Actionable Patient Safety Solution (APSS) #12A: VENOUS THROMBOEMBOLISM (VTE)

Executive Summary Checklist

Venous thromboembolism (VTE) is associated with increased mortality, poor patient outcomes, increased length of stay, and decreased patient satisfaction. It is the most common preventable hospital complication as well as the most common cause of preventable mortality in hospitals.

- Accurately stratifying risk by ensuring that providers perform a VTE risk assessment
- Measure appropriate quality measures related to VTE to close performance gap
- Complete in depth chart review for hospital-associated thrombosis events to identify opportunities for improvement and then acting on lessons learned
- Adhere to VTE best practices from national organizations such as Agency for Healthcare Research and Quality’s VTE Safety Toolkit (AHRQ, 2016). The toolkit contains 10 components that are evidence-based guidelines for preventing, diagnosing, treating, and educating patients and providers about VTE. The components are as follows:
  - VTE prophylaxis guidelines, VTE risk assessment tool, DVT diagnostic algorithm, PE diagnostic algorithm, HIT (heparin-induced thrombocytopenia) assessment, VTE treatment pathway, DVT outpatient treatment order set, Vascular laboratory requisition, Neural-axial anesthesia guidelines, Patient education (prevention and treatment) pamphlets
- Ensure healthcare professionals receive, at the least, annual training on new VTE policies and processes
- Assess risk for VTE among patients hospitalized with:
  - Injury to vein: fracture, surgery
  - Slow blood flow: bedrest, limited mobility, paralysis
  - Increased estrogen: birth control, pregnancy and recent childbirth, hormone replacement therapy
  - Chronic illness: cancer, heart/lung disease, atrial fibrillation, inflammatory bowel disease (Crohn’s Disease and ulcerative colitis)
  - Other: personal or family history of DVT/PE, age, obesity, central lines, or clotting disorders
- Educate patient and families on VTE risks, complications, and importance of mechanical and medication prophylaxis.
- Select technologies that show early evidence to reduce VTEs and positively impact both patient and provider outcomes in the clinical settings
  - Implement an EHR with prompt decision making support to ensure that every patient has a valid VTE prevention plan in place at all times during their hospitalization.
The Performance Gap

A venous thromboembolism (VTE) is defined as a blood clot in the lung (pulmonary embolism or PE) or in deep veins of the arm or leg (Deep Vein Thrombosis or DVT). VTEs are associated with increased mortality, poor patient outcomes, increased length of stay and decreased patient satisfaction. It is the most common preventable hospital complication as well as the most common cause of preventable mortality in hospitals. It is estimated that 60,000 to 100,000 Americans die from VTE each year and 10-30% of those patients will die within one month of diagnosis (Beckman et al., 2010). VTEs affect all races, ages and genders. It is estimated that over 50% of all VTE in a given community are associated with hospitalization (Heit et al., 2000). Healthcare institutions should take all precautions in order to prevent blood clots in their patients.

It is important to realize that even though trauma and surgery contribute to the risk for VTE, at least half of all hospital-acquired VTE occur in patients hospitalized with medical illnesses. Although classic clinical symptoms of DVT include red or painful swelling of a limb, the clinical examination for DVT is notoriously poor in both sensitivity and specificity. In some studies of hospitalized patients, only a minority of those found to have DVT have classical clinical findings to suggest the diagnosis (Cook et al, 2005). Because of this, clinical decision rules have been developed to help guide the diagnostic evaluation (Wells et al., 1997). Although patients with acute PE typically endorse shortness of breath, tachypnea, and/or tachycardia, sudden cardiac arrest is the first symptom in 25% of PE patients (ONC, 2014). Thus one must maintain a high level of clinical suspicion to diagnose VTE. The better policy, both from a patient safety and a cost-consciousness point of view, is primary prevention to avoid their occurrence to begin with. All patients admitted to the acute care setting should be evaluated for their risk of VTE, and then guideline appropriate VTE prophylaxis should be reliably administered. This strategy results in significant reduction in the incidence of hospital-acquired VTE.

Once clinically suspected, clinical prediction rules should be utilized to guide appropriate diagnostic evaluation. Diagnostic imaging for confirmation includes venous doppler, V/Q scans or the highly sensitive computerized tomography angiography (CTA) of the chest. With the latter, small subsegmental, possibly non-clinical, pulmonary emboli can now be detected thus increasing a hospital’s reported VTE rate.

Patients who develop a VTE have a higher in-hospital mortality rate, and will have approximately 33% chance of developing another clot within 10 years (PCAST, 2014). Patients identified to have an acute VTE will require a secondary prophylaxis program. For most patients, this entails prolonged anticoagulation and close follow-up to carefully manage the risk and benefits of secondary prophylaxis.

Leadership Plan

Identify: Senior executive leadership that is committed to a reduction in VTE
- Team ideally is led by a physician and administrative champions, ideally the Chief Nursing Officer
- Gather staff that have an in depth knowledge base of disease process and prevention of VTE such as:
  - Physicians
  - Nursing Leaders
  - Advanced Practice Providers such as Physical and Occupational Therapists
  - Physicians in training
  - Residents
  - Bedside Nurses
  - Quality Improvement staff
  - Safety/Risk
  - Pharmacy
  - Information Technology team with Electronic Medical Record

Plan: Senior executive leadership and clinical/safety leaders should agree on the best implementations in order to close their performance gap.
Plan should include measurable appropriate quality metrics

**Timeline set:** Senior executive leadership should select a goal and set a timeline to achieve said goal

**Resources allocated:** Senior executive leaders should set specific budget for said goal and plan

**System leadership and engagement:** Clinical and safety leaders should act as change agents and drive implementation

**Practice Plan**

**Complete** in depth chart review of hospital-associated thrombosis events. Identify trends such as:

- Service line
- Physician
- Diagnosis
- Risk score ([Appendix A](#): Caprini Score, Padua Prediction Score, IMPROVE score, or “3-bucket”model)
- Hospital units
- Pharmacological prophylaxis ordered
  - Pharmacological prophylaxis missed doses
  - Patient Refusal of pharmacological prophylaxis
- Mechanical prophylaxis ordered
  - Patient refusal of mechanical prophylaxis
- Patient mobility

**Identify** gaps in care that promote VTE development

**Adhere** to the Agency for Healthcare Research and Quality’s Venous Thromboembolism Safety Toolkit: A System’s Approach to Patient Safety

**Implement** interventions that reduce VTE

- Ensure interventions are patient-centered
- Incorporate VTE Risk Assessment into EHR for all new admissions
  - Reassess risk periodically upon change in level of care, clinicians, and prior to discharge.
- Ensure the ordering of appropriate VTE prophylaxis according to risk assessment
  - Consider adoption of VTE power plans/order sets
  - Continue VTE prophylaxis past discharge if recommended
- Ensure timely and reliable delivery of pharmacological and/or mechanical prophylaxis as indicated
  - Track/trend missed doses, patient refusals and ensure that patient resistance or refusal is met with education about the purpose of prophylaxis and risks if not administered.
- Develop specific and reliable protocols, endorsed by local surgical champions, for reliable mechanical or pharmacologic prophylaxis to be applied prior to induction of anesthesia, as appropriate
- Consider nursing protocol for application of mechanical prophylaxis in pre-op areas
- Understand your staff’s perception of the importance of VTE prophylaxis
  - Educate knowledge deficits
  - Consider yearly competence in VTE
Ensure that all team members - physicians, nurses, patient care assistants, trainees, pharmacists, transport personnel, physical therapists, patients and family members are aware of their role in VTE-P.

Patient Mobility

- Utilize mobility trackers
- Design and implement a plan when pharmacological prophylaxis is contraindicated, such as proactive monitoring.

**Educate** patients and families about the risks, complications, the importance of VTE prophylaxis, and the symptoms of DVT and PE.

**Technology Plan**

*Suggested technologies are limited to those proven to show benefit or are the only known technologies with a particular capability. Other technology options may exist or emerge after the publication of this APSS, please send information on any additional technologies, along with appropriate evidence, to info@patientsafetymovement.org.*

With regard to VTE, there are a few novel technology platforms that offer a low entry cost that work alongside the Electronic Health Record (EHR). These technology platforms are secure with multimedia functions and can host checklists, education and much more to improve best practices and engagement across the care continuum. There is also technology that is important in the prevention of blood clots, like compression devices. Examples of those devices and technology solutions are detailed below and may be helpful in VTE prevention.

- **Compression Devices**
  - Either Graduated Compression Stockings (GCS) and/or Intermittent Pneumatic Compression Device (IPC), or AE (anti-embolic) pumps should be used adjunct to other forms of prevention, like pharmacological solutions
    - **GCS such as:**
      - Anti-embolism stockings, anti-thrombosis stockings, elastic support hose, graduated compression elastic stockings, Jobst stockings, surgical hose, TED hose, white hose, thrombosis stockings. When using GCS, appropriate fitting is essential to ensure safety from injury and effectiveness. Notably, 15-20% of patients cannot effectively wear AES because of unusual limb size or shape (Geerts et al., 2001).
    - **IPC AE pumps such as:**
      - Alternating Leg Pressure (ALP), athrombic pumps-calf/thigh, Continuous Enhanced Circulation Therapy (CECT), DVT boots-calf/thigh, EPC cuffs/stockings-External pneumatic compression-calf/thigh, Flotron/Flotron DVT system-thigh, Impulse pump-thigh, Intermittent pneumatic compression stockings, Intermittent compression device (ICD), KCI stockings, Leg pumppers, PAS (Pulsatile anti-embolic stockings), Plexipulse-calf/thigh, Pneumatic intermittent impulse compression device, Rapid inflation asymmetrical compression (RIAC) devices, Sequential compression device, Sequential pneumatic hose, Thromboguard, Thrombus pumps-calf/thigh, Vascutherm, VasoPress DVT System, Venodyne boots-calf/thigh

- **Electronic Health Record (EHR)**
○ Web-based/EHR predictive algorithms that elicit specific data such as but not limited to vital signs (BP, Temp, HR, RR, and SpO2) lab values, nurses notes, and event reports.
○ The EHR can be a key component of a VTE prevention program by enabling computerized decision support to ensure that every patient has a valid VTE prevention plan at all times during their hospitalization (Morrison and England, 2015; Doyle and Hospital, n.d.).

**Metrics**

**Topic 1:**

**Hospital Acquired Potentially Preventable Venous Thromboembolism Rate (VTE-6)**

VTE-6 assesses the number of patients diagnosed with confirmed VTE during hospitalization (not present at admission) who did not receive VTE prophylaxis between hospital admission and the day before date of the first positive VTE diagnostic test.

**Process Measure Formula:**

**Numerator:** Patients who received no VTE/PE prophylaxis prior to the day before the date of the first positive VTE diagnostic test.

**Denominator:** Patients who developed confirmed VTE/PE during hospitalization.

* Rate is typically displayed: Numerator/Denominator*1000

**Metric Recommendations:**

**Indirect Impact:**

All admitted patients

**Direct Impact:**

All admitted patients

**Lives Spared Harm:**

\[
\text{Lives Spared Harm} = (\text{VTE or PE Rate}_{\text{baseline}} - \text{VTE or PE Rate}_{\text{measurement}}) \times \text{Total Patient Days}_{\text{baseline}}
\]

**Lives Saved:**

\[
\text{Lives Saved} = \text{Lives Spared Harm} \times 0.104
\]

**Notes:**

Measure exclusions age < 18 years, LOS > 120 days, comfort measures only, clinical trials, principal diagnosis of VTE or VTE present on admission, provider reason for not administering mechanical and pharmacologic prophylaxis.

**Data Collection:**

Chart abstraction.

**Mortality (will be calculated by the Patient Safety Movement Foundation):**

Estimated mortality per VTE is 0.104

**Reference:**

- Mortality and Cost per Case Information from AHRQ
**Topic 2:**

**Hospital Acquired Venous Thromboembolism Rate**  
Rate of patients having a hospital acquired VTE/PE

**Process Measure Formula:**

**Numerator:** Number of patients having a VTE/PE  
**Denominator:** Total patient days  
*Rate is typically displayed: Numerator/Denominator * 1,000

**Metric Recommendations:**

**Indirect Impact:**  
All admitted patients

**Direct Impact:**  
All admitted patients

**Lives Spared Harm:**  
\[ \text{Lives Spared Harm} = (VTE \text{ or PE Rate}_{\text{baseline}} - VTE \text{ or PE Rate}_{\text{measurement}}) \times \text{Total Patient Days}_{\text{baseline}} \]

**Lives Saved:**  
\[ \text{Lives Saved} = \text{Lives Spared Harm} \times 0.104 \]

**Notes:**  
Hospital acquired VTEs are identified through ICD diagnosis codes. The ICD9 diagnosis codes are: 45111, 45119, 45181, 45340, 45341, 4151, 41511, 41513, 41519. The ICD10 diagnosis codes are: I8010, I8011, I8012, I8013, I80201, I80202, I80203, I80209, I80211, I80212, I80213, I80219, I80222, I80223, I80229, I80231, I80232, I80233, I80239, I80291, I80292, I80293, I80299, I82401, I82402, I82403, I82409, I82411, I82412, I82413, I82419, I82421,
I82422, I82423, I82429, I82431, I82432, I82433, I82439, I824Y1, I824Y2, I824Y3, I824Y9, I2602, I2609, I2692, I2699. Qualifying diagnoses that are present on admission are excluded from the numerator.

Total patient days come from daily census counts for each inpatient nursing unit. Census counts are electronically derived at the same time of day each day. These counts may be collected manually if an electronic source is not available.

Data Collection:
Data collected from final diagnosis codes for encounter as determined by a professional health information coder.

Mortality (will be calculated by the Patient Safety Movement Foundation):
Estimated mortality per VTE is 0.104, as listed under Topic 1.

Workgroup

Co-Chairs:
Brandyn Lau (Johns Hopkins Medicine)
Steven Barker (Patient Safety Movement Foundation; Masimo)
Michael Becker (Masimo)

Members:
Latif Asad (Doctella)
Ann Bilyew (ClearLine MD)
Jose Branco (Brazilian Institute of Patient Safety)
Jessica Duke (Baptist Health)
Jeff Dunn (Redivus Health)
Amer Haider (Doctella)
Ariana Longley (Patient Safety Movement Foundation)
Jacob Lopez (Patient Safety Movement Foundation)
Amy Lukanski (University of Pittsburgh Medical Center)
Brendan Miney (Talis Clinical)
Timothy Morgenthaler (Mayo Clinic)
Daryn Munley (Decisio Health, Inc.)
Todd Pollock (University of Pittsburgh Medical Center)
Amy Sofranko (University of Pittsburgh Schools of the Health Sciences)
Michael Wong (Physician-Patient Alliance for Health & Safety)

Metrics Integrity:
Nathan Barton (Intermountain Healthcare)
Robin Betts (Intermountain Healthcare)
Jan Orton (Intermountain Healthcare)

Conflicts of Interest Disclosure
The Patient Safety Movement Foundation partners with as many stakeholders as possible to focus on how to address patient safety challenges. The recommendations in the APSS are developed by workgroups that may include patient safety experts, healthcare technology professionals, hospital leaders, patient advocates, and medical technology industry volunteers. Some of the APSS recommend technologies offered by companies involved in the Patient
Safety Movement Foundation that the workgroups have concluded, based on available evidence, are beneficial in addressing the patient safety issues addressed in the APSS. Workgroup members are required to disclose any potential conflicts of interest.

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Appendix A

Calculation of the Caprini Risk Score

The table below depicts the different scores for the factors represented in the Caprini score (Caprini, 1991). The Caprini score is calculated by adding the scores of all factors present in the patient. The Caprini score is interpreted in the following way (Caprini, 2005):

<table>
<thead>
<tr>
<th>5 points</th>
<th>3 points</th>
<th>2 points</th>
<th>1 point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke (in the previous month)</td>
<td>Age ≥ 75 years</td>
<td>Age: 61-74 years</td>
<td>Age 41-60 years</td>
</tr>
<tr>
<td>Fracture of the hip, pelvis, or leg</td>
<td>Prior episodes of VTE</td>
<td>Arthroscopic surgery</td>
<td>BMI &gt; 25 Kg/m2</td>
</tr>
<tr>
<td>Elective arthroplasty</td>
<td>Positive family history for VTE</td>
<td>Laparoscopy lasting more than 45 minutes</td>
<td>Minor surgery</td>
</tr>
<tr>
<td>Acute spinal cord injury (in the previous month)</td>
<td>Prothrombin 20210 A</td>
<td>General surgery lasting more than 45 minutes</td>
<td>Edema in the lower extremities</td>
</tr>
<tr>
<td></td>
<td>Factor V Leiden</td>
<td>Cancer</td>
<td>Varicose veins</td>
</tr>
<tr>
<td></td>
<td>Lupus anticoagulants</td>
<td>Plaster cast</td>
<td>Pregnancy</td>
</tr>
<tr>
<td></td>
<td>Anticardiolipin antibodies</td>
<td>Bed bound for more than 72 hours</td>
<td>Post-partum</td>
</tr>
<tr>
<td></td>
<td>High homocysteine in the blood</td>
<td>Central venous access</td>
<td>Oral contraceptive</td>
</tr>
<tr>
<td></td>
<td>Heparin induced thrombocytopenia</td>
<td></td>
<td>Hormonal therapy</td>
</tr>
<tr>
<td></td>
<td>Other congenital or acquired thrombophilia</td>
<td></td>
<td>Unexplained or recurrent abortion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sepsis (in the previous month)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Serious lung disease such as pneumonia (in the previous month)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Abnormal pulmonary function test</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Acute myocardial infarction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Congestive heart failure (in the previous month)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bed rest</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Inflammatory bowel disease</td>
</tr>
</tbody>
</table>
Scoring and Recommended Prophylaxis (Gould et al., 2012)

<table>
<thead>
<tr>
<th>Caprini Score</th>
<th>Risk</th>
<th>VTE Incidence</th>
<th>Recommended Prophylaxis</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>Very low-low</td>
<td>&lt;1.5%</td>
<td>Early ambulation, IPC</td>
</tr>
<tr>
<td>3-4</td>
<td>Moderate</td>
<td>3%</td>
<td>LMWH; UFH; or IPC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>If high bleeding risk, IPC until bleeding risk diminishes.</em></td>
</tr>
<tr>
<td>5-8</td>
<td>High</td>
<td>6%</td>
<td>LMWH + IPC; or UFH + IPC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>If high bleeding risk, IPC until bleeding risk diminishes.</em></td>
</tr>
<tr>
<td>&gt;8</td>
<td>Very high</td>
<td>6.5-18.3%</td>
<td>LMWH + IPC; or UFH + IPC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>If high bleeding risk, IPC until bleeding risk diminishes.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Consider extended duration prophylaxis.</td>
</tr>
</tbody>
</table>

* Abdominal or pelvic surgery for cancer should receive extended VTE prophylaxis with LMWH x 30 days (AHRQ, 2016).

IPC = intermittent pneumatic compression
LMWH = low-molecular-weight heparin
UFH = unfractionated heparin
Calculation of the Padua Prediction Score

The table below depicts the Padua Predictive score for VTE among hospitalized patients (Barbar et al., 2010).

A score of:

- ≥4: high risk of VTE
- ≤4: low risk for VTE.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active cancer</td>
<td>3</td>
</tr>
<tr>
<td>Previous VTE</td>
<td>3</td>
</tr>
<tr>
<td>Decreased mobility</td>
<td>3</td>
</tr>
<tr>
<td>Thrombophilia</td>
<td>3</td>
</tr>
<tr>
<td>Previous trauma or surgery within that last month</td>
<td>2</td>
</tr>
<tr>
<td>Age ≥ 70</td>
<td>1</td>
</tr>
<tr>
<td>Heart and/or respiratory failure</td>
<td>1</td>
</tr>
<tr>
<td>Ischemic stroke or acute myocardial infarction</td>
<td>1</td>
</tr>
<tr>
<td>Acute rheumatologic disorder and/or acute infection</td>
<td>1</td>
</tr>
<tr>
<td>Obesity</td>
<td>1</td>
</tr>
<tr>
<td>Hormonal therapy</td>
<td>1</td>
</tr>
</tbody>
</table>
Calculation of the IMPROVE Predictive Score

The IMPROVE score for VTE assesses the risk of VTE among hospitalized patients. The predictive score includes 4 independent risk factors for VTE, which are present at admission. The associative score includes 7 variables present either at admission or during hospitalization (Spyropoulos et al., 2011).

**IMPROVE Predictive Score**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior episode of VTE</td>
<td>3</td>
</tr>
<tr>
<td>Thrombophilia</td>
<td>3</td>
</tr>
<tr>
<td>Malignancy</td>
<td>1</td>
</tr>
<tr>
<td>Age more than 60 years</td>
<td>1</td>
</tr>
</tbody>
</table>

**Interpretation of the IMPROVE Predictive Score**

<table>
<thead>
<tr>
<th>Score</th>
<th>Predicted VTE risk through 3 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.5%</td>
</tr>
<tr>
<td>1</td>
<td>1.0%</td>
</tr>
<tr>
<td>2</td>
<td>1.7%</td>
</tr>
<tr>
<td>3</td>
<td>3.1%</td>
</tr>
<tr>
<td>4</td>
<td>5.4%</td>
</tr>
<tr>
<td>5-8</td>
<td>11%</td>
</tr>
</tbody>
</table>

**IMPROVE Associative Score**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior episode of VTE</td>
<td>3</td>
</tr>
<tr>
<td>Thrombophilia</td>
<td>2</td>
</tr>
<tr>
<td>Paralysis of the lower extremity during the hospitalization</td>
<td>2</td>
</tr>
<tr>
<td>Current malignancy</td>
<td>2</td>
</tr>
<tr>
<td>Immobilization for at least 7 days</td>
<td>1</td>
</tr>
<tr>
<td>ICU or CCU admission</td>
<td>1</td>
</tr>
<tr>
<td>Age more than 60 years</td>
<td>1</td>
</tr>
</tbody>
</table>

**Interpretation of the IMPROVE Associative Score**

<table>
<thead>
<tr>
<th>Score</th>
<th>Predicted VTE risk through 3 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.4%</td>
</tr>
<tr>
<td>1</td>
<td>0.6%</td>
</tr>
<tr>
<td>2</td>
<td>1.0%</td>
</tr>
<tr>
<td>3</td>
<td>1.7%</td>
</tr>
<tr>
<td>4</td>
<td>2.9%</td>
</tr>
<tr>
<td>5-10</td>
<td>7.2%</td>
</tr>
</tbody>
</table>
Executive Summary Checklist

Inadvertent air embolism causes serious mortality and morbidity in hospitalized patients.

☐ Healthcare leadership should support the design and implementation of standards and provider training programs for AE risk reduction by:
  ● Accurately stratifying risk by ensuring that providers perform an AE Risk Assessment.
  ● Measure appropriate quality indicators related to AE, to close performance gap.
  ● Complete an in-depth chart review for in-hospital air embolism events to identify opportunities for improvement, and act on the lessons learned from that review.
  ● Adhere to AE best practices from national organizations.
  ● Ensure that healthcare professionals receive annual training on AE policies and processes.

☐ Assess patient-specific increased risk for AE among patients with the following:
  ● Known presence of right-to-left shunt anatomy, including patent foramen ovale (PFO), patent ductus arteriosus (PDA), atrial septal defect (ASD), etc.
  ● Requirements for large volumes of intravenous fluids, or rapid infusions using pressurized systems (e.g., major trauma surgery).
  ● Presence of or need for central venous access of any type.
  ● High-Risk surgical procedure or surgery in a high-risk position (surgery site above heart).

☐ Educate patients and families on AE risks, complications, signs and symptoms.

☐ Select technologies that reduce incidence of AE by preventing and detecting air in intravenous access lines (e.g., Clearline®).

☐ Implement an EHR with decision making support to ensure that every patient has an AE prevention and detection plan in place at all times during hospitalization.
The Performance Gap

Air embolism (AE) is defined as the presence of air (or other gas) in either the arterial or venous circulation. In the hospital setting, this is usually the result of inadvertent injection of air into the venous system. However, it can also result from traumatic injuries, surgical procedures, or exposure of venous access systems (e.g., central venous lines) to the open air. Inadvertent air injections can be sudden, as from an air-filled syringe or pumping system, or gradual, as through a continuous IV infusion. Outside of the hospital, air embolism can occur during SCUBA diving or with blast injuries.

In adults with normal anatomy (no right-left shunts), venous air embolism will enter the pulmonary circulation and become trapped in the lungs. Small amounts of pulmonary air embolism may be well tolerated – even up to 50 ml or more in a healthy adult. However, at some point the air load in the lung capillaries will impede the pulmonary circulation, resulting in pulmonary hypertension and eventually right-heart failure (cor pulmonale). This can lead to circulatory collapse and death.

The problem of venous AE becomes more immediately serious in the presence of any form of right-to-left (or transpulmonary) shunt, such as patent foramen ovale (PFO), atrial septal defect (ASD) or patent ductus arteriosus (PDA). PFO has an incidence of 25-30% in otherwise healthy adults, and most of these are asymptomatic and undiagnosed (HAGEN, SCHOLZ and EDWARDS, 1984). The presence of one of these forms of R-L shunt allows venous AE to bypass the lungs and enter the arterial circulation as a “paradoxical embolism,” where even small amounts of air can block circulation to vital organs. The brain is particularly vulnerable to arterial air embolism, where even a few milliliters of air can cause a major stroke. Because of the high incidence of undiagnosed PFO in adults, we usually do not know which patients are at risk. For any patient with a known diagnosis of potential right-left shunt, the increased risk of AE must be documented in the EMR, and clearly explained to all care team members. The incidence of right-left shunts is much greater in newborns than adults; hence all infants should be treated as high risk for venous AE entering the arterial circulation.

Signs and symptoms of air embolism in conscious patients can include chest pain, dyspnea, shortness of breath, decreased level of consciousness, unconsciousness, sudden cardiac arrest, or neurological deficit from transient ischemic attack (TIA) or stroke. (See also signs and symptoms of VTE, in APSS #12A above.) Slower infusions of venous air may be asymptomatic until serious damage to the pulmonary circulation has occurred. The patient’s ability to tolerate and compensate for air embolism is variable, depending on general health status and presence of specific diseases (e.g., cerebrovascular).

The literature on the various types of venous or arterial air emboli seems to agree on one important point: most of these should be considered “never events” – potential disasters that should never occur if proper safeguards, precautions, and procedures are followed. A retrospective case study by Albin showed that air embolism occurred in 100 of 400 patients who underwent craniotomy in the sitting position – an incidence of 25% (Albin, 2011)! Other surgical procedures that create high risk for air embolism include cardiopulmonary bypass, in which there are many reports of fatal cases (van, Koene and Mariani, 2014; Robich et al., 2017), as well as intrathoracic surgery, major joint surgery, Cesarean section, eye surgery (Gayer et al., 2016), pacemaker placement(Xiao et al., 2016), and major trauma. An excellent review of venous air embolism during surgery is found in (Palmon, Moore, Lundberg and Toung, 1997).

AE can also occur when any type of intravascular cannula is used. This includes standard peripheral intravenous catheters, central venous catheters, pulmonary artery catheters, dialysis catheters, and arterial catheters – in other words, with any external cannulation of the circulation for any reason. Pressurized intravenous infusion systems create a particularly serious risk of massive venous air embolism. One-liter plastic bags of intravenous crystalloid, such as Lactated Ringer’s Solution, contain up to 150 cc of air. If this air is not carefully removed before the fluid bag is placed in a pressurized device, it can be forcefully pumped into the patient’s vein. There have been a number of published case reports of fatal or near-fatal AE from this mechanism (Adhikary and Massey, 1998; Aldridge, 2005). Central circulation catheters (CVP, PA, “triple lumen”, etc.) pose an even higher risk. If such a catheter becomes disconnected and exposed to atmosphere in a sitting, spontaneously breathing patient, the negative intrathoracic pressure during inspiraion can rapidly suck massive amounts of air directly into the heart, with fatal results (Ploner, Saltuari, Marosi, Dolif and Salsa, 1991).
An excellent review and bibliography of the diagnosis and treatment of all of these types of air embolism can be found in (Mirski, Lele, Fitzsimmons and Toung, 2007). Annual death rates from AE are difficult to document, because of the wide variety of causes and clinical settings of these cases. The serious nature of this problem is evidenced by the fact that there have been over 4,000 publications on the topic in the past 30 years (Mirski 2007).

Leadership Plan

**Identify:** Senior executive leadership that is committed to a reduction in AE

- Team ideally is led by a physician and administrative champions, ideally the Chief Medical Officer or Chief Nursing Officer
- Gather staff that have an in-depth knowledge base of disease process and prevention of VTE such as:
  - Physicians
  - Nursing Leaders
  - Advance Practice Providers such as Physical and Occupational Therapists
  - Physicians in training
  - Residents
  - Bedside Nurses
  - Quality Improvement staff
  - Safety/Risk
  - Pharmacy
  - Information Technology team with Electronic Medical Record

**Plan:** Senior executive leadership and clinical/safety leaders should agree on the best implementations in order to close their performance gap.

- Plan should include measurable appropriate quality metrics

**Timeline:** Senior executive leadership should select a goal and set a timeline to achieve said goal

**Resources allocated:** Senior executive leaders should set specific budget for said goal and plan

**System leadership and engagement:** Clinical and safety leaders should act as change agents and drive implementation

Practice Plan

**Prevention**

- Almost all in-hospital AE events are preventable and should never occur. This is the goal of this APSS: to make AE a “never event.”
- Care providers must be educated in all of the possible causes of AE (see: Performance Gap).
- For each potential AE cause, develop a check-list protocol to be followed for avoidance of the event.
  - Example: Pressurized intravenous infusion systems.
    - Eliminate all air from IV infusion bags before connecting to patient.
    - Use an air detection technology, such as ClearLine®, to detect and eliminate air from infusion tubing.
- During surgery: When possible, avoid having surgical site well above level of the heart (e.g., “sitting craniotomy”).
○ Use Positive End-Expiratory Pressure (PEEP) on ventilator during high-risk procedures on mechanically ventilated patients.

● **Diagnosis/Detection**
  ○ Symptoms in conscious patient: chest pain, dyspnea, shortness of breath, decreased level of consciousness, unconsciousness.
  ○ Clinical signs: hypotension, decreased end-tidal CO2, rapid or irregular heartbeat, “mill-wheel” murmur, decreased SpO2 (late sign), peaked P-waves on ECG.
  ○ Special monitors: trans-esophageal echo (TEE), precordial Doppler, transcranial Doppler, pulmonary artery catheter, end-tidal nitrogen.

● **Treatment**
  ○ First, prevent further air entrainment by removing the underlying cause: reposition patient, stop intravenous air infusion, flood surgical field, etc.
  ○ Increase inspired oxygen fraction FiO2 to 100%.
  ○ Turn supine patient to 45-degree left-side down position – “Durant Maneuver.”
  ○ Promptly start CPR with chest-compression if no palpable pulse. Compressions may help purge air from heart.
  ○ If a central venous (CVP) or pulmonary artery (PA) catheter is present, attempt to aspirate air from the right atrium.
  ○ Use pharmacological hemodynamic support as needed, including inotropes (dobutamine) and vasoconstrictors (phentolamine, norepinephrine) to support systemic blood pressure.
  ○ Hyperbaric oxygen therapy: unproven but supported by some clinical evidence.
  ○ Intravenous fluorocarbons: unproven in humans, supported by animal studies.

● **Complete** an in-depth chart review of hospital-associated AE events. Identify trends such as:
  ○ Service line.
  ○ Physician.
  ○ Diagnosis.
  ○ Risk factors.
  ○ Hospital units.
  ○ Patient mobility.

● **Identify** gaps in care that increase risk for AE development.

● **Implement**
  ○ Ensure interventions are patient-centered
  ○ Incorporate AE Risk Assessment into EHR for all new admissions.
  ○ Reassess risk periodically upon change in level of care, clinicians, and prior to discharge.
  ○ Understand your staff’s perception of the importance of AE precautions.
  ○ Consider yearly competence in AE prevention, detection, treatment.
  ○ Ensure that all team members - physicians, nurses, patient care assistants, trainees, pharmacists, transport personnel, physical therapists, patients and family members are aware of their roles in AE-prevention.

● **Educate** patients and families about the risks, complications, the importance of AE prophylaxis, and the symptoms of AE.

**Technology Plan**

*Suggested technologies are limited to those proven to show benefit or are the only known technologies with a particular capability. Other technology options may exist or emerge after the publication of this APSS, please send information on any additional technologies, along with appropriate evidence, to info@patientsafetymovement.org.*
With regard to VTE, there are a few novel technology platforms that offer a low entry cost that work alongside the Electronic Health Record (EHR). These technology platforms are secure with multimedia functions and can host checklists, education and much more to improve best practices and engagement across the care continuum. There is also technology that is important in the prevention of blood clots, like compression devices. Examples of those devices and technology solutions are detailed below and may be helpful in VTE prevention.

- “ASA Standard Monitors” should be used and watched carefully in every procedure done under general, regional, or local anesthesia. Particular attention must be paid to end-tidal CO2, which may provide early detection.
- High AE Risk Cases (e.g. sitting craniotomy): Use the following additional detection and treatment technologies when possible:
  - Precordial Doppler Ultrasonography: Early detection.
  - Trans-Esophageal Echocardiography (TEE): Early detection.
  - Pulmonary Artery Catheter: Potential treatment by aspiration from right atrium and ventricle.
  - End-tidal nitrogen (N2) monitoring: If there is no nitrogen in the inspired gas, then sudden appearance of end-tidal N2 implies AE until proven otherwise.
- Use air removal from infusion precautions with all intravenous cannulas, especially central venous (CVP).
  - Consider ClearLine® or equivalent technology for detecting and removing air from infusion fluids.
  - Ensure that all central venous catheters (CVP, PA, “triple lumen”, etc.) use Luer-Lock or other secure locking technology to guard against inadvertent disconnection. A disconnected CVP in a sitting, spontaneously breathing patient can be rapidly fatal.
- Electronic Health Record (EHR)
  - Web-based/EHR predictive algorithms that elicit specific data such as but not limited to vital signs (BP, Temp, HR, RR, and SpO2) lab values, nurses notes, and event reports.
  - The EHR can be a key component of a VTE prevention program by enabling computerized decision support to ensure that every patient has a valid VTE prevention plan at all times during their hospitalization (Morrison and England, 2015; Doyle and Hospital, n.d.).
Workgroup

Co-Chairs:
Michael Becker, PhD, RN, Masimo

Members:
Jim Augustine (US Acute Care Solutions)
Ann Bilyew (ClearLine MD)
Jestin Carlson (Allegheny Health Network)
Richard Cooper (University of Toronto)
*Abbey Curran (ClearLine MD)
Lorraine Foley (Society for Airway Management)
Drew Fuller (Emergency Medicine Associates)
Kate Garrett (Ciel Medical)
Victor Grazette (Virginia Hospital Center)
David Hughes (Patient Safety Movement Foundation, Do It For Drew Foundation)
Hans Huitink (Vanderbilt University Medical Center)
Steven J. Barker (Patient Safety Movement Foundation; Masimo)
Thomas Kallstrom (American Association for Respiratory Care)
Arthur Kanowitz (Securisyn)
Ariana Longley (Patient Safety Movement Foundation)
Jacob Lopez (Patient Safety Movement Foundation)
Ariel MacTavish (Medtronic)
Rhea May (Medtronic)
Kellie Quinn (Retired)
Kenneth Rothfield (Medical City Healthcare)
Stacey Schoenenberger (St. Vincent’s Healthcare)
Michael Taylor (Fairview Hospital)
Dianne Vass (Emergency Medicine Patient Safety Foundation)

Metrics Integrity:
Nathan Barton (Intermountain Healthcare)
Robin Betts (Intermountain Healthcare)
Jan Orton (Intermountain Healthcare)

Conflicts of Interest Disclosure

The Patient Safety Movement Foundation partners with as many stakeholders as possible to focus on how to address patient safety challenges. The recommendations in the APSS are developed by workgroups that may include patient safety experts, healthcare technology professionals, hospital leaders, patient advocates, and medical technology industry volunteers. Some of the APSS recommend technologies offered by companies involved in the Patient Safety Movement Foundation that the workgroups have concluded, based on available evidence, are beneficial in addressing the patient safety issues addressed in the APSS. Workgroup members are required to disclose any potential conflicts of interest.

*This Workgroup member has reported a financial interest in an organization that provides a medical product or technology recommended in the Technology Plan for this APSS. References


