis (Pulmonary)
- Thrombosis (Coronary)

During CPR:

- **Airway** ([bag mask ventilation]).
- **Breathing** (100% FiO₂).
- **Circulation** (confirm adequate IV or IO access) .
 - Consider IV fluids wide open.
- **Assign roles for:** Chest compressions, airway, vascular access, documentation, code cart, time keeping. Orders should be explicitly acknowledged and repeated.

Drug Doses and Treatments:

Epinephrine dosing: 1mg IV, repeats every 3-5 minutes

Vasopressin 40 Units IV can be given to replace the first or second dose of epinephrine.

Hyperkalemia treatment:

- Calcium gluconate (10mg/kg) or Calcium chloride (10mg/kg) IV;
- Sodium bicarbonate 1-2mEq/kg, slow IV push
- Insulin 10 Units regular IV with 1-2 amps D50W (Dextrose 50% in Water)

Toxin Treatments:

Narcotic Overdose:

- Naloxone 0.04 to 0.4 mg IV, may repeat dosing if response inadequate.

Local Anesthetic overdose:

Intralipid administration:

- 1.5mL/kg IV bolus
- Repeat 1-2 times for persistent asystole
- Start infusion 0.25 to 0.5 mL/kg/min for 30-60 minutes for refractory hypotension

Beta-blocker overdose:

- Glucagon (2-4mg IV push)

Calcium channel blocker overdose:

- Calcium chloride (1g IV).

4

* In patient without an advanced airway: **Cycle of CPR = 30 compressions at a rate of 100/min, followed by two breaths Provide 5 cycles of CPR where "CPR x 2 minutes"** is noted

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5: Cardiac Arrest – VF/VT

Condition: Shockable pulseless cardiac arrest.

Objective: Restore pulse, hemodynamic stability.

5

Top Priority = Early Defibrillation.

- **Call for help.**
- **Get defibrillator.**
- **CPR (100 chest compressions/minute + 8 breaths per minute).***
 - Ensure full chest recoil with minimal interruptions.
- **Shock at highest setting.** ←
- **Epinephrine.**
- **CPR x 2 minutes.**

- **Check pulse & rhythm (confirm shockable).****
- **Shock at highest setting.**
- **Epinephrine.**
- **CPR x 2 minutes.**

- **Check pulse & rhythm (confirm shockable).****
- **Shock at highest setting.**
- **Amiodarone.**
- **CPR x 2 minutes.**

- **Check pulse and rhythm (confirm shockable).**** →

During CPR:

- **Airway** ([bag mask ok if ventilation adequate]).
- **Breathing** (100% FiO₂).
- **Circulation** (confirm adequate IV or IO access).
 - Consider IV fluids wide open.
- **Assign roles for:** Chest compressions, defibrillation, airway, vascular access, documentation, code cart, time keeping. Orders should be explicitly acknowledged and repeated.

Defibrillator:

1. Turn defibrillator ON, set to DEFIB mode.
2. Place electrodes on chest per packing instructions.
3. Deliver shock (“Charge” button → “Shock” button)

Drug Doses and additional considerations:

Epinephrine dosing: 1mg IV, repeat every 3-5 minutes.

Vasopressin 40 Units IV can be given to replace the first or second dose of epinephrine.

Amiodarone dosing: 300 mg IV/IO once, then consider additional 150 mg IV/IO once.

Lidocaine can be given if Amiodarone unavailable:
1 to 1.5 mg/kg first dose, then 0.5 to 0.75 mg/kg IV/IO, maximum 3 doses or 3 mg/kg.

Magnesium dosing: Consider giving (loading dose 1 to 2 g IV/IO) for torsades de pointes.

* In patient without an advanced airway: **Cycle of CPR = 30 compressions at a rate of 100/min, followed by two breaths. Give 5 cycles of CPR where “CPR x 2 minutes” is noted**

** If **Aystole/PEA** develops at any point, **GO TO** Cardiac Arrest: Asystole/PEA checklist

** If **pulse at any point**, begin post-resuscitation care

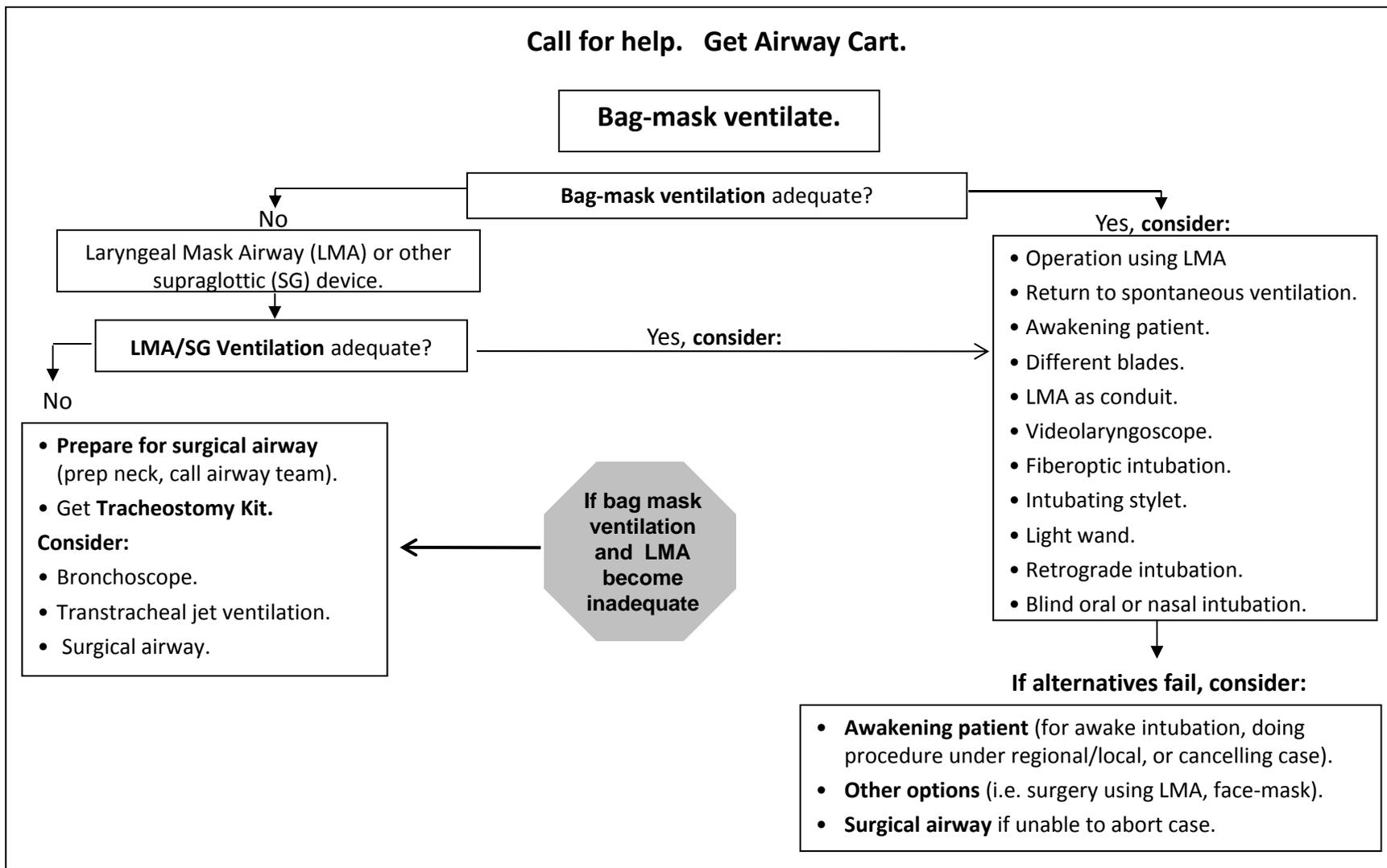
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6: Failed Airway

Condition: Failed airway (2 unsuccessful attempts or oxygen saturation less than 85%).
Objective: Establish adequate oxygenation/ventilation.

6



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7: Fire

Condition: Signs of fire in OR, in the airway, or on patient (smoke, odor, flash).

Objective: Protect patient, contain fire.

Activate fire alarm/Get fire-extinguisher/Remove source of heat.

Airway Fire

- Stop flow of medical gases (oxygen/Nitrous Oxide).
- Disconnect breathing circuit.
- Remove endotracheal tube (must balance against airway loss).
- Remove flammable material from airway.
- Pour saline into endotracheal tube, if kept.

Non-airway Fire

- Stop flow of medical gases (oxygen/Nitrous Oxide).
- Remove drapes and flammable materials from patient.
- Extinguish fire with saline, soaked gauze, or other means.
- ****Do not use alcohol based solutions****
- ****Do not use any liquid for fires on or in energized electrical equipment (Laser, ESU/Bovie, Anesthesia Machine, etc.)****

7

If Fire Not Extinguished On First Attempt

Use fire extinguisher (CO₂) to extinguish fire (Safe in wounds).

If Fire Persists

- Evacuate patient (Per institutional protocol).
- Close OR door.
- Turn **OFF** gas supply to room.

Fire Extinguished

- Maintain or reestablish airway.
- Avoid oxidizer-rich environment (if possible).
- Assess for inhalation injury, consider bronchoscopy.
- Examine ET tube to see if fragments may be left behind.
- Discuss continuation of case with surgeon.

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8: Hemorrhage

Condition: Acute massive bleeding.

Objective: Stop bleeding, maintain hemodynamic stability, avoid coagulopathy.

- **Call for help.**
- **IV fluids opened?**
 - **IV access** adequate?
- **Call blood bank:**
 - **Massive transfusion protocol** activated (if available)?
 - **Blood products** ordered (in addition to PRBCs)?
 - **FFP** (consider 1:1 ratio with PRBCs).
 - **Platelets** (if indicated; consider 1:1 ratio with PRBC's).
 - **Cryoprecipitate** (if indicated; per institution protocol).
- **Additional lap sponges** requested?
- **Rapid infuser** (or pressure bags) requested?
- **Labs sent?**
 - CBC, PT/PTT/INR, Fibrinogen, Lactate, ABG, Potassium.

Have we considered:

- **Additional surgical techniques and/or personnel?**
 - **Hemostatic agents?**
 - **Vascular instruments or consultation?**
- **Damage control surgery** (pack, close, resuscitate)?
- **Warming** the room and patient?
- **Factor VII** (per institution protocol)?

Transfusion Considerations:

Cryoprecipitate	Fibrinogen greater than 100 mg/dL
Red Blood Cells	Hematocrit greater than 21%
Platelets	Platelet count greater than 50,000/microliter
Fresh Frozen Plasma	PT/PTT less than 1.5 times control

- **Cell Saver** (for nonmalignant, noncontaminated cases)

Hyperkalemia Treatment:

- Calcium gluconate (10mg/kg) or Calcium chloride 10mg/kg) IV;
- Sodium bicarbonate 1-2mEq/kg, slow IV push.
- Insulin 10 Units regular IV with 1-2 amps D50W (Dextrose 50% in Water).

8

9: Hypotension

Condition: Unexplained drop in blood pressure.

Objective: Restore hemodynamic stability.

9

- **Call for help.**
- **Equipment** checked for malfunction (arterial line, blood pressure cuff)?
- **Pulses** checked?
- **Intravenous fluids** opened?
- **FiO₂** increased to 100%?
- Surgical field inspected for **bleeding?** If Bleeding **GO TO:** Hemorrhage Checklist.
- Have we considered:
 - **decreasing anesthesia?**
 - **patient position?**
 - **additional IV?**
- **Have we considered the following causes:**

Surgical

- Retraction
- Vagal stimulation
- Mechanical/surgical manipulation
- Vascular Compression

Nursing

- Other evidence of bleeding:
 - Amount of **blood in suction canister**
 - Number of **bloody sponges**
 - **Blood on the floor**
- Drugs used on the field (i.e. intravascular injection of local drugs)

Anesthesia/OR Team

Airway:

- Unexplained Hypoxia (**GO TO:** Hypoxia Checklist)
- Increased PEEP

Breathing:

- Pneumothorax
- Pulmonary Edema
- Hypoventilation
- Persistent hyperventilation

Circulation:

- Myocardial ischemia
- Pulmonary Embolism
- Air embolism (**GO TO:** Air Embolism Checklist)
- Other emboli (fat, septic, CO₂)
- Tamponade
- Bradycardia (**GO TO:** Bradycardia – Unstable Checklist)
- Tachycardia (**GO TO:** Tachycardia – Unstable Checklist)
- Bone Cementing (**Methyl methacrylate effect**)
- Malignant Hyperthermia (**GO TO:** Malignant Hyperthermia Checklist)

Drugs/allergy:

- **Recent drugs** given/dose error/allergy

10: Hypoxia

Condition: Unexplained oxygen desaturation.

Objective: Restore oxygenation.

10

- Call for help.
- Pulse oximeter placement checked?
- FiO₂ increased to 100%?
- Hand ventilation initiated?
- Oxygen source checked?
- Circuit checked? (disconnection, kinks, holes)
- End tidal CO₂ confirmed?
- Breath sounds checked?
- ET tube position checked?
- Blood gas drawn?

Suspected Airway/Breathing Issue?

Yes

Have we considered:

- Suctioning (mucus plug)
- Removing circuit and using ambu-bag
- Bronchoscopy
- Pulling ETT and Mask Ventilation/Re-Intubation

Consider causes:

- Airway:**
- Right mainstem intubation
 - Bronchospasm?
 - Ventilator settings, leading to auto-peep
- Breathing:**
- Aspiration
 - Atelectasis
 - Obesity/positioning
 - Pneumothorax
 - Chest X-Ray, chest tube, needle decompression considered
 - Hypoventilation
 - Pulmonary Edema

No

Consider causes:

- Circulation:**
- Embolism
 - Pulmonary Embolus
 - Air Embolism? (**GO TO:** Air Embolism Checklist)
 - Other Emboli (e.g. fat, septic, CO₂)
 - Heart disease?
 - Congestive Heart Failure
 - Coronary Artery Disease
 - Myocardial Ischemia
 - Cardiac Tamponade
 - Congenital/anatomic Defect
 - Electrocardiogram, Transesophageal echocardiogram, bypass considered?
 - Severe Sepsis
 - If hypoxia associated with hypotension (**GO TO:** Hypotension Checklist)
- Drugs/allergy:**
- Recent drugs given
 - Dose error/ allergy/anaphylaxis

11: Malignant Hyperthermia

Condition: Unexpected, unexplained increase in end-tidal CO₂; prolonged masseter muscle spasm after succinylcholine; unexpected, unexplained tachycardia.

Objective: Restore normal hemodynamic parameters, metabolic function, temperature.

- **Call for help.**
- **Get Malignant Hyperthermia (MH) Kit.**
- **Volatile Anesthetics stopped/transitioned to non-triggering anesthetics?**
 - Don't delay treatment to change circuit or CO₂ absorber.
 - Request chilled IV saline.
- **FiO₂ increased to 100%?**
- **Hyperventilation initiated?**
 - 10 L/min or more (or 2-4 times the patient's minute ventilation).
- **Dantrolene given?**
 - Assign dedicated person to mix dantrolene.
- **MH hotline called? 1-800-644-9737 (Outside United States: 00+1+303-389-1647).**
- **Procedure terminated** (if possible)?
- **Bicarbonate** given for suspected metabolic acidosis?
 - Maintain pH greater than 7.2.
- **Patient cooled** if temperature greater than 38.5°C?
 - Lavage open body cavities.
 - NG lavage with cold water.
 - Apply ice externally.
 - Cold saline infused intravenously.

**** Stop cooling if temperature less than 38°C. ****
- **Hyperkalemia** treated if suspected?
- **Dysrhythmias** treated if present?
 - Standard antiarrhythmics are acceptable; **don't use Calcium Channel Blockers.**
- **Labs sent?** (ABG, venous blood gas, electrolytes, serum creatine kinase, serum/urine myoglobin, coagulation profile)
- **Foley catheter placed?**
 - Monitor urine output.
- **ICU called/disposition arranged?**

Drug Doses and Treatments:

Dantrolene: 2.5mg/kg IV every 5 minutes until symptoms subside. (Mix each ampule with 60mL sterile water. May require up to 30mg/kg).

Bicarbonate: 1-2mEq/kg for suspected metabolic acidosis (may give even if blood gas values not available).

Hyperkalemia Treatment:

- Calcium gluconate (10mg/kg) or Calcium chloride (10mg/kg) IV;
- Sodium bicarbonate 1-2mEq/kg, slow IV push.
- Insulin 10 Units regular IV with 1-2 amps D50W (Dextrose 50% in Water).

11

12: Tachycardia - Unstable

Condition: Hemodynamic instability, tachycardia with pulses.

Objective: Restore hemodynamic stability, adequate perfusion.

- Call for help.
- Get code cart/defibrillator.

Prepare for immediate synchronized cardioversion:

1. Sedate all conscious patients unless deteriorating rapidly.
2. Turn monitor/defibrillator ON, set to DEFIB mode.
3. Place electrodes on chest per packing instructions.
4. Press SYNC button to engage synchronization mode.
5. Look for mark/spike on the R-wave indicating synchronization mode.
(Adjust SIZE button if necessary until SYNC markers seen with each R-wave).

6. Cardiovert at appropriate energy level, begin with lower level and progress as needed:

(“Energy select” buttons → “Charge” button → “Shock” button [press and hold])

Atrial fibrillation	120J. → SYNC* → 150J. → SYNC* → 200J
Mono-morphic VT	100J. → SYNC* → 150J. → SYNC* → 200J.
Other SVT, atrial flutter	50J. → SYNC* → 100J. → SYNC* → 150J. → SYNC* → 200J.
Poly-morphic VT and unstable	Treat as VF, GO TO: Cardiac Arrest – VF/VT Checklist.

7. Check monitor; if tachycardia persists, increase energy level.
8. Consider expert consultation.

During Resuscitation:

- Airway (assess and secure)
- Breathing (100% FiO₂)
- Circulation (confirm adequate IV or IO access)
 - Consider IV fluids wide open.
 - Consider 12-lead ECG.

12

* Repeat steps 4 and 5 (engage and confirm synchronization mode) after delivery of each synchronized shock.

** If VF/Unstable VT develops GO TO: Cardiac Arrest – VF/VT Checklist

** If PEA develops, GO TO: Cardiac Arrest – Asystole/PEA Checklist

Schematic of team participation in the crisis scenarios:

Scenarios	
1	Anaphylaxis
2	Tachycardia
3	Bradycardia, unexplained hypotension/hypoxia
4	Malignant hyperthermia
5	Asystole
6	Hemorrhage, ventricular fibrillation
7	Hemorrhage
8	Ventricular fibrillation
9	Air embolism

Sequence 1	Sequence 2	Sequence 3	Sequence 4	Sequence 5	Sequence 6	Sequence 7	Sequence 8	Sequence 9
4	4	5	6	4	2	6	1	2
2	2	3	4	6	6	2	5	1
7	6	4	2	2	1	4	3	5
8	5	2	3	5	4	1	2	3
3	3	6	1	1	5	5	4	4
9	1	1	5	3	3	3	6	6
5	--	--	--	--	--	--	--	--
1	--	--	--	--	--	--	--	--

Crisis checklists available
Crisis checklists unavailable

Details on team participation:

- Each of the 17 teams participated in one and only one sequence (i.e. each of the first eight sequences was repeated with a different team that had the opposite availability of the crisis checklists). As there were an odd number of teams, sequence 9 was not repeated.
- For the first two study dates (which corresponds to sequence 1), a longer study session was conducted and eight scenarios were performed (i.e. one of the scenarios [hemorrhage, ventricular fibrillation] was split into two separate simulations and an additional scenario was added [air embolism]).
- For the last fifteen study dates (which corresponds to sequences 2-9), a crossover design was used (i.e. each team randomly performed either their first three scenarios OR their last three scenarios with the checklists available) to reduce potential spillover effects of teams using the checklists in an alternating fashion.
- Failed airway and fire were not simulated due to resource constraints, as well as a need to limit the length of the study day for a given participating team.
- The randomization of the scenario order and checklist availability was performed using a random number generator (Microsoft Excel 2007, Redmond, WA). To avoid an overabundance of the same type of crisis in either the intervention or control group, the order of these scenarios were randomized such that each team managed one of each scenario-type (i.e. one cardiac arrest, one case of unstable bradycardia or tachycardia, and one non-ACLS case [anaphylaxis or malignant hyperthermia]) with the checklists available and a different one of each type by memory alone.

Checklist Development:

As noted in the manuscript, a detailed description of the development and pilot testing of the crisis checklists can be found elsewhere.¹ Briefly, we reviewed the literature to determine the most common life-threatening crises that occur in the operating room as well as the critical evidence-based processes of care necessary for their appropriate management. Following a previously established methodology,² we drafted a set of checklists and vetted them for content by a multidisciplinary group of experts (including surgeons, anesthesiologists, nurses, operating room directors, experts in medical simulation and education, and a lead checklist developer from the Boeing Aircraft Corporation). The refined checklists were then assessed for usability during trial runs in a high fidelity simulation environment. This cycle was repeated until the group felt that the checklists had the greatest potential to reduce harm and death in the operating room. This resulted in the development of twelve checklists (for air embolism, anaphylaxis, asystolic cardiac arrest, failed airway, hemorrhage, malignant hyperthermia, operating room fire, ventricular fibrillation, unexplained hypotension, unexplained hypoxia, unstable bradycardia, and unstable tachycardia) with triggers for key life-saving evidence-based processes of care for each crisis (e.g. calling for help early, using synchronized cardioversion for unstable tachycardia, treating hyperkalemia in malignant hyperthermia). After the initial checklist development, minor modifications were made based on updates to national consensus guidelines and lessons learned from early pilot testing.^{3,4}

Key Processes tracked:

Key Processes for Asystolic Cardiac Arrest:

1. Chest compressions are initiated within one minute of onset of asystole or pulseless electrical activity (PEA).^{3,5}
2. After onset of asystole/PEA, chest compressions (once initiated) are given without prolonged interruption(s) (No pause greater than 30seconds).^{3,5,6}
3. Patient does not receive shock while pulse/rhythm indicates asystole/PEA.⁷
4. Initial dose of epinephrine (or vasopressin) given within 3 minutes of onset of asystole/PEA.³ [*Note: After the release of the 2010 update on the Advanced Cardiac Life Support guidelines by the American Heart Association, participating teams were neither penalized nor rewarded for giving atropine for asystolic cardiac arrest*].
5. Repeat dose of epinephrine (or vasopressin) given within 3-5 minutes after the first dose.³
6. At least one team member in the room explicitly calls for outside help (e.g. phone call) within 1 minute of onset of Asystole/PEA.³
7. At least one member reads aloud the H's and T's (or explicitly discusses the causes in any order) within 10 minutes of the start of asystole/PEA.³

Key Processes for Air Embolism:

8. FiO₂ increased to 100% within 3 minutes of air embolism (indicative signs: significantly decreased end-tidal CO₂ and oxygen desaturation).^{8,9}

- Implicit by increasing FiO2 to 100%: Nitrous oxide anesthetic stopped within 3 minutes of air embolism.^{10, 11}

9. Attempts made to stop the source of air entry within 5 minutes of air embolism (Scenario specific. Examples include: surgical site lowered below level of heart; wound filled with irrigation; intermittent jugular venous compression for head and neck/cranial cases; explicit search for entry point).^{8, 12-14}
10. At least one team member explicitly call for help (e.g. phone call) within 3 minutes of the onset of air embolism.³

Key Processes for Anaphylaxis:

11. Epinephrine given within 3 minutes of anaphylaxis (indicative signs: hypotension/hemodynamic instability, wheezing, significant urticaria).¹⁵⁻²⁸
12. Potential causative agents removed within 3 minutes of anaphylaxis (Scenario specific. Examples include: removal of latex foley catheter; removal of IV antibiotics).^{16, 29}
13. FiO2 increased to 100% within 3 minute of anaphylaxis.¹⁵⁻¹⁸
14. Fluid bolus given or fluids placed wide open within 3 minutes of anaphylaxis.^{15-18, 27, 28}
15. Hydrocortisone administered within 5 minutes of anaphylaxis.^{16, 18, 30, 31}
16. At least one team member in the room explicitly calls for outside help (e.g. phone call) within 3 minutes of onset of anaphylaxis.³

Key Processes for Hemorrhage followed by Ventricular Fibrillation:

17. Blood bank is notified within 5 min of sudden unexpected significant blood loss.³²
18. Intravenous fluids opened or fluid bolus given within 5 min of sudden unexpected blood loss.³³

19. Packed red blood cells are administered within 10 minutes of sudden unexpected blood loss with hemodynamic instability.³²
20. At least one team member in the room explicitly calls for outside help (e.g. phone call) within 5 minutes of onset of sudden unexpected blood loss.³
21. Chest compressions are initiated within one minute of onset of ventricular fibrillation.^{3,5}
22. After onset of ventricular fibrillation, chest compressions (once initiated) are given without prolonged interruption(s) (No pause greater than 30 seconds, except for when explicitly clearing patient and delivering shocks).^{3,5,6}
23. Patient receives a shock within 3 minutes of onset of ventricular fibrillation.^{3,7,34}
24. Patient receives the appropriate joule setting when all shocks delivered.^{3,7}
25. Initial dose of epinephrine (or vasopressin) given within 5 minutes of onset of ventricular fibrillation.³
26. Initial dose of amiodarone (or lidocaine) given after epinephrine (or vasopressin).³
27. Repeat dose of epinephrine (or vasopressin) given within 3-5 minutes after the first dose.³
28. At least one team member in the room explicitly calls for outside help (e.g. phone call) within 1 minute of onset of ventricular fibrillation.³
29. At least one team member calls for the defibrillator within 1 minute of the onset of ventricular fibrillation.^{3,7,34}

Key Processes for Unexplained Hypotension/Hypoxia followed by Unstable Bradycardia:

30. IV fluids opened wide or fluid bolus given within 3 minutes of unstable hypotension.³⁵⁻³⁷
31. FiO₂ increased to 100% within 3 minutes of unstable hypotension/hypoxia.³⁸

32. Hand Ventilation initiated within 3 minutes of hypoxia.³⁸
33. Breath sounds auscultated within 3 minutes of hypoxia.^{38, 39}
34. Suction provided through the endotracheal tube.³⁸
35. At least one team member in the room explicitly calls for outside help (e.g. phone call) within 3 minutes of onset of unstable hypotension/hypoxia.³
36. Atropine given within 5 minutes of unstable bradycardia.^{3, 40, 41}
37. Transcutaneous pacing established within 3 minutes of unstable bradycardia onset.^{3, 42, 43}

Key Processes for Malignant Hyperthermia:

38. Dantrolene given within 7 minutes of MH.⁴⁴⁻⁴⁶
39. All volatile anesthetics stopped within 3 minute of onset of MH (increased ETCO₂, tachycardia, febrile).⁴⁷
40. FiO₂ increased to 100% within 3 minute of onset of MH.⁴⁷
41. Patient hyperventilated (i.e. 2-4 times the minute ventilation the patient was initially receiving) within 3 minute of onset of MH.^{44, 45, 47}
42. Attempts made to cool the patient within 5 minutes of MH (cooling blanket, gastric lavage, and/or external ice packs).^{44, 45}
43. Drugs given to treat hyperkalemia within 5 minutes of rhythm change.⁴⁴⁻⁴⁸

44. At least one team member in the room explicitly calls for outside help (e.g. phone call) within 3 minutes of onset of malignant hyperthermia.^{3, 47, 48}

Key Processes for Unstable Tachycardia:

45. Synchronized cardioversion initiated within 5 minutes of unstable tachycardia onset (i.e. pads on patient; appropriate synchronization established with SYNC markers on each R wave).³

46. At least one team member in the room explicitly calls for outside help (e.g. phone call) within 2 minutes of onset of unstable tachycardia.³

47. At least one team member calls for the defibrillator within 2 minutes of the onset of unstable tachycardia.³

Additional Survey Questions and Responses from the Participant Survey:

Table S1: Participant perceptions of the crisis checklists.

Checklist Survey Question	Mean Likert Response Across all Checklist Scenarios (N=196 responses; 67 participants) (1=Disagree Strongly, 5=Agree Strongly) (+/- standard deviation)
The checklist helped me feel better prepared during the emergency scenario.	4.4 +/- 0.81
The checklist was easy to use.	4.3 +/- 0.84
The font was clear and easy to read	4.7 +/- 0.64
I would use this checklist if I were presented with this operative emergency in real life.	4.5 +/- 0.76
The checklist did not disrupt clinical flow of the operative emergency	4.4 +/- 1.02
If I were having an operation and experienced this intraoperative emergency, I would want the checklist to be used.	4.7 +/- 0.60

Table S2: Participant perceptions of the scenarios

Survey Question	Mean Likert Response Across all Scenarios (N=423 responses; 67 participants) (1=Disagree Strongly, 5=Agree Strongly) (+/- standard deviation)
The scenario was realistic.	4.6 +/- 0.68
The scenario was appropriately challenging.	4.7 +/- 0.54
This scenario will help me provide safer patient care.	4.5 +/- 0.71
This scenario prompted realistic responses from me.	4.6 +/- 0.65
I felt I did things during this training day that I would never have had a chance to practice otherwise.	4.0 +/- 1.19
The knowledge gained will be helpful to me in my practice.	4.5 +/- 0.77
I enjoyed the training session.	4.7 +/- 0.65
I learned something new.	4.3 +/- 0.87
This training session should be taken by all OR staff.	4.7 +/- 0.64

Table S3: Overall participant perceptions

Survey Question	Mean Likert Response Across all Scenarios (N=67 responses; 67 participants) (1=Disagree Strongly, 5=Agree Strongly) (+/- standard deviation)
Overall session:	4.7 +/- 0.44
Quality of emergency checklists:	4.6 +/- 0.58
Quality of scenarios:	4.6 +/- 0.58
I would like this type of simulation session again.	4.7 +/- 0.65
If these sessions were held offsite (simulation center in a neighboring hospital), I would still want to attend.	4.6 +/- 0.96
In the scenarios where a checklist was available and used, I felt less stressed.	4.2 +/- 1.04
I plan to utilize what I learned into my practice.	4.7 +/- 0.60

Table S4: Participant perceptions regarding the best potential location for the crisis checklists

What would be the best location for these checklists?	Frequency of response (%)*
On the side of or near the anesthesia cart	38.4%
On a specified location on the OR wall	30.3%
On the operative field	1.0%
With the patient's chart	0.0%
Near the circulator's station or computer	22.2%
On or attached to the code cart	4%
Other	4%

* Represents 99 responses from 67 participants, some of whom offered multiple locations in which the checklist could reside or who felt the checklist should be provided in more than one location in the operating room.

Additional statistical details on the primary multivariate analysis reported in the results section:⁴⁹

We used multivariate relative risk regression for dichotomous outcomes (using the log link function instead of the logistic link function) to compare failure rates with and without the checklist while accounting for clustering of the results within a team (using generalized estimating equations with an exchangeable correlation structure and a robust variance) and adjusting for institution, scenario, and time of day. Since the log link function was used, the exponentiated regression coefficients can be interpreted directly as adjusted multivariate relative risks;⁵⁰ we chose the log link function since the failure rate was not rare for the crises without the checklist, and thus adjusted odds ratios from logistic regression would not be a good approximation of the relative risk.

Additional details from the post-hoc analysis adjusting for whether the team experienced checklist or usual care simulation first:

As noted in the manuscript, additional post-hoc analyses were done (the number of post-hoc analyses reported in the manuscript equals the number performed). This included a post-hoc analysis re-running the primary multivariate analysis reported in the results section (see page 27 of this supplementary file) while adjusting for whether the team experienced the checklist or usual care simulation first. The effect of the “checklist block” covariate (i.e. whether the team experienced the checklist or usual care simulation first) was not significant ($p=0.8898$). The effect of the checklist was still significant ($p<0.001$) in this post-hoc analysis.

Information on sample size and power calculations:

When performing power calculations, because we did not have background data on performance during crises, we extrapolated adherence to best practices using data on best practices during operations from the surgical safety checklist study by Haynes et al,⁵¹ which did not focus on crisis situations. Based on the secondary analysis from this study, the rates of failure of adherence to best practices was expected on average to be 15% without the crisis checklists and 9% with checklists. Each team for the crisis checklist study was to be given three scenarios with the checklists available and three scenarios working from memory alone. Thus, across six scenarios, each team was to be measured on a total of 49 process measures for adherence (yes or no), with approximately half the processes for a given team with the checklist available [the manuscript reflects 47 key processes as some of the scenarios were consolidated to limit the length of the study day and some were revised after the publication of the 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care]. These process measures with and without the checklist were compared using a robust generalized estimating equation Wald test for binary outcomes (adherence yes or no), accounting for clustering of process measures within teams. Using a GEE Wald test with a 2-sided type I error rate of 5% with 20 teams and 980 total process measures (490 with and 490 without the checklist), we estimated to have over 80% power to detect a decrease in the adherence failure rate from 15% without the checklist to 9% with the checklist. In our study protocol, we noted a target recruitment of 100 teams to have room to accommodate more teams if they were readily available. In our power calculation, an intra-cluster correlation coefficient (ICC) within teams was estimated to be approximately 0.1, as is commonly used in this type of study.⁵²

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