Crisis Checklists for the Operating Room: Development and Pilot Testing


BACKGROUND: Because operating room crises are rare events, failure to adhere to critical management steps is common. We sought to develop and pilot a tool to improve adherence to lifesaving measures during operating room crises.

STUDY DESIGN: We identified 12 of the most frequently occurring operating room crises and corresponding evidence-based metrics of essential care for each (46 total process measures). We developed checklists for each crisis based on a previously defined method, which included literature review, multidisciplinary expert consultation, and simulation. After development, 2 operating room teams (11 participants) were each exposed to 8 simulations with random assignment to checklist use or working from memory alone. Each team managed 4 simulations with a checklist available and 4 without. One of the primary outcomes measured through video review was failure to adhere to essential processes of care. Participants were surveyed for perceptions of checklist use and realism of the scenarios.

RESULTS: Checklist use resulted in a 6-fold reduction in failure of adherence to critical steps in management for 8 scenarios with 2 pilot teams. These results held in multivariate analysis accounting for clustering within teams and adjusting for learning or fatigue effects (11 of 46 failures without the checklist vs 2 of 46 failures with the checklist; adjusted relative risk = 0.15, 95% CI, 0.04–0.60; p = 0.007). All participants rated the overall quality of the checklists and scenarios to be higher than average or excellent.

CONCLUSIONS: Checklist use can improve safety and management in operating room crises. These findings warrant broader evaluation, including in clinical settings. (J Am Coll Surg 2011;213:212–219. © 2011 by the American College of Surgeons)
Checklists are tools that can improve standardization, teamwork, and overall performance in crisis situations. Checklists for routine perioperative use have been shown in multiple studies to substantially reduce death and complications, and are rapidly becoming established as the standard of care. Checklists are standard in management of emergencies in aviation and other high-reliability fields, but they have not achieved widespread consideration for use in operating room crises.

Previous evidence suggests that cognitive aids (of which checklists are a subset) are correlated with improved management of operating room crises, and anesthesiologists have developed crisis management manuals to specifically aid their management in operating room crises. However, the efficacy of team checklists in improving the management of operating room crises remains untested and unknown.

We hypothesized that such checklists could aid surgical teams and their patients considerably. We therefore followed a structured process for development of team checklists for the most common and life-threatening operating room crises we could identify. To study the role of the checklists in the management of these infrequent and unpredictable crises, we carried out pilot testing in a high-fidelity simulator. We sought to determine the usability and promise of these checklists for reducing failure of adherence to critical steps in management.

METHODS
This project proceeded in 2 phases: checklist development and pilot testing of the checklists in a high-fidelity anesthesia simulator.

Checklist development
Checklist development proceeded according to previously established methodology. First, an extensive literature search was performed to identify the most common life-threatening operating room crises and their corresponding evidence-based treatments. After this review, initial drafts of checklists were completed and reviewed by local experts for content verification. Next, a multidisciplinary expert panel consisting of Harvard-affiliated operating room directors, surgeons, anesthesiologists, nurses, specialists in simulation and surgical education, and a lead checklist developer from the Boeing Aircraft Corporation was convened to formally review the content and design of the checklists. Iterative refinements were made after trial runs in a high-fidelity operating room simulator and re-review by our expert panel. The final product contained checklists for 10 specific crises (ie, air embolism, anaphylaxis, unstable bradycardia, unstable tachycardia, cardiac arrest with asystole, cardiac arrest with ventricular fibrillation, failed airway, fire, hemorrhage, and malignant hyperthermia) and 2 scenarios (ie, hypotension, hypoxia) for which a diagnosis is unclear (see Fig. 1; full checklists are available in Appendix 1, available online).

As part of this effort, we also defined a set of evidence-based critical, lifesaving processes for each crisis, resulting in a total of 46 key processes across all scenarios considered essential to management of these crises (see Appendix 2, available online).

Pilot testing
Two surgical teams (11 participants) were recruited to participate in a series of simulated emergencies in a high-fidelity operating room simulator. All teams consisted of active clinicians and included a surgical attending, surgical resident, anesthesia attending, anesthesia resident, and circulating nurses/surgical technologists. Each team performed 8 simulated operations in which 1 or more of the crisis events occurred (failed airway and operating room fire were not simulated because of resource constraints). No crisis simulation was repeated. The teams were randomly assigned to checklist use for 4 of the 8 scenarios, meaning that they managed 4 with use of a checklist and 4 from memory alone (see Table 1). Before simulations, teams were instructed on proper checklist use.

As a primary outcomes measure, the teams were videotaped and assessed for failure to adhere to essential processes in the management of each crisis (measures from Appendix 2, available online, which were based on the checklist items, were scored in a binary yes/no fashion). Where necessary to measure time to complete essential processes, times were measured from the onset of the crisis (eg, the appearance of a flat-lined heart monitor and loss of a pulse for asystole). The video analysis was performed by independent review of the videos by 2 physician reviewers (AFA, JEZ). In cases where there was disagreement, decisions were made by a third expert reviewer (a senior attending surgeon, WRB, for any processes initiated by a surgeon participant; a senior attending anesthesiologist, AMB, for any processes initiated by an anesthesiology or nursing participant). Participants were also surveyed for their assessment of the use and functionality of the checklists, as well as the reality and quality of the scenarios. Results were reported using 5-point Likert scales (1 = disagree strongly, 5 = agree strongly; or 1 = poor, 5 = excellent).

Data were analyzed using SAS version 9.2 (SAS Institute). All p values were 2-sided, and p values <0.05 were
considered significant. Agreement between 2 physician video reviewers was assessed using Cohen’s \( \kappa \). Percentages were used to summarize failure rates with and without the checklist. Multivariate generalized estimating equations were used to account for clustering of results within a team and to adjust for learning effect when comparing the failure rates with and without the checklist. The participant survey Likert scores were summarized using means with standard deviations and interquartile ranges.

RESULTS

Survey results: checklist usability

The pilot teams found the crisis checklists straightforward, usable, and beneficial. Table 2 demonstrates the aggregate mean Likert scores across all scenarios where a checklist was used (1 = disagree strongly, 5 = agree strongly). Participants reported that on average the checklists made them feel better prepared for emergencies (4.2 ± 0.95; interquartile range [IQR] 4 to 5), the checklists were easy to use (4.1 ± 0.92; IQR 4 to 5), they would use the checklists if presented with these emergencies in real life (4.3 ± 0.75; IQR 4 to 5), and that they would want practitioners to use the checklists if they experienced an operating room crisis as patients themselves (4.4 ± 0.68; IQR 4 to 5). All participants rated the overall quality of the checklists to be “above average” or “excellent” (4 or 5 on Likert scale). None of the participants disagreed strongly with any of the checklist survey questions, and all participants requested copies of the checklists for their own use.

Table 1. Pilot Study Design

<table>
<thead>
<tr>
<th>Simulation no.</th>
<th>Emergency</th>
<th>Team 1</th>
<th>Team 2</th>
<th>No. of key processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Malignant hyperthermia</td>
<td>*</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Tachycardia</td>
<td></td>
<td>*</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Hemorrhage</td>
<td>*</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Ventricular fibrillation/ventricular tachycardia</td>
<td></td>
<td>*</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>Bradycardia, unexplained hypotension/hypoxia</td>
<td></td>
<td>*</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>Air embolism</td>
<td>*</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Asystole</td>
<td></td>
<td>*</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>Anaphylaxis</td>
<td></td>
<td>*</td>
<td>6</td>
</tr>
<tr>
<td>Total no. of key processes over the 8 simulations</td>
<td></td>
<td></td>
<td></td>
<td>46</td>
</tr>
</tbody>
</table>

*Emergency checklists provided for simulation scenario.
The scenario was realistic 4.5

Scenario survey question

<table>
<thead>
<tr>
<th>Checklist survey question</th>
<th>Mean Likert response, mean +/- SD (IQR)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>The checklist helped me feel better prepared during the</td>
<td>4.2 +/- 0.95 (4–5)</td>
</tr>
<tr>
<td>emergency scenario</td>
<td></td>
</tr>
<tr>
<td>The checklist was easy to use</td>
<td>4.1 +/- 0.92 (4–5)</td>
</tr>
<tr>
<td>I would use this checklist if I were presented with this</td>
<td>4.3 +/- 0.75 (4–5)</td>
</tr>
<tr>
<td>operative emergency in real life</td>
<td></td>
</tr>
<tr>
<td>If I were having an operation and experienced this intra-</td>
<td>4.4 +/- 0.68 (4–5)</td>
</tr>
<tr>
<td>operative emergency, I would want the checklist to be used</td>
<td></td>
</tr>
</tbody>
</table>

*IQR, interquartile range.

Simulation testing: failure of adherence to critical management steps

Agreement was excellent from video review between the independent physician reviewers (κ = 0.92), with only 2 of the 92 processes tracked adjudicated by a senior reviewer. As the key processes were hard end points (eg, “Did a member of the team call for help within 1 minute of asystole?”), adjudications were easily made, and there was full agreement between all reviewers immediately after video replay.

Rates of failure to adhere to critical management steps in operating crises fell considerably with use of the checklists (Fig. 2). Performance in scenarios in which checklists were not used resulted in an overall failure rate of 24% (11 of 46 key processes), and performance in scenarios in which checklists were used resulted in a failure rate of 4% (2 of 46 key processes). This difference was significant in a multivariate analysis using general estimating equations to account for clustering of results within teams and adjusting for time of day to account for potential learning effect or fatigue effect (ie, teams can do better at the end of the day because they have been exposed to emergency scenarios and are better prepared, or can do worse because of fatigue). Results were significant in this multivariate analysis (relative risk = 0.15; 95% CI, 0.04–0.60; p = 0.007).

Survey results: evaluation of the crisis scenarios

Table 3 demonstrates the aggregate mean Likert scores across all scenarios. Participants reported that on average the scenarios were realistic (4.5 ± 0.77; IQR 4 to 5), were appropriately challenging (4.7 ± 0.64; IQR 4.5 to 5), prompted realistic responses (4.3 ± 0.92; IQR 4 to 5), would help them provide safer care (4.4 ± 0.77; IQR 4 to 5), and that the knowledge gained from the scenarios would be helpful in their practice (4.2 ± 0.86; IQR 4 to 5). All participants rated the overall quality of the scenarios to be “above average” or “excellent” (4 or 5 on Likert scale).

DISCUSSION

Operating room crises require rapid, coordinated management in stressful, time-critical settings, relying largely on clinicians’ retained knowledge and skill. Failure to adhere to critical steps in management of such crises is common and hazardous to patients. In this study, we report the structured development of a set of operating room crisis checklists and their effect on reducing failures to adhere to critical steps in management of operating room crises in a high-fidelity simulator. The study participants found the checklists to be highly usable and subjectively beneficial. In addition, all participants rated the overall quality of the checklists to be “above average” or “excellent,” and reported that they would want them available for use in real emergencies. The checklists also appeared objectively likely to be beneficial. Teams managing simulated crises exhibited an overall failure rate of 24% when working from memory alone, compared with a 4% failure rate when
using the checklists. The difference in performance remained highly statistically significant in a multivariate model that accounted for clustering of results within teams and adjusted for possible learning or fatigue effects. Given that the teams managed 10 widely different crisis situations, these results suggest checklists reduce major vulnerabilities for teams facing many operating room crises. In the broader scope of the development of surgical checklists, crisis checklists can address a previously unmet need; whereas checklists for routine settings can help to prevent crises, crisis checklists can serve as useful aids once such events occur.

The results should be interpreted in the context of the study design: a patient safety intervention trialed in simulation before being tested clinically. This is analogous to the study design of investigational drugs, where interventions are tested for toxicity, efficacy, and superiority to existing therapy before widespread dissemination and clinical use. High-fidelity simulation is increasingly accepted in medicine as a method of evaluating clinician management of emergencies. Training using simulation in medicine has demonstrated improved retention of knowledge necessary for management of crises, as well as improved management of simulated crises. In addition, assessments of clinical performance during simulated crises have demonstrated face validity and initial construct validity, and the feasibility of accurately assessing technical performance through video review has been established. Evidence also suggests that clinicians highly value simulation in the training and preparation for emergencies, believing it to be integral to their preparation for such events.

Although no medical simulation study to date has conclusively linked simulator results to actual clinical performance, simulations must be deemed realistic and prompt realistic responses by participants to infer this potential. To this end, participants in our study reported that the scenarios were realistic (mean Likert 4.5) and prompted realistic responses (mean Likert 4.3), improving the likelihood of correlated performance. It is worth noting that no study in aviation or nuclear power has definitively demonstrated the use of simulation in improving safety in these fields, despite broad acceptance of simulation. This was also not a blinded study. Subjects could not be blinded to checklist use for obvious reasons. Neither could our video reviewers. However, the key processes measured were objective measures (eg, “Was a shock delivered within 3 minutes of ventricular fibrillation?”) and were easily observed on video review, leaving little room for subjective interpretation. The results suggest promising value to using crisis checklists in surgery.

**CONCLUSIONS**

Operating room crises are stressful, time-critical situations that challenge clinicians’ cognition and recall in ways that routine operations do not, making crises particularly amenable to checklist intervention. We have developed a set of operating room crisis checklists and demonstrated their potential ability to reduce failure of adherence to critical crisis management steps, adding considerably to the growing body of evidence supporting checklist use in surgery. A larger study of surgical teams is required to establish convincing value. Also, the best way to integrate these checklists into clinical use (as well as the best medium of presentation, eg, paper-based, plasma screen, hand-held, or tablet technologies) remains unknown. Recent evidence suggests that high rates of patient harm persist despite widespread quality improvement efforts and focused successes of patient-safety initiatives. Development and testing of simple, effective methods for improved safety and performance in surgery remains critically necessary, and this approach might well provide one.

**Author Contributions**

Study conception and design: Ziewacz, Arriaga, Bader, Berry, Edmondson, Wong, Lipsitz, Hepner, Peyre, Boorman, Smink, Ashley, Gawande

Acquisition of data: Ziewacz, Arriaga, Bader, Berry, Edmondson, Wong, Lipsitz, Hepner, Nelson, Smink, Gawande

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Drafting of manuscript: Ziewacz, Arriaga, Bader, Berry, Wong, Gawande

Critical revision: Ziewacz, Arriaga, Bader, Berry, Edmondson, Wong, Lipsitz, Hepner, Peyre, Nelson, Boorman, Smink, Ashley, Gawande

Acknowledgments: The authors would like to thank Joan Vi-tello, Dante Foster, Alvin Kwok, Charles Pozner, Christopher Dodgion, Yelena Kuznetsov, Gloria Hicks, Priya Agrawal, Ami Karlage, Robin Smeland-Wagman, Richard Kaufman, Andrew Camerato, Stephen Poole, Seth Jones, Beenawatte Baldeo, Michael Trioli, Luke Funk, Marcus Semel, and Jonathan Spector for their assistance with this project.
REFERENCES


Appendix 1:

OR Critical Event Checklists

STOP

READ OUT LOUD:
Has somebody called for help?

Who is going to be the team leader?

O.R. Critical Event Guide

1: Air Embolism

- 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?
- Vasopressors (e.g., dobutamine, norepinephrine)?
- Chest compressions [100/min; to force air through lock, even if not in cardiac arrest]?
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 μg/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? (1-2 mg IV or IM every 5 minutes, in patients taking beta blockers)
  - Hydrocortisone (100 mg IV)?
  - Tryptase level? (useful to guide future management)

Drug Doses:
- Epinephrine doses:
  1 to 5 cc (0.1-0.5 mg) IV, depending on severity, diluted 1:10,000 before bolus.
  0.1 cc (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.

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

O.R. Critical Event Guide

3: Bradycardia - Unstable

Condition: Hemodynamic instability, persistent bradycardia with pulses.

Objective: Restore hemodynamic stability, adequate perfusion.

During Resuscitation:
- Airway (assess and secure)
- Breathing (100% O₂)
- Circulation (confirm adequate IV or IO access)
  - Consider 12-lead ECG.
  - Consider 22-French sheath.

Beta-blocker overdose:
- Glucagon (2-4mg IV push).

Calcium channel blocker overdose:
- Calcium chloride (1g IV).

Overdose Treatments:

- 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 pacing electrodes and 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).
  5. Set final milliamperes to 10mA above this level.
- Confirm pulse present.**
- If pacing ineffective (or while awaiting pacer):
  - Consider Epinephrine (2 to 10 μg/min)
  - Dopamine (2 to 10 μg/kg/min).
- Consider expert consultation.

** If PEA develops, GO TO: Cardiac Arrest – Asystole/PEA Checklist
O.R. Critical Event Guide

4: Cardiac Arrest – Asystole/PEA

Condition: Non-shockable pulseless cardiac arrest.
Objective: Restore pulse, hemodynamic stability.

- Call for help.
- CPR (100 chest compressions/min + 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
- Hypoxemia
- Hyperkalemia
- Hypothermia
- Tension Pneumothorax
- Tamponade (Cardiac)
- Thrombosis (Coronary/Pulmonary)
- Toxic (narco/g415c, local anesthe/g415c, beta blocker, channel blocker)
- Trauma (bleeding outside the surgical cavity)

* 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.

** 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.

O.R. Critical Event Guide

5: Cardiac Arrest – VF/VT

Condition: Shockable pulseless cardiac arrest.
Objective: Restore pulse, hemodynamic stability.

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

* 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.
** 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 Asystole/PEA develops at any point, GO TO Cardiac Arrest: Asystole/PEA checklist
** If pulse at any point, begin post-resuscitation care
6: Failed Airway

**Condition:** Failed airway (2 unsuccessful attempts or oxygen saturation less than 85%).

**Objective:** Establish adequate oxygenation/ventilation.

**Call for help. Get Airway Cart.**

- **Bag-mask ventilate.**

  - **Bag-mask ventilation adequate?**
    - Yes, consider:
      - Operation using LMA
      - Return to spontaneous ventilation
      - Awakening patient
      - Different blades
      - LMA as conduit
      - Videolaryngoscope
      - Fiberoptic intubation
      - Intubating stylet
      - Light wand
      - Retrograde intubation
      - Blind oral or nasal intubation

  - If alternatives fail, consider:
    - Awakening patient (for awake intubation, doing procedure under regional/local, or cancelling case)
    - Other options (i.e. surgery using LMA, face-mask)
    - Surgical airway if unable to abort case

- **Are LMA/NG ventilation adequate?**
  - No Prepare for surgical airway (prop neck, call airway team)
  - Get Tracheostomy Kit
  - Consider:
    - Bronchoscope
    - Transtracheal jet ventilation
    - Surgical airway

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.)**

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

If 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
O.R. Critical Event Guide

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 PRBCs).
  - Cryoprecipitate (if indicated; 1 unit).
- 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:**

- FFP:
  - If first fibrinogen level is...
    - <100 mg/dL: Order 2 more pools of cryoprecipitate
    - 100-200 mg/dL: Order 1 more pool of cryoprecipitate

- Platelets:
  - Red blood cells to hematocrit > 21%.
  - Platelets to serum platelet level > 50K/mL

- Fresh frozen plasma to PT/PTT < 1.5 times control
- Cell saver (for normovolemic, noncontaminated cases)

**Hemorrhage Treatment:**

- Calcium gluconate (10mg/kg) or Calcium chloride 10mg/kg IV:
- Sodium bicarbonate 1.2mEq/kg, slow IV push
- Insulin 10 units regular, 1-2 amp 550W (0.1 units)
- Insulin/kg and 1mEq/kg, 550W for pediatric patients.

O.R. Critical Event Guide

9: Hypotension

**Condition:** Unexplained drop in blood pressure.

**Objective:** Restore hemodynamic stability.

- Call for help.
- Equipment checked for malfunction (arterial line, blood pressure cuff)?
- Pulse 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:**

<table>
<thead>
<tr>
<th>Surgical</th>
<th>Nursing</th>
<th>Anesthesia/CR Team</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retraction</td>
<td>Other evidence of bleeding</td>
<td></td>
</tr>
<tr>
<td>Vagal stimulation</td>
<td>Amount of blood in suction container</td>
<td></td>
</tr>
<tr>
<td>Mechanical/surgical manipulation</td>
<td>Number of bloody sponges</td>
<td></td>
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<tr>
<td>Vascular Compression</td>
<td>Blood on the floor</td>
<td></td>
</tr>
<tr>
<td>Drugs used on the field (i.e. Intravenous injection of local drugs)</td>
<td></td>
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</tr>
</tbody>
</table>

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

- Breathing:
  - Pneumothorax
  - Pulmonary Edema

- Circulation:
  - Myocardial Ischemia
  - Acute pancreatitis
  - Pulmonary Embolism
  - Severe hypotension
  - Air embolism (GO TO: Air Embolism Checklist)
  - Other embol (e.g., fat, debris, 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)

- Drug/Allergy:
  - Recent drug given/dose error/allergy
10: Hypoxia

**Condition:** Unexplained oxygen desaturation.

**Objective:** Restore oxygenation.

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

**Suspected Airway/Breathing Issue?**

**Yes**

- **Suctioning** (maximally)
- **Removing circuit and using ambo bag**
- **Bronchoscopy**
- **Pulling ET and Most Ventilation/Re-intubation**

**Have we considered:**

- **Suctioning** (maximally)
- **Removing circuit and using ambo bag**
- **Bronchoscopy**
- **Pulling ET and Most 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
  - Hyperventilation
  - Pulmonary Edema

**No**

- **Embolism**
- **Other Emboli (eg: fat, septic, CO)**

**Heart disease?**
- **Congestive Heart Failure**
- **Coronary Artery Disease**
- **Myocardial ischemia**
- **Cardiac Tamponade**
- **Congestive anatomic defect**
- **Electrocardiogram, Transesophageal echocardiogram, bypass considered?**

**Severe Sepsis**
- **If hypoxia associated with hypotension (SO 2 TD: Hypotension Checklist)**
- **Shock/efficacy**
- **Recent drugs given**
  - Dose error, allergy/anaphylaxis

O.R. Critical Event Guide

11: Malignant Hyperthermia

**Condition:** Unexplained, unexpected increase in end tidal CO2; prolonged muscle spasm after succinylcholine, unexplained, unexplained tachycardia.

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

- **Call for help.**
- **Get Malignant Hyperthermia (MH) Kit.**
- **Volatile Anesthetics stopped/transitional 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 2-4x patient’s minute ventilation).
- **Dantrolene given?**
  - Administer dedicated person to mix dantrolene.
- **MH hotline called?** 1-800-664-9737.
- **Procedure terminated (if possible)?**
- **Bicarbonate given for suspected metabolic acidosis?**
  - Maintain pH > 7.2.
- **Patient cooled if temperature > 38.5°C?**
  - Lavage open body cavities.
  - NG lavage with cold water.
  - Apply ice externally.
  - Cold saline infused intravenously.
  - **Stop cooling if temperature < 38°C.**
- **Hyperkalemia treated if suspected?**
- **Dysrhythmias treated if present?**
  - Standard antirhythmics are acceptable; don’t use Calcium Channel Blockers.
- **Labs sent?** (ARB, venous blood gas, electrolytes, serum CK, serum/urine myoglobin, coagulation profile)
- ** Foley catheter placed?**
  - Monitor urine output.
- **ICU called/disposition arranged?**

**Drug Doses and Treatments:**

- **Dantrolene:** 1.5mg/kg 1-3mg/kg IV every 5 minutes until symptoms subside. Mix each ampule with 60cc sterile water. May require up to 10mg/kg/h.

- **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 (30mg/kg) IV.
  - Sodium bicarbonate 1-2mEq/kg, slow IV push.
  - Insulin 10 units regular IV with 2 amp 5050 (0.1 units insulin/kg and 1mEq/kg D5W for pediatric patients).
Appendix 2: Key processes tracked for the Agency for Healthcare Research and Quality Operating Room Crisis Checklist Project

**Key processes for cardiac arrest: VF/VT**

1. After onset of pulseless VF/VT, chest compressions (once initiated) are given without prolonged interruption(s) (no pause >30 seconds, except for when explicitly clearing patient and delivering shocks).1,2
2. Patient receives a shock within 3 minutes of onset of pulseless VF/VT.1,3-5
3. Patient receives the appropriate joule setting when all shocks delivered.4
4. Initial dose of epinephrine (or vasopressin) given within 5 minutes of onset of pulseless VF/VT.5
5. Initial dose of amiodarone (or lidocaine) given after epinephrine (or vasopressin).5,6
6. Repeat dose of epinephrine (or vasopressin) given within 3 to 5 minutes after the first dose.5,6
7. At least 1 team member in the room explicitly calls for outside help (eg, phone call) within 1 minute of onset of pulseless VF/VT.5
8. At least 1 team member calls for the defibrillator within 1 minute of the onset of VF/VT.3,5

**Key processes for cardiac arrest: asystole/pulseless electrical activity (PEA)**

9. After onset of asystole/PEA, chest compressions (once initiated) are given without prolonged interruption(s) (no pause >30 seconds).1,2
10. Patient does not receive shock if pulse/rhythm indicates asystole/PEA.4
11. Initial dose of epinephrine (or vasopressin) given within 3 minutes of onset of asystole/PEA.5,6
12. Atropine given (or explicitly considered) within 5 minutes of start of asystole/PEA.5
13. Repeat dose of epinephrine (or vasopressin) given within 3 to 5 minutes after the first dose.5,6
14. At least 1 team member in the room explicitly calls for outside help (eg, phone call) within 1 minute of onset of asystole/PEA.5
15. At least 1 member reads aloud the Hs and Ts (or explicitly discusses the causes in any order) within 10 minutes of the start of asystole/PEA.5

**Key processes for air embolism**

16. FiO₂ increased to 100% within 3 minutes of air embolism (indicative signs are substantially decreased end-tidal CO₂ and oxygen desaturation).7,9
Implicit by increasing $\text{FiO}_2$ to 100%: nitrous oxide anesthetic stopped within 3 minutes of air embolism.\textsuperscript{10,11}

17. Attempts are 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).\textsuperscript{7,12-14}

18. At least 1 team member explicitly calls for help (eg, phone call) within 3 minutes of the onset of air embolism.\textsuperscript{5}

**Key processes for anaphylaxis**

19. Epinephrine given within 3 minute of anaphylaxis (indicative signs are hypotension/hemodynamic instability, wheezing, confederate points out urticaria).\textsuperscript{15-27}

20. Potential causative agents removed within 3 minutes of anaphylaxis (Scenario-specific. Examples include removal of latex Foley catheter; removal of IV antibiotics).\textsuperscript{16,28}

21. $\text{FiO}_2$ increased to 100% within 3 minute of anaphylaxis.\textsuperscript{15-18}

22. Fluid bolus given or fluids placed wide open within 3 minutes of anaphylaxis.\textsuperscript{15-18,27}

23. Hydrocortisone administered within 5 minutes of anaphylaxis.\textsuperscript{16,18,29,30}

24. At least 1 team member in the room explicitly calls for outside help (eg, phone call) within 3 minutes of onset of anaphylaxis.\textsuperscript{5}

**Key processes for hemorrhage**

25. Blood bank is notified within 5 minutes of sudden unexpected substantial blood loss.\textsuperscript{31}

26. Intravenous fluids opened or fluid bolus given within 5 minutes of sudden unexpected blood loss.\textsuperscript{32}

27. Packed red blood cells are administered within 10 minutes of sudden unexpected blood loss with hemodynamic instability.\textsuperscript{31}

28. At least 1 team member in the room explicitly calls for outside help (eg, phone call) within 5 minutes of onset of sudden unexpected blood loss.\textsuperscript{5}

**Key processes for bradycardia**

29. Atropine given within 5 minutes of unstable bradycardia.\textsuperscript{33-35}

30. Transcutaneous pacing established within 3 minutes of unstable bradycardia onset.\textsuperscript{33-36,37}

31. $\text{FiO}_2$ increased to 100% within 3 minutes of unstable bradycardia. (Note that this key process was only counted once for the bradycardia/hypotension/hypoxia scenario.)

32. At least 1 team member explicitly calls for help (eg, phone call) within 3 minutes of the onset of unstable bradycardia.\textsuperscript{5}

**Key processes for malignant hyperthermia (MH)**

33. Dantrolene given within 7 minutes of MH.\textsuperscript{38-40}

34. All volatile anesthetics stopped within 3 minutes of onset of MH (increased ETCO\textsubscript{2}, tachycardia, febrile).\textsuperscript{41}

35. $\text{FiO}_2$ increased to 100% within 3 minutes of onset of MH.\textsuperscript{41}

36. Patient hyperventilated (ie, 2 to 4 times the minute ventilation the patient was initially receiving) within 3 minutes of onset of MH.\textsuperscript{38,39,41,42}

37. Attempts made to cool the patient within 5 minutes of MH (cooling blanket, gastric lavage, and/or external ice packs).\textsuperscript{38,39}

38. Drugs given to treat hyperkalemia within 5 minutes of rhythm change.\textsuperscript{38-42}

39. At least 1 team member in the room explicitly calls for outside help (eg, phone call) within 3 minutes of onset of MH.\textsuperscript{5}

**Key processes for tachycardia**

40. Synchronized cardioversion initiated within 5 minutes of unstable tachycardia onset (ie, pads on patient; appropriate synchronization established with SYNC markers on each R wave).\textsuperscript{43}

41. At least 1 team member in the room explicitly calls for outside help (eg, phone call) within 2 minutes of onset of unstable tachycardia.\textsuperscript{5}

42. At least 1 team member calls for the defibrillator within 2 minutes of the onset of unstable tachycardia.\textsuperscript{43}

**Key processes for hypotension/hypoxia**

43. IV fluids opened wide or fluid bolus given within 3 minutes of unstable hypotension.\textsuperscript{44-46}

44. $\text{FiO}_2$ increased to 100% within 3 minutes of unstable hypotension/hypoxia.\textsuperscript{47}

45. Hand ventilation initiated within 3 minutes of hypoxia.\textsuperscript{47}

46. Breath sounds auscultated within 3 minutes of hypoxia.\textsuperscript{47,48}

47. Suction provided through the endotracheal tube.\textsuperscript{47}

48. At least 1 team member in the room explicitly calls for outside help (eg, phone call) within 3 minutes of onset of unstable hypotension/hypoxia.\textsuperscript{5} (Note that this key process was only counted once for the bradycardia/hypotension/hypoxia scenario.)
REFERENCES