ATRIAL FIBRILLATION ABLATION/PULMONARY VEIN ISOLATION (PVI)

PATIENT DEMOGRPAHY

The prevalence of atrial fibrillation (AF) increases with age and is rare in adults younger than 55 who do not have structural heart disease. In older population, the incidence of new cases ranges from 2 or 3 per 1000 population per year in the age group of 55-64 years to 35 in patients older than 85. AF may be an independent risk factor for death after adjustment for other risk factors.

There is ongoing debate regarding ablation versus rate control for patients in AF refractory to electrical or chemical cardioversion. Primary indication for catheter ablation is the presence of symptomatic AF that is refractory or intolerant to at least one class 1 or class 3 antiarrhythmic drug, and ablation may be appropriate in selected, symptomatic patients with heart failure, a reduced ejection fraction, or both.

DISEASE BACKGROUND AND PROCEDURAL DESCRIPTION

In AF, the rapid atrial rate is initiated by a single focus of abnormal activity, most commonly near one of the pulmonary vein ostia in the LA. Once initiated, the fibrillation is maintained by multiple micro-reentrant circuits in the atria. New onset AF is usually self-limiting and sinus rhythm is restored spontaneously. However, over time the atria of patients with AF remodel—atria dilate, undergo fibrosis and inflammation, and the electrical property of the atrial tissue becomes altered—thus paroxysmal AF becomes persistent AF. Due to the competing micro-reentrant circuits, the ECG will not show distinct P wave or the saw tooth pattern but rather small amplitude oscillations. Ventricular response varies. Paroxysmal and persistent AFs are often amenable to ablation. The ectopic foci for AF in most patients are usually located in the four pulmonary vein ostia of the left atrium (LA).

Several methods for procedural rhythm control are possible:

- Ablation of the Atrioventricular Node and Implantation of a Pacemaker

- The Maze Procedure is performed by a cardiac surgeon that aim to electrically isolate the ectopic foci and prevent the propagation of the aberrant impulse to the AV node, either with
  - Full thickness incisions of both atria (necessitating sternotomy and cardiopulmonary bypass) OR
  - Cryoablation of the LA surrounding the pulmonary veins (usually done thorocoscopically).

- Focal ablation of ectopic foci/pulmonary vein ostia isolation (PVI, the procedure discussed here). Ablation of cardiac/vascular tissue is performed most commonly with radiofrequency (RF) energy to induce a transmural heat injury, which later scars to isolate the electrical propagation of impulses. Other methods include cryoablation via catheter or balloon and laser ablation via balloon. Catheters are typically introduced into the right atrium from the femoral vein up the iliac vein and vena cava. Each catheter has multiple electrodes along its tip capable of recording electrogram with the exception that the most distal electrode can also stimulate and pace. In order to access the LA where the PVI is performed, the catheter either crosses a pre-existing patent Foramen Ovale (PFO) or via a trans-septal puncture. Catheters are guided with fluoroscopy, intracardiac echocardiography, and with the assistance of various mapping systems that help locate the ectopic foci, identify the depolarization pattern, position the ablation catheter, and evaluate ablation results. The ablation of cardiac tissue is performed most commonly with radiofrequency (microwave) energy to induce a transmural heat injury (60 to 70 degree Celsius at the catheter tip), which scars to isolate the electrical propagation of impulses. The tip is actively cooled with saline irrigation to avoid over-heating and the undesirable formation of coagulum. Coagulum prevents effective tissue lesion, and the catheter needs to be withdrawn to remove the coagulum.

PRE-OPERATIVE ASSESSMENT

- **Standard ASA NPO guidelines** should be followed for this elective procedure.

- A thorough assessment of the patient's **airway** and **respiratory status** is essential since the airway will be far from the anesthesia provider with potential obstacles such as the fluoroscopic equipment and drapes. History of reactive airway disease, COPD, OSA, GERD, pleural effusion, or pulmonary edema from acute heart failure may affect the anesthetic management.

- In addition to the arrhythmia, the overall **cardiovascular and functional status** of the patient should be assessed. Other etiologies of AF may have significant cardiovascular and systemic manifestations. The patient may be frail from chronic de-conditioning, have reduced ventricular function due to tachycardia-induced cardiomyopathy, or have other structural heart diseases. LA enlargement is often associated with AF, which may present additional challenges during mapping/ablation. It is important to note the patient's symptoms during atrial fibrillation, rapid rates, or other arrhythmias.

- **Anti-platelet agents and anticoagulants** should be noted. Anti-platelet agents are usually not stopped. Warfarin is usually not stopped as long as patient has been on chronic, stable, therapeutic dose. Other agents are stopped at the proceduralist's discretion. Regardless, this may increase the risk of bleeding or hematoma during and after the procedure, by anesthesia and the proceduralist.

- Patient with **chronic renal insufficiency** or end-stage renal disease will need to have their electrolytes and fluid status assessed carefully. The team should be mindful of exposure to nephrotoxic contrast agents in patients with reduced GFR; however, EP stuides do not commonly expose the patient to contrast.

- Patients who suffer from **chronic back or leg pain** may not tolerate spending extended periods in a supine position without proper positioning, padding and analgesia.

- It is important to set **proper expectation** for the patient. He should be warned that he may wake up feeling the Foley catheter and significant pressure in his groin area (for hemostasis), and despite that, he needs to remain still.

PRE-OPERATIVE PREPARATION

- Routine checks of **anesthesia machine, extension circuit, emergency airway equipment, suction** and **resuscitation medications** are imperative because access to additional equipment and anesthesia providers are limited. Usually, two infusion pumps and an invasive pressure transducer are available in each lab. At UCSF, a glidescope is located outside the EP control room. Contact the off-site anesthesia technician if you need any additional equipment.

- **Blood products:** are usually not required, but a blood type and antibody screen should be current.

- **Antibiotic** is not indicated for this percutaneous procedure.

ACCESS/FLUIDS

- At UCSF, the EP nurse will start a peripheral IV in the pre-op holding area, usually 18 or 20 gauge (left arm).

- An additional 18 gauge IV is recommended. However, remember that the introducer sheaths placed by the proceduralist may be used for central venous access. As a heparin infusion is necessary prior to transseptal puncture, the EP team would use the right IJ sheath so the EP nurse cab draw ACT samples from the femoral sheath without contamination. In the absence of RIJ access, the heparin can be infused through the PIV (some anesthesia provider prefer a separate PIV).

- **Anticipated blood loss** is minimum, usually associated with initial access and flushing of the sheaths.

- **Continuous irrigation of ablation catheters (1 to 2 L total) and sheath (30 mL/hour each), may add significant volume** and may prompt diuretic use at request of the proceduralist.

MONITORS

- **Standard ASA monitors**: The EP staff will assist you in placing radiolucent ECG leads to ensure that they do not interfere with the fluoroscopic images or the rest of electrophysiology monitors. Sometimes, the anesthesia ECG leads can be connected to the mapping system directly.

- **Invasive arterial monitor** is placed due to concerns of perforation during PVI. The patient's cardiopulmonary co-morbidities should determine whether pre-induction arterial catheter is necessary.

- **Temperature** in patients having LA ablations should have esophageal temperature probe placed near the posterior wall of the LA to monitor for excessive heat injury and the risk of atrial perforation. Its position can be confirmed by fluoroscopy. A lower body forced-air warming blanket will be used.

- **Urinary bladder catheter** is placed due to the length of the procedure.

ANESTHETIC TECHNIQUES

- **Anxiolytic premedication** should not be given routinely in the holding area as most ambulating patients (at UCSF) are expected to walk into the EP lab and position themselves up-right on the table while monitors and patches are placed.

- Broncho-dilator, anti-reflux medication and antacid should be given as indicated by the anesthetic technique and the patient's co-morbidities.

- **The anesthetic of choice for PVI performed at UCSF is GA**, due to the length of the procedure and lower incidence of pulmonary vein reconnection. **Induction of GA and secure the airway with ETT** according to the patient's history and exam**.** In the absence of any contraindication, either succinylcholine or a non-depolarization agent can be used.
    - The advantage of succinylcholine is that, in the case of left atrial (appendage) thrombus discovered on the TEE exam, the patient can be awoken quickly without residual paralysis.
    - The advantage of a non-depolarizing agent is that the patient will be paralyzed and this decreases the risk of bucking or biting during TEE probe insertion. Usually the TEE exam is comprehensive and takes 15 to 45 minutes, which is enough time for twitch to appear and the muscle relaxation reversed.
    - Alternatively, the TEE can be performed under MAC, if the suspicion of thrombus is high and the patient is sick, before deciding if GA and ablation are indicated.

- The choice of **maintenance** of anesthesia is up to the anesthesia provider. The local anesthetic infiltration decreases the amount of pain of the vascular access, so minimal intra-operative opiate is needed. The goal is to maintain hemodynamic stability. The choice of agent has little effect on the procedure itself. Repeat neuromuscular blockade is avoided in order to detect phrenic never stimulation. Consider utilizing IV acetaminophen.

- **Emergence**: Following anti-coagulation reversal, removal of the venous sheaths, and manual hemostasis, most patients are extubated in the procedure room. Special caution should be made to avoid excessive coughing, vomiting, and bending at the waist during extubation immediately following hemostasis. EP staff often applies additional manual compression during extubation. Attention to suctioning the oropharynx and ET tube, prophylactic antiemetic treatment. Alternatively, in the absence of contra-indications, deep extubation is an option.

- **Recovery after GA** will be in the 4th floor PACU. Patients who had MAC may be recovered in the EP holding room unless the anesthesia provider feels that additional monitoring is necessary in the PACU or ICU due to co-morbidities or intra-operative events, or if the recovery is expected to exceed the hours of EP staff. Depending on the size of the sheath and the use of anti-coagulation, the patient will need to remain supine with the hips straight for 4 to 6 hours because of risk of bleeding.

KEY PROCEDURE-RELATED POINTS

- Often, a post-intubation, **pre-ablation TEE** is performed to rule out intra-cardiac thrombus, especially in the left atrial appendage. The EP may bypass a TEE if the patient is in sinus rhythm, has consistently therapeutic INR with warfarin, or is on a direct anti-Xa or anti-thrombin inhibitor for more than 30 days without a missed dose. Here at UCSF, TEE is performed by the echocardiography team. Both the echo fellow AND the echo attending have to consent the patient SEPARATELY (another reason to avoid midazolam).

- Access is primarily through sheaths placed in the femoral veins by the proceduralist. Local anesthetic is used even for patient under GA. This is performed by the EP fellow, usually prior to attending time out.

- **Trans-septal access** increases the risk of thromboembolism, and requires **heparinization**. The anesthesia provider will be asked to give the bolus dose, while the EP staff will manage the infusion and check ACT.

- Hemodynamic fluctuation is often seen, usually associated with tachy- or brady-cardia, and pacing. The changes are often self-limiting, but may require treatment.

- **Infusion of isoproterenol**, a non-selective beta agonist with chronotropic, dromotropic, inotropic and vasodilatory effects, is commonly used for elicit/evaluate tachyarrythmias and is administered by the EP nurse. Phenylephrine infusion is commonly used to counteract the vasodilation effect.

- AF during the procedure may require **direct current cardioversion**.

- **To avoid phrenic nerve injury, pacing is performed** before any energy delivery. Diaphragm movement would indicate phrenic nerve capture, and the catheter will be repositioned.

POTENTIAL COMPLICATIONS

- **Arrhythmia** that is hemodynamically significant is always a risk.

- **Vascular complications** at the access site are not uncommon and range from self-limited site hematoma to retroperitoneal bleeding requiring urgent/emergent vascular surgery interventions. Resuscitation with fluids, blood products, and vasoactive medications may be necessary.

- **Aortic perforation** is a relatively rare complication that can occur during trans-septal puncture with a specialized needle (Brockenbrough) and the advancement of trans-septal sheath (Mullins).

- **Cardiac perforation** may occur due to catheter manipulation, during Trans-septal puncture or as a result of ablation. This may result in pericardial effusion, and potentially causing tamponade. This is usually

indicated by persistent hemodynamic instability unrelated to the induced arrhythmia and refractory to routine vasoconstrictors and fluid. The EP team should be informed when this is suspected. Blood products should be ordered immediately. Consider reversing anticoagulation in consultation with the proceduralist. One or more of the femoral sheaths can be used for volume resuscitation. The management of effusion varies:
  - "Wait-and-watch" approach when the effusion is small and self-limiting,
  - Emergent pericardial drain placement,
  - Rapid mobilization for surgical decompression of the tamponade.

- **Left atrial esophageal fistula** is often a late complication that occurs after significant injury to the posterior wall of the LA. This injury is catastrophic.

- **Stroke** is possible due to the increased risk of thromboembolism with left sided catheter. In addition, the trans-septal access creates a temporary path for paradoxical embolism.

- **Phrenic nerve injury**. This is more common with cryoablation than the RF ablation commonly used at UCSF.

SPECIAL ERGONOMIC CONSIDERATIONS

- **Extensions** on breathing circuit, oxygen supply, IV tubing, and infusion tubing are necessary to allow the unobstructed movement of the fluoroscopy equipment. Consider consolidating and securing monitors, circuits, and tubing such that they clear the C-arm, biplane and avoid tangling. Tourniquets and blue clamps are often useful. The patient's arms will be secured, padded and tucked, limiting our access. One should consider attaching two pre-flushed infusion lines that can be used for anesthetic agents such as propofol or remifentanil, and vasoactive agents.

- **Hazards to the anesthesia provider**
  - **Equipment is in motion**
    Be aware of the c-arm when it is in motion as it can move quickly and endanger heads and shins and may snag loose wires and tubings.
  - **Ionizing radiation**
    Consider time (limiting exposure), distance (inverse square law), and shielding (both garments and barriers) when in ionizing radiation environments. Particular attention should be granted to protecting the lens of the eye, thyroid, hematopoietic centers in long bones, and reproductive organs as these are particularly sensitive to ionizing radiation. The exposure is greatest as it exits the collimator (the part below the table) in path to the image intensifier (the part above the patient). However, scatter radiation is produced as the X ray encounters items in its path (the patient). Areas on the body that are often overlooked ("weak spots") include neck, shoulder/arm pits, and back. Lead (radiation protective) garments should cover the neck to the knees and are designed to be worn when facing the source.
  - **Magnetic fields**
    At UCSF, one of the EP rooms (EP1) is equipped with the Siemens Stereotaxis NIOBE® magnetic navigation system that can be used to manipulate wires and catheters in the patient's body. The magnets are material and cannot be turned off, but the magnetic field is tempered when in the stored position. The magnetic field is not on par with the electromagnet used in MRI; however, MRI precautions are recommended.

DURATION 5 - 8 hours

REFERENCES

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CARDIOVERSION

PATIENT DEMOGRPAHY

The prevalence of atrial fibrillation (AF) increases with age and is rare in adults younger than 55 who do not have structural heart disease. In older population, the incidence of new cases ranges from 2 or 3 per 1000 population per year in the age group of 55-64 years to 35 in patients older than 85. AF patients usually have some underlying heart disease such as hypertension, coronary artery disease, mitral valve disease (including rheumatic heart disease), or heart failure. The association with hyperthyroidism, pulmonary embolism, obstructive pulmonary diseases, and heavy alcohol use are also well documented.

Atrial flutter (AFL) is rare in young adults with incidence rates range from 5 in 100,000 (< 50 years old) to 587 in 100,000 (> 80 years old). It is often associated with underlying heart disease. Many diseases that cause AF can also cause AFL, and AFL can also be a side effect of anti-arrhythmic agents used to suppress AF. Common risk factors for developing AFL include male gender, advanced age, heart failure and chronic obstructive lung disease. Lastly, both AF and AFL can occur after cardiac and thoracic surgeries.

In general, cardioversion is performed in those patients who are symptomatic. Thromboembolic disease is a major cause of morbidity and mortality in patients with AF or AFL. The use of transesophageal echocardiography can rule out any intracardiac thrombus, especially in the left atrial appendage, and facilitate earlier cardioversion.

DISEASE BACKGROUND AND PROCEDURAL DESCRIPTION

In AFL, the likely etiology is a single macro-reentrant atrial circuit. So called “typical” flutter involves a region of cardiac tissue that connects the tricuspid valve annulus and the inferior vena cava (IVC), which is the main target in electrophysiologic study and catheter ablation. In the absence of this ridge of tissue, it is called an “atypical” flutter, and the reentrant circuit can be elsewhere in the right atrium (RA) or infrequently left atrium (LA). On ECG, AFL usually shows the typical sawtooth wave (atrial depolarization at around 300 bpm) with a regular ventricular response at a ratio of 1:2 or 1:4, although odd ratio or variable AV conduction is possible. Patients with AFL will choose watchful waiting as this arrhythmia may spontaneously revert to sinus. On the other hand, catheter ablation is highly successful in eliminating typical aflutter. Those patients who are waiting for ablation may undergo electrical cardioversion.

In AF, the rapid atrial rate is initiated by a single focus of abnormal activity, most commonly near one of the pulmonary vein ostia in the LA. Once initiated, the fibrillation is maintained by multiple micro-reentrant circuits in the atria. New onset AF is usually self-limiting and sinus rhythm is restored spontaneously. However, over time the atria of patients with AF remodel—atria dilate, undergo fibrosis and inflammation, and the electrical property of the atrial tissue becomes altered—thus paroxysmal AF becomes persistent AF. Due to the competing micro-reentrant circuits, the ECG will not show distinct P wave or the saw tooth pattern but rather small amplitude oscillations. Ventricular response varies. Besides emergency cardioversion in hemodynamically unstable patients, elective cardioversion is usually performed in patients with new onset AF, persistent AF who is symptomatic, or those initiating long term anti-arrhythmic agents such as sotolol or dofetilide. For this last group, UCSF typically admit these patients for the initiation of the anti-arrhythmic drug, which can have serious side effects including QT prolongation, ventricular arrhythmia and heart failure, and schedule a cardioversion preemptively in case they do not revert to sinus after 48 - 72 hours, which they often do.

The energy of the cardioversion will be determined by the EP physician. Typically AFL will require less energy than AF for successful conversion. The placement of the external patch is usually posterior-anterior, but in cases of pre-existing pacemaker or internal cardioverter-defibrillator, the EP physician will use a safe alternative.

PRE-OPERATIVE ASSESSMENT

- **Standard ASA NPO guidelines** should be followed for this elective procedure.

- A thorough assessment of the patient's **airway** and **respiratory status** is essential since there is a risk for airway obstruction during TEE insertion and examination. History of reactive airway disease, COPD, OSA, GERD, pleural effusion, or pulmonary edema from acute heart failure may affect the anesthetic management.

- In addition to the arrhythmia, the overall **cardiovascular and functional status** of the patient should be assessed. Other etiologies of AF may have significant cardiovascular and systemic manifestations. The patient may be frail from chronic de-conditioning, have reduced ventricular function due to tachycardia-induced cardiomyopathy, or have other structural heart diseases.

- **Anti-platelet agents and anticoagulants** should be noted. Given the risk of thromboembolism associated with AF or AFL and the noninvasive nature of cardioversion, they are not stopped. However, the echocardiographer may be appropriately concerned if INR is significantly above the therapeutic range due to the risk of airway trauma and bleeding during probe insertion.

PRE-OPERATIVE PREPARATION

- EP Work flow will sometime prefer to have the cardioversion take place in the nook at the far end of the holding room thus eliminate the need to use the EP lab and the subsequent room turn over and cleaning. Ultimately the anesthesia provider makes the decision.

- Routine checks of **emergency airway equipment, oxygen, suction** and **resuscitation medications** are imperative. At UCSF, a glidescope is located outside the EP control room. The EP staff, as a rule, will call the anesthesia technician to bring an anesthesia machine and a cart if the cardioversion is planned in the holding room. In some circumstances (e.g. cardioversion without TEE in a patient with a benign airway exam) the anesthesia provider may feel comfortable providing a brief MAC while monitoring using the EP monitors and charting vital signs and medications manually on APEX without the anesthesia machine.

ACCESS/FLUIDS

- At UCSF, the EP nurse will start a peripheral IV in the pre-op holding area.

MONITORS

- **Standard ASA monitors**: In the holding room, the anesthesia provider may choose to connect monitors to the anesthesia machine or rely on the monitors placed by the EP staff as long the vital signs can be either automatically imported to the APEX record (by selecting the right device) or manually entered without affecting patient care. Rarely, the irregularity of pulses can frustrate the non-invasive BP cuff.

- **If invasive arterial monitor** is needed in a hemodynamically unstable patient, then perhaps the ICU would be a better place for the cardioversion.

ANESTHETIC TECHNIQUES

- **Anxiolytic premedication** should not be given routinely until the patient has been consented by the following: the EP fellow/attending, the echocardiography fellow (if TEE is planned) and the echocardiography attending (separate from the fellow).

- Broncho-dilator, anti-reflux medication and antacid should be given as indicated by the anesthetic plan and the patient's co-morbidities, but is rarely necessary for MAC cases.

- **The anesthetic of choice for cardioversion, even with TEE, is MAC.** The anesthetic goal is to provide sedation and comfort during TEE exam and ensure amnesia for the jolt of electricity. The most stimulating portion is usually the TEE probe insertion. Most echocardiographers prefer to topicalize the airway as they typically do for patients in the echo lab. However, some anesthesia providers are concerned about blunted airway reflexes and the risk of airway obstruction after the procedure, and the topicalization step can be skipped. A small propofol bolus will usually facilitate the passing of the probe. The use of GA should be determined by the patient's cardiopulmonary co-morbidities and airway assessment.

- The **emergence after MAC** should be straight forward, which involves discontinuing the sedation and monitoring for any airway obstruction before either leaving the EP lab or handing off the patient to the EP nurse if already in the holding room. Patients after GA will recover in the 4th floor PACU.

KEY PROCEDURE-RELATED POINTS

- **The insertion of the TEE probe is most stimulating and stressful portion** of the procedure as the patient may buck, cough, obstruct and/or desaturate during this time. Jaw thrust, and turning the head to one side or the other by the anesthesia provider may be helpful. Remember to have suction available.

POTENTIAL COMPLICATIONS

- **Airway obstruction and desaturation**, especially with TEE. **Airway trauma with potential bleeding.**

- **Unsuccessful cardioversion.** While most patients revert to sinus rhythm after a single shock, this may not be the case in patients with underlying structural heart disease, such as those with large atria, or those with long standing history of AF. Additional shockS with higher energy may be used. The EP team will decide when to stop.

- **Arrhythmia or conduction abnormality** is sometime observed after cardioversion, but is often transient.

- **Stroke** is a known complication, even in weeks after restoring sinus rhythm. Patients are instructed to continue their anti-coagulation medications.

- Skin burn

SPECIAL ERGONOMIC CONSIDERATIONS

- If done in the holding room, there is **limited space** to accommodate an EP nurse with his 12-lead ECG machine and monitors, the anesthesia provide(s) with an anesthesia machine, monitors and a cart, a two-member EP team, and a two-member echocardiography team with the TEE machine. If in the EP lab, patient can remain on the gurney.

- Ensure the patient is positioned properly and **arms and other body parts are protected** as they may move and be injured during the shock.

- **Stay clear of the patient** prior to the delivery of synchronized shock.

DURATION 5 – 45 minutes

REFERENCES

Benjamin EJ, Wolf PA, D'Agostino RB, Silbershatz H, Kannel WB, Levy D. Impact of atrial fibrillation on the risk of death: the Framingham Heart Study. *Circulation* 1998;98:946-52.

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PACEMAKER/IMPLANTABLE CARDIOVERTER-DEFIBRILLATOR IMPLANTATION;

Generator change; Lead insertion

PATIENT DEMOGRAPHY

A patient may need a PM for a number of conditions. In general, symptomatic bradyarrhythmia or conduction defect is an unambiguous indication. In asymptomatic patients, high grade heart blocks, usually those with lesions below the atrio-ventricular (AV) node, are strong indications. Common indications for PM include:

- Symptomatic bradycardia
- Sick sinus syndrome,
- Second degree (Mobitz II) AV block
- Complete AV block
- Bifascicular or trifascicular block
- High grade block post myocardial infarction

The main indications for an ICD are for primary prevention of ventricular tachycardia or ventricular fibrillation (VT/VF) in patients at high risk of sudden cardiac death (SCD) due to VT/VF or for secondary prevention in those who had history of sustained VT/VF and/or SCD. These patients usually have underlying cardiac disease such as coronary artery disease, structural heart disease or various other cardiomyopathies. EF < 35% is generally the threshold for ICD. Other selected groups include those with:

- Congenital long QT syndrome
- Brugada syndrome
- Hypertrophic cardiomyopathy
- Arrhythmogenic right ventricular cardiomyopathy

A subset of patients are recommended to have biventricular (BiV) leads for cardiac resynchronization therapy (CRT) for low ejection fraction (EF <35%), NYHA class III-IV and QRS interval > 120ms.

Taken together, PMs and ICDs are types of cardiovascular implantable electronic devices (CIED). As such, patients who need CIED implantation may range from a robust endurance athlete, a transplant candidate in chronic heart failure, or a post-surgical patient with complete heart block.

PROCEDURAL DESCRIPTION

For ICDs, at least a single ventricular lead (with two defib coils) is inserted into the RV. For PMs, usually two leads, one for RA and one RV (“dual chamber”), are inserted. In some incidence, a single atrial lead is sufficient. For CRT, an additional LV lead is needed.

For the implantation of a new CIED, the preferred location is at the left upper chest. The proceduralist will infiltrate the skin with local anesthetic. The majority of proceduralists at UCSF will make the skin incision and perform dissection prior to getting venous access. A micropuncture needle is used to access the subclavian/axillary vein, using a combination of fluoroscopic and ultrasound guidance. After inserting the guide wire, the needle is exchanged for a dilator sheath. When difficulty is encountered (obtaining access or passing wires), a venogram is performed to ascertain the patency of the vein. Alternatively, venous access is done percutaneously prior to incision. This has the advantage of avoiding an unnecessary skin incision if the vein on that side is unfavorable for access.

Once the sheath(s) is in place, a lead with a rigid stylet is inserted. After confirm its position on fluoroscopy, the lead is secured in the endocardium using a screw system. . If more than one lead is planned, the RV lead is positioned first before the same steps are repeated for the RA lead. Typically the ventricular lead is secured in the RV apex, and the atrial lead is secured in the right atrial appendage. For BiV pacing, a lead is inserted into the coronary sinus in order to capture the LV. Then the outer sheath is peeled apart and removed. After the stylet is removed, the device company representative will check the sensing threshold and lead impedance. When satisfied, the external end of the lead is secured. Then a pocket is created and irrigated with antibiotic solution. The leads are connected to the generator, and the generator is placed in the pocket. After a repeat impedance check by the rep and one last fluoroscopic check, the incision is then closed.

PRE-OPERATIVE ASSESSMENT

- **Standard ASA NPO guidelines** should be followed for this elective procedure.

- A thorough assessment of the patient's **airway and respiratory status** is essential since the airway will be far from the anesthesia provider with potential obstacles such as the fluoroscopic equipment and drapes. History of reactive airway disease, COPD, OSA, GERD, pleural effusion, or pulmonary edema from acute heart failure may affect the anesthetic management.

- The **overall cardiovascular and functional status** of the patient should be assessed. The patient may range from young and healthy to someone who has severely reduced ventricular function. The indication for the CIED is important. If the heart block is paroxysmal, associated symptoms should be noted, and back up pacing should be made available by the EP team. For PM generator change, it is important to note the patient's underlying rhythm and whether there is AV conduction. Again, this may determine whether a temporary pacing lead is needed.

- **Anti-platelet agents and anticoagulants use** should be noted. Anti-platelet agents are usually not stopped. Warfarin is usually not stopped as long as the INR is not supra-therapeutic. Other agents are stopped at the proceduralist's discretion. Regardless, their use may increase the risk of bleeding or hematoma during and after the procedure. At UCSF, the EP team usually postpones the procedure if the patient is on heparin infusion.

- Patient with **chronic renal insufficiency** or end-stage renal disease will need to have their electrolytes and fluid status assessed carefully. The team should be mindful of exposure to nephrotoxic contrast agents in patients with reduced GFR. Not infrequently, a venogram, usually of left upper extremity, is performed to delineate the vascular anatomy.

- Patients who suffer from **chronic back or leg pain** may not tolerate spending extended periods in a supine position without proper positioning, padding and analgesia.

- It is important to set **proper expectation** for the patient, who may say "just put me to sleep." Most CIED placements or generator changes at UCSF are done under MAC, even conscious sedation by EP nurses sometime.

PRE-OPERATIVE PREPARATION

- Routine checks of **anesthesia machine, emergency airway equipment, suction and resuscitation medications** are imperative because access to additional equipment and anesthesia providers are limited. Usually, two infusion pumps and an invasive pressure transducer are available in each lab. At UCSF, a video laryngoscope (Glidescope) is located outside the EP control room. Contact the off-site anesthesia technician if you need any additional equipment.

- **Blood products** are usually not required, but a blood type and antibody screen should be current.

- **Antibiotic** usually 1 to 2 g of cefazolin is given prior to skin incision.

ACCESS/FLUIDS

- At UCSF, the EP nurse will start a peripheral IV in the pre-op holding on the side of planned subclavian access (usually left arm). Additional PIV is usually not necessary.

- **Anticipated blood loss** is minimal and is usually associated with skin incision and the creation of a pocket.

- **Intravenous fluid** should be given to maintain hemodynamic stability, but be mindful that a Foley catheter is not always present. Rarely, diuretic is administered in heart failure patients who is volume overloaded.

MONITORS

- **Standard ASA monitors**: The EP staff will assist you in placing radiolucent ECG leads to ensure that they do not interfere with the fluoroscopic images or the rest of electrophysiology monitors.

- **Invasive arterial monitor** is indicated based on the patient's cardiac status and the anesthetic plan, and is rarely needed when a light MAC is planned. However, it is reasonable in someone who 1) had a history of malignant arrhythmia and cardiac arrest, or 2) has severely reduced cardiac function AND defibrillation threshold (DFT) testing is planned.

- **Temperature** can be monitored with an axillary probe. A lower body forced air warmer is used.

- **Urinary bladder catheter** is usually not needed for straight forward cases. Discuss with the EP team for longer procedures, or when the patient is in heart failure.

ANESTHETIC TECHNIQUES

- **Anxiolytic premedication** should not be given routinely in the holding area as most ambulating patients are expected to walk into the EP lab and sit up-right on the table while monitors and patches are placed.

- Broncho-dilator, anti-reflux medication and antacid should be given as indicated by the anesthetic technique and the patient's co-morbidities.

- Vast majority of CIED procedures at UCSF are performed **under MAC**. The **anesthetic goal** is to provide analgesia and to ensure both patient safety and patient cooperation. Your anesthetic may range from a detailed pre-operative discussion, verbal reassurance, generous local anesthesia supplemented with minimal sedation in a motivated patient, to general anesthesia in an uncooperative patient with airway obstruction. Common pharmacological options include: 1) **midazolam and fentanyl**; 2) **propofol** infusion with intermittent fentanyl bolus; 3) **Remifentanil** infusion (in selected population); 4) Small doses of **ketamine** (patients who have significant cardiac disease or are at risk of airway obstruction). The most stimulating parts include the initial incision and the expansion of the generator pocket.

- **Supplemental oxygen** can be provided with **nasal cannula with CO2 monitoring**. Alternatives include oral/nasal airway, simple face mask, non-rebreather, or anesthesia mask with straps to provide PEEP (it is time to reassess your "MAC").

- The **emergence** should be straight forward, which involves discontinuing the sedation, usually once the pocket is closed, and monitoring for any airway obstruction before leaving the EP lab. The EP staff will place the affected arm in a sling, and they prefer a relatively cooperative patient.

- **Recovery** of a patient after general anesthesia will be in the 4th floor PACU, while the patient who had **MAC will be recovered in the EP holding room** unless the anesthesia provider felt that a higher level of care (PACU or ICU) is necessary due to co-morbidities or intra-operative events, or if the length of recovery is expected to exceed the hours of EP staff. The patient will need to keep the arm to minimize the risk of bleeding. Postoperative pain is minimal with local anesthetic infiltration.

KEY PROCEDURE-RELATED POINTS

- For new CIED or when there is a concern for the subclavian/innominate vein patency, the anesthesia provider will be asked to perform a **venogram** by injecting 10 mL of contrast followed by saline flush through the PIV on that side. For a patient with a history of contrast allergy, discuss the need for diphenhydramine and hydrocortisone with the EP team.

- If implanting an ICD, discuss with the EP team whether they **plan to perform DFT testing by induce ventricular tachyarrhythmia**. Anesthesia needs to be deepened prior to the test. Invasive monitor may be necessary if the patient has reduced EF.

- For generator changes, **the device will be interrogated and reprogrammed prior to skin incision**. If the patient has a complete heart block or underlying rhythm is severe bradycardia (i.e. pacemaker dependent), the EP team may need to place a temporary pacing lead, usually via the femoral vein. Alternatively, if the AV nodal conduction is relatively functional, it may be possible to disconnect one lead while the old generator maintains pacing via the remaining lead. Once the first lead is connected to the new generator, the second lead can be safely disconnected.

- Hemodynamic fluctuation is sometimes seen with tachy- or brady-cardia, and pacing. The changes are often self-limiting, but may require treatment in patients with low EF.

POTENTIAL COMPLICATIONS

- **Vascular injury** from accessing the subclavian vein is possible but rare due to the open procedure. **Bleeding** from the generator pocket is another risk, and the risk increases with anti-thrombotic or anti-coagulation treatment.

- **Transient arrhythmia,** but can be sustained and hemodynamically significant**.**

- **Pneumothorax.**

- **Pericardial effusion** from lead perforation. **Cardiac tamponade** is a rare complication. This is usually indicated by persistent hemodynamic instability unrelated to the induced arrhythmia and refractory to routine vasoconstrictors and fluid. The EP team should be informed when this is suspected and can assist in placing additional invasive monitors and vascular access for resuscitation. Blood products should be ordered immediately. Consider reversing anticoagulation in consultation with the proceduralist. One or more of the femoral sheaths can be used for volume resuscitation. The management of effusion varies:
    - "Wait-and-watch" approach when the effusion is small and self-limiting,
    - Emergent pericardial drain placement,
    - Rapid mobilization for surgical decompression of the tamponade.

SPECIAL ERGONOMIC CONSIDERATIONS

- At UCSF, **the anesthesia machine and cart are positioned to the right of the patient**, as the proceduralists prefer to stand to the left of the patient for left subclavian access.

- **Extensions** on breathing circuit, oxygen supply, IV tubing, and infusion tubing are necessary to allow the unobstructed movement of the fluoroscopy equipment. Consider consolidating and securing monitors, circuits, and tubing such that they clear the C-arm, biplane and avoid tangling. Tourniquets and blue clamps are often useful. The patient's arms will be secured, padded and tucked, limiting our access. One should consider attaching two pre-flushed infusion lines that can be used for anesthetic agents such as propofol or remifentanil, and vasoactive agents.

- **Hazards to the anesthesia provider**
  - **Equipment is in motion**
    Be aware of the c-arm when it is in motion as it can move quickly and endanger heads and shins and may snag loose wires and tubings.
  - **Ionizing radiation**
    Consider time (limiting exposure), distance (inverse square law), and shielding (both garments and barriers) when in ionizing radiation environments. Particular attention should be granted to protecting the lens of the eye, thyroid, hematopoietic centers in long bones, and reproductive organs as these are particularly sensitive to ionizing radiation. The exposure is greatest as it exits the collimator (the part below the table) in path to the image intensifier (the part above the patient). However, scatter radiation is produced as the X ray encounters items in its path (the patient). Areas on the body that are often overlooked ("weak spots") include neck, shoulder/arm pits, and back. Lead (radiation protective) garments should cover the neck to the knees and are designed to be worn when facing the source.
  - **Magnetic fields**
    At UCSF, one of the EP rooms (EP1) is equipped with the Siemens Stereotaxis NIOBE® magnetic navigation system that can be used to manipulate wires and catheters in the patient's body. The magnets are material and cannot be turned off, but the magnetic field is tempered when in the stored position. The magnetic field is not on par with the electromagnet used in MRI; however, MRI precautions are recommended.

DURATION 1.5 - 4 hours

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SUPRAVENTRICULAR TACHYCARDIA ABLATION

PATIENT DEMOGRAPHY

Paroxysmal supraventricular tachycardia (PSVT) is defined as a heart rate greater than 100 beats per minute, usually with a narrow QRS complex (< 120ms) and has a regular R-R interval. In other words, it would be more accurately called regular narrow complex tachyarrhythmia. It has acute onset and termination and do not originate in the ventricles. While atrial fibrillation (AF) is technically a type of this group of tachyarrhythmias, AF ablation is discussed separately.

Narrow complex tachycardia can occur in patients of all ages. The overall incidence is 35 cases per 100,000 person-years. While the typical patient is relatively young, otherwise healthy, the tachycardic episodes, though infrequent, can be quite psychologically or physically debilitating. The most common complaint would be palpitation and diaphoresis with associated symptoms of dizziness or lightheadedness. Less common would be chest discomfort or shortness of breath. Rarely syncope, usually in those who have underlying cardiac disease, is reported. Although life style changes (avoidance of caffeine, nicotine, alcohol and other stimulants) and anti-arrhythmia medication can be effective in many patients, some cannot tolerate the side effect of medication and/or are refractory to pharmacologic treatments. The patient has been informed of the risks and benefits of catheter-based ablation, as an alternative to medical management, and has chosen to proceed with this invasive procedure. In order to localize the abnormal conducting tissue, the patient is instructed to stop anti-arrhythmia medication and/or beta-blocker a few days prior to the procedure.

DISEASE BACKGROUND AND PROCEDURAL DESCRIPTION

Besides AF, other causes of regular narrow complex tachycardia include sinus tachycardia, atrial flutter, atrio-ventricular nodal reentrant tachycardia (AVNRT), atrio-ventricular reciprocating tachycardia (AVRT), (focal) atrial tachycardia, multifocal atrial tachycardia (MAT), sino-atrial nodal reentrant (SANRT), and other reentrant or junctional tachycardias. Reentry pathways such as those in AVNRT and AVRT are by far the most common causes, making up 60% and 30% of the cases respectively. Re-entry circuits arise from competing pathways (cardiac tissue) with differences in conduction velocity and refractory period such that a recurrent ectopic circuit (depolarization loop) is triggered and sustained, causing repeated depolarization of the ventricles via the His-Purkinje system. Other PSVT is caused by increased automaticity of the cardiac tissue.

In AVNRT, the reentry circuit is contained entirely within the AV node (functionally speaking). The reentry circuit is usually in the right atrium (RA) and behaves like atrial tissue. Of the two pathways, the slow pathway is usually the target of ablation, commonly runs posterior to the tricuspid annulus and anterior to the coronary sinus (CS) ostium. The ablation can be guided by electrogram, or less commonly, based on anatomy only. In AVRT, the reentry circuit consists of the AV node (normal pathway) and an accessory pathway. The accessory pathway connects the right ventricle and the RA, is contained within the atrio-ventricular (AV) groove, and behaves like ventricular tissue. AVRT can conduct in either direction-orthodromic (with electric impulse entering the ventricle via the AV node) or antidromic (via the accessory pathway). Right sided accessory pathways are usually located along the tricuspid annulus or the CS ostium from the inferior vena cava. Left sided pathways can be located and ablated by a catheter either in the left atrium/ventricle (via transseptal/retrograde approaches) or within the CS, which runs along the left AV groove.

Wolff-Parkinson-White (WPW) is a subtype of AVRT with a characteristic delta pre-excitation wave pattern on ECG that is common in younger adults. WPW pattern occurs in about 1 to 3 per 1,000 persons in the general population, but the prevalence is higher in first-degree relatives. It is more common in men than women, and men have a higher incidence of multiple accessory pathways. WPW may also be associated with congenital defects within the heart such as Ebstein's anomaly.

Since these pathways can usually be located by catheters in the RA, venous access is typically sufficient. The diagnostic procedure begins with venous access to bilateral femoral and/or right internal jugular (RIJ) veins. A total of four to five sheaths are placed. Then various recording and pacing electrode arrays on catheters are inserted into the heart. Ablation catheters are typically introduced into the RA from the femoral vein up the iliac vein and vena cava. Each catheter has multiple electrodes along its tip capable of recording electrogram with the exception that the most distal electrode can also stimulate and pace. Catheters are guided with fluoroscopy, intracardiac echocardiography, and with the assistance of various mapping systems that help locate the ectopic foci, identify the depolarization pattern, position the ablation catheter, and evaluate ablation results. The ablation of ectopic foci and pathways of cardiac tissue is performed most commonly with radiofrequency (microwave) energy to induce a transmural heat injury (60 to 70 degree Celsius at the catheter tip), which scars to isolate the electrical propagation of impulses. The tip is actively cooled with saline irrigation to avoid over-heating and the undesirable formation of coagulum. Coagulum prevents effective tissue lesion, and the catheter needs to be withdrawn to remove the coagulum. Other methods include cryoablation via catheter or balloon and laser ablation via balloon. Rarely, left atrial access, via a pre-existing patent Foramen Ovale (PFO) or via a trans-septal puncture, is required.

It is thought that any sedation that suppresses the endogenous catecholamine release may decrease the frequency of arrhythmia, and make the mapping of the pathway and thus ablation more difficult. It would be ideal to minimize the amount of sedation the patient receives during mapping.

PRE-OPERATIVE ASSESSMENT

- **Standard ASA NPO guidelines** should be followed for this elective procedure.

- A thorough assessment of the patient's **airway and respiratory status** is essential since the airway will be far from the anesthesia provider with potential obstacles such as the fluoroscopic equipment and drapes. <u>History of reactive airway disease, COPD, OSA, GERD, pleural effusion, or pulmonary edema from acute heart failure</u> may affect the anesthetic management.

- In addition to the arrhythmia, the **overall cardiovascular and functional status** of the patient should be assessed. The patient may range from an elite athlete to someone who is frail from chronic de-conditioning, have reduced ventricular function due to tachycardia-induced cardiomyopathy, or have other structural heart diseases. It is important to note the patient's symptoms during SVT episodes, which may range from asymptomatic to syncope, with the latter especially concerning.

- **Anti-platelet agents and anticoagulants use** should be noted, though it is rare in this population.

- Patient with **chronic renal insufficiency** or end-stage renal disease will need to have their electrolytes and fluid status assessed carefully. The team should be mindful of exposure to nephrotoxic contrast agents in patients with reduced GFR; however, EP studies do not commonly expose the patient to contrast.

- Patients who suffer from **chronic back or leg pain** may not tolerate spending extended periods in a supine position without proper positioning, padding and analgesia.

- It is important to set **proper expectation** for the patient, who may say "just put me to sleep." As most SVT ablations at UCSF are done under MAC, the patient should expect to be awake once mapping starts.

PRE-OPERATIVE PREPARATION

- Routine checks of **anesthesia machine, emergency airway equipment, suction and resuscitation medications** are imperative because access to additional equipment and anesthesia providers are limited. Usually, two infusion pumps and an invasive pressure transducer are available in each lab. At UCSF, <u>a video laryngoscope (Glidescope) is</u> located outside the EP control room. Contact the off-site anesthesia technician if you need any additional equipment.

- **Blood products** are usually <u>not required</u>, but a blood type and antibody screen should be current.

- **Antibiotic** is <u>not indicated</u> for this percutaneous procedure.

ACCESS/FLUIDS

- At UCSF, the EP nurse will start a peripheral IV in the pre-op holding, usually 18 or 20 gauge (left arm).

- Most patients having a SVT study/ablation will have a RIJ sheath placed by the proceduralist for CS cannulation.

- Additional PIV is usually not necessary. Remember that the introducer sheaths may be used for central venous access. Sometimes, when a heparin infusion is necessary (left sided ablation), the EP team would use the right IJ sheath so the EP nurse can draw ACT samples from the femoral sheath without contamination. In the absence of RIJ access, the heparin can be infused through the PIV (some anesthesia providers prefer a separate PIV).

- **Anticipated blood loss** is minimum, usually associated with initial access and flushing of the sheaths.

- **Continuous irrigation of ablation catheters (1 to 2 L total) and sheath (30 mL/hour each), may add significant volume** and may prompt diuretic use at request of the proceduralist.

MONITORS

- **Standard ASA monitors**: The EP staff will assist you in placing radiolucent ECG leads to ensure that they do not interfere with the fluoroscopic images or the rest of electrophysiology monitors. Sometimes, the anesthesia ECG leads can be connected to the mapping system directly.

- **Invasive arterial monitor** is <u>not required</u>; however, it can be useful and is recommended in those patients who have significant symptoms, such as syncope, or have a history of ischemic heart disease or cardiomyopathy and may not tolerate rapid pacing/heart rate. <u>If an arterial (femoral) sheath is placed for left sided ablation (retrograde approach), pressure can be transduced</u> from the sheath and monitored by anesthesia.

- **Temperature** should be monitored as the procedure can be lengthy. An axillary probe is sufficient for patients not under general anesthesia. A lower body forced air warmer is used.

- Discuss with the EP team regard the need for **urinary bladder catheter**, depending on the expected length of the procedure. A condom catheter may be an alternative for a male patient.

ANESTHETIC TECHNIQUES

- **Anxiolytic premedication** <u>should not be given routinely</u> in the holding area as most ambulating patients are expected to walk into the EP lab and sit up-right on the table while monitors and patches are placed.

- Broncho-dilator, anti-reflux medication and antacid should be given as indicated by the anesthetic technique and the patient's co-morbidities.

- Vast majority of catheter ablations for PSVT at UCSF are performed **under MAC** and is preferred by the EP team. The **anesthetic goal** is to provide analgesia during the initial painful portion of the procedure (Foley and vascular access) and to ensure both patient safety and patient cooperation thereafter that will maximize the chance for a successful study. The most stimulating portion of the study is in the beginning. Your anesthetic may range from a detailed pre-operative discussion, verbal reassurance, generous local anesthesia supplemented with minimal sedation in a motivated patient, to deep sedation in a less cooperative patient who has a reassuring airway. Common pharmacological options include: 1) **midazolam and fentanyl**; 2) **propofol** infusion with intermittent fentanyl bolus; 3) **Remifentanil** infusion (in selected population).

- **Little to no sedation is preferred** during the mapping portion of the study. With the exception of remifentanil in pediatric population, there is scant evidence on the effect of various anesthetic on the inducibility of tachyarrhythmia. Nonetheless, one tries to minimize any sedative medication as long as the patient is comfortable enough to remain cooperative. One should consider IV acetaminophen early in the procedure especially in MAC cases.

- Once the initial electrophysiological study is completed the sedation may be deepened for the subsequent ablation, even GA perhaps. <u>Always communicate with the EP team regarding the necessity or permissibility of deeper sedation.</u>

- **Supplemental oxygen** can be provided with **nasal cannula with CO2 monitoring**. Alternatives include oral/nasal airway, simple face mask, non-rebreather, or anesthesia mask with straps to provide PEEP (it is time to reassess your "MAC").

- The **emergence** should be straight forward, which involves discontinuing the sedation and monitoring for any airway obstruction before leaving the EP lab. The EP staff will remove the sheaths, hold pressure for at least 15 minutes, and they prefer a relatively cooperative patient.

- **Recovery** of a patient after general anesthesia will be in the 4th floor PACU, while the patient who had **MAC will be recovered in the EP holding room** unless the anesthesia provider felt that a higher level of care (PACU or ICU) is necessary due to co-morbidities or intra-operative events, or <u>if the length of recovery is expected to exceed the hours of EP staff</u>. The patient will need to keep the legs unflexed for at least 4 to 6 hours to minimize the risk of bleeding.

KEY PROCEDURE-RELATED POINTS

- A complete EP study is performed to identify etiology of SVT, which may have <u>multiple etiologies</u> (e.g. AF and AVNRT). Those patients referred to tertiary medical centers such as UCSF may have had recurrent arrhythmias and prior ablations. The subsequent study/ablation procedure may be time-consuming.

- Access is primarily through sheaths placed in the femoral veins and RIJ sheath for a CS catheter, which are usually placed by the proceduralist. Local anesthetic is used even for patients under GA. This is performed by the EP fellow, usually <u>prior to attending time out</u>.

- Ablations for SVT commonly only require right heart access. However, AVRT may include accessory pathways adjacent to the tricuspid and/or mitral annuli, and this may require left atrial catheterization. **If left sided study is necessary, heparinization is required** to reduce the risk of thromboembolism from the left side catheters. The anesthesia provider will be asked to give heparin boluses, while the EP staff will manage the infusion and check ACT. <u>Extreme caution should be used to avoid venous air and paradoxical embolism.</u>

- Hemodynamic fluctuation is often seen, usually associated with tachy- or brady-cardia, and pacing. The changes are often self-limiting, but may require treatment.

- **Infusion of isoproterenol**, a non-selective beta agonist with chronotropic, dromotropic, inotropic and vasodilatory effects, is commonly used for elicit/evaluate tachyarrythmias and is administered by the EP nurse.

POTENTIAL COMPLICATIONS

- **Arrhythmia** that is hemodynamically significant is always a risk. **Iatrogenic complete heart block**, previously used therapeutically, is a possible risk with ablation adjacent to the AV node and bundle of His.

- **Vascular complications** at the access site are not uncommon and range from self-limited site hematoma to retroperitoneal bleeding requiring urgent/emergent vascular surgery interventions. Resuscitation with fluids, blood products, and vasoactive medications may be necessary.

- **Cardiac perforation** may occur due to catheter manipulation, during Trans-septal puncture or as a result of ablation. This may result in pericardial effusion, and potentially causing tamponade. This is usually indicated by persistent hemodynamic instability unrelated to the induced arrhythmia and refractory to routine vasoconstrictors and fluid. The EP team should be informed when this is suspected. Blood

products should be ordered immediately. Consider reversing anticoagulation in consultation with the proceduralist. One or more of the femoral sheaths can be used for volume resuscitation. The management varies:
  - "Wait-and-watch" approach when the effusion is small and self-limiting,
  - Emergent pericardial drain placement,
  - Rapid mobilization for surgical decompression of the tamponade.

- Esophageal injury or atrial-esophageal fistula is less common in right sided ablation, but still possible and catastrophic when it occurs.

- Stroke is possible due to the risk of thromboembolism with left sided catheters or in patients with PFOs.

- Aortic perforation is a relatively rare complication that can occur during trans-septal puncture with a specialized needle (Brockenbrough) and the advancement of trans-septal sheath (Mullins).

SPECIAL ERGONOMIC CONSIDERATIONS

- **Extensions** on breathing circuit, oxygen supply, IV tubing, and infusion tubing are necessary to allow the unobstructed movement of the fluoroscopy equipment. Consider consolidating and securing monitors, circuits, and tubing such that they clear the C-arm, biplane and avoid tangling. Tourniquets and blue clamps are often useful. The patient's arms will be secured, padded and tucked, limiting our access. One should consider attaching two pre-flushed infusion lines that can be used for anesthetic agents such as propofol or remifentanil, and vasoactive agents.

- **Hazards to the anesthesia provider**
  - **Equipment is in motion**
    Be aware of the c-arm when it is in motion as it can move quickly and endanger heads and shins and may snag loose wires and tubings.
  - **Ionizing radiation**
    Consider time (limiting exposure), distance (inverse square law), and shielding (both garments and barriers) when in ionizing radiation environments. Particular attention should be granted to protecting the lens of the eye, thyroid, hematopoietic centers in long bones, and reproductive organs as these are particularly sensitive to ionizing radiation. The exposure is greatest as it exits the collimator (the part below the table) in path to the image intensifier (the part above the patient). However, scatter radiation is produced as the X ray encounters items in its path (the patient). Areas on the body that are often overlooked ("weak spots") include neck, shoulder/arm pits, and back. Lead (radiation protective) garments should cover the neck to the knees and are designed to be worn when facing the source.
  - **Magnetic fields**
    At UCSF, one of the EP rooms (EP1) is equipped with the Siemens Stereotaxis NIOBE® magnetic navigation system that can be used to manipulate wires and catheters in the patient's body. The magnets are material and cannot be turned off, but the magnetic field is tempered when in the stored position. The magnetic field is not on par with the electromagnet used in MRI; however, MRI precautions are recommended.

DURATION

4 - 6 hours

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VENTRICULAR TACHYCARDIA ABLATION

PATIENT DEMOGRAPHY

A heart rate greater than 100 beats per minute, with a wide QRS complex (> 120ms) is presumed to be VT until proven otherwise. While sustained VTs are usually life threatening, patients with nonsustained monomorphic VT (NSVT) are often asymptomatic and are diagnosed on routine ECG or other cardiac monitoring. Based on ECG, the cardiologist can usually determine whether the arrhythmia is truly VT or rather supraventricular tachycardia with aberrant conduction. The presence or absence of structural heart disease is the main determining factor whether the patient is at risk for developing sustained VT and sudden cardiac death (SCD). As such, patients scheduled for VT ablation can range from health young adults, to patients in end stage heart failure with left ventricular assist devices, and anything in between.

NSVT is usually self-limiting as it by definition should last no more than 30 seconds. During these episodes, palpitation, diaphoresis, dizziness or lightheadedness are common complaints. Less frequently there would be chest discomfort and shortness of breath. Rarely, syncope can occur in those with underlying heart disease and with a decrease in cardiac output. Ambulatory monitoring may determine whether the VT lasts longer, with more severe symptoms, which would carry worse prognosis. The prognosis of NSVT usually is benign in those without heart disease. In addition to underlying structural disease, polymorphic VT and prolonged QT interval are other risk factors for malignant rhythm and SCD. Beta blocker or calcium channel blocker can be used before other anti-arrhythmics are tried. Catheter-based ablation is an alternative to medical management, and some patients choose this invasive procedure. In order to localize the abnormal conducting tissue, the patient is instructed to stop anti-arrhythmia medication and/or beta-blocker a few days prior to the procedure.

DISEASE BACKGROUND AND PROCEDURAL DESCRIPTION

The incidence of NSVT in the general population is 0 to 4 percent. Some research suggests that NSVT may be a risk factor for future cardiac disease. On the other hand, the presence of structural heart disease increases the risk of NSVT, and other more concerning VTs such as sustained monomorphic VT and polymorphic VT. Structural heart diseases include:

- Coronary artery disease and post-myocardium infarction (MI) scar
- Non-ischemic dilated cardiomyopathy
- Hypertrophic cardiomyopathy
- Valvular diseases
- Congenital cardiomyopathy

In many of these patients, they may already have ICDs for primary prevention of SCD.

The formation of reentrant circuit is based on the differences in the electrophysiologic properties of the cardiomyocytes. In those with cardiac diseases, injured myocytes, fibrosis from previous infarction, ventricular dysfunction and remodeling, electrolyte imbalance (K, Mg etc) predispose the myocardium to VT. In the absence of structural disease, common types of NSVT include:

- Right ventricular outflow tract (RVOT) tachycardia
- Idiopathic left ventricular tachycardia
- Long QT syndromes
- Arrhythmogenic RV cardiomyopathy

The diagnostic procedure begins with venous access to bilateral femoral and/or right internal jugular (RIJ) veins. A total of four to five sheaths are placed. Then various recording and pacing electrode arrays on catheters are inserted into the heart. For left sided access, either a trans-septal approach via a pre-existing patent Foramen Ovale (PFO) or a needle puncture through the interatrial septum, or retrograde approach via one of the femoral arteries is used. Each catheter has multiple electrodes along its tip capable of recording electrogram with the exception that the most distal electrode can also stimulate and pace. Catheters are guided with fluoroscopy, intracardiac echocardiography, and with the assistance of various mapping systems that help locate the ectopic foci, identify the depolarization pattern, position the ablation catheter, and evaluate ablation results. The ablation of ectopic foci and pathways of cardiac tissue is performed most commonly with radiofrequency (microwave) energy to induce a transmural heat injury (60 to 70 degree Celsius at the catheter tip), which scars to isolate the electrical propagation of impulses. The tip is actively cooled with saline irrigation to avoid over-heating and the undesirable formation of coagulum. Coagulum prevents effective tissue lesion, and the catheter needs to be withdrawn to remove the coagulum. Other methods include cryoablation via catheter or balloon and laser ablation via balloon.

It is thought that any sedation that suppresses the endogenous catecholamine release may decrease the frequency of arrhythmia, and make the mapping of the pathway and thus ablation more difficult. It would be ideal to minimize the amount of sedation the patient receives during mapping.

PRE-OPERATIVE ASSESSMENT

- **Standard ASA NPO guidelines** should be followed for this elective procedure.

- A thorough assessment of the patient's **airway and respiratory status** is essential since the airway will be far from the anesthesia provider with potential obstacles such as the fluoroscopic equipment and drapes. <u>History of reactive airway disease, COPD, OSA, GERD, pleural effusion, or pulmonary edema from acute heart failure</u> may affect the anesthetic management.

- In addition to the arrhythmia, the **overall cardiovascular and functional status** of the patient should be assessed. While some patients who have NSVT without associated underlying structural heart disease, many other do, and they tend to be older and diseases are diagnosed with additional cardiac evaluation such as echocardiography, stress test or other cardiac imaging.

- **Anti-platelet agents and anticoagulants use** should be noted, though it is rare in this population. Anti-platelet agents are usually not stopped. Warfarin is usually not stopped as long as patient has been on chronic, stable, therapeutic dose. Other agents are stopped at the proceduralist's discretion. Regardless, this may increase the risk of bleeding or hematoma during and after the procedure, by anesthesia and the proceduralist.

- Patient with **chronic renal insufficiency** or end-stage renal disease will need to have their electrolytes and fluid status assessed carefully. The team should be mindful of exposure to nephrotoxic contrast agents in patients with reduced GFR; however, EP stuides do not commonly expose the patient to contrast.

- Patients who suffer from **chronic back or leg pain** may not tolerate spending extended periods in a supine position without proper positioning, padding and analgesia.

- It is important to set **proper expectation** for the patient, who may say "just put me to sleep." As most VT ablations at UCSF are done under MAC, the patient should expect to be awake once mapping starts.

PRE-OPERATIVE PREPARATION

- Routine checks of **anesthesia machine, emergency airway equipment, suction and resuscitation medications** are imperative because access to additional equipment and anesthesia providers are limited. Usually, two infusion pumps and an invasive pressure transducer are available in each lab. At UCSF, <u>a video laryngoscope (Glidescope) is</u> located outside the EP control room. Contact the off-site anesthesia technician if you need any additional equipment.

- **Blood products** are usually <u>not required</u>, but a blood type and antibody screen should be current.

- **Antibiotic** is <u>not indicated</u> for this percutaneous procedure.

ACCESS/FLUIDS

- At UCSF, the EP nurse will start a peripheral IV in the pre-op holding, usually 18 or 20 gauge (left arm).

- Sometimes for VT study/ablation, a RIJ sheath is placed by the proceduralist for CS cannulation.

- Additional PIV is usually not necessary. Remember that the introducer sheaths may be used for central venous access. Sometimes, when a heparin infusion is necessary (left sided ablation), the EP team would use the right IJ sheath so the EP nurse can draw ACT samples from the femoral sheath without contamination. In the absence of RIJ access, the heparin can be infused through the PIV (some anesthesia providers prefer a separate PIV).

- **Anticipated blood loss** is minimum, usually associated with initial access and flushing of the sheaths.

- **Continuous irrigation of ablation catheters (1 to 2 L total) and sheath (30 mL/hour each), may add significant volume** and may prompt diuretic use at request of the proceduralist.

MONITORS

- **Standard ASA monitors**: The EP staff will assist you in placing radiolucent ECG leads to ensure that they do not interfere with the fluoroscopic images or the rest of electrophysiology monitors. Sometimes, the anesthesia ECG leads can be connected to the mapping system directly.

- **Invasive arterial monitor** is not required; however, it can be useful and is recommended in those patients who have a history of structural heart disease, low ejection fraction and may not tolerate rapid pacing/heart rate. If an arterial (femoral) sheath is placed for left sided ablation (retrograde approach), pressure can be transduced from the sheath and monitored by anesthesia.

- **Temperature** should be monitored as the procedure can be lengthy. An axillary probe is sufficient for patients not under general anesthesia. A lower body forced air warmer is used.

- Discuss with the EP team regard the need for **urinary bladder catheter**, but is highly recommended as the procedure can be lengthy. A condom catheter may be an alternative for a male patient.

ANESTHETIC TECHNIQUES

- **Anxiolytic premedication** should not be given routinely in the holding area as most ambulating patients are expected to walk into the EP lab and sit up-right on the table while monitors and patches are placed.

- Broncho-dilator, anti-reflux medication and antacid should be given as indicated by the anesthetic technique and the patient's co-morbidities.

- Majority of catheter ablations for VT at UCSF are performed **under MAC** and is preferred by the EP team. The **anesthetic goal** is to provide analgesia during the initial painful portion of the procedure (Foley and vascular access) and to ensure both patient safety and patient cooperation thereafter that will maximize the chance for a successful study. The most stimulating portion of the study is in the beginning. Your anesthetic may range from a detailed pre-operative discussion, verbal reassurance, generous local anesthesia supplemented with minimal sedation in a motivated patient, to deep sedation in a less cooperative patient who has a reassuring airway. Common pharmacological options include: 1) **midazolam and fentanyl**; 2) **propofol** infusion with intermittent fentanyl bolus; 3) **Remifentanil** infusion (in selected population).

- **Little to no sedation is preferred** during the mapping portion of the study. With the exception of remifentanil in pediatric population, there is scant evidence on the effect of various anesthetic on the inducibility of tachyarrhythmia. Nonetheless, one tries to minimize any sedative medication as long as the patient is comfortable enough to remain cooperative. One should consider IV acetaminophen early in the procedure especially in MAC cases.

- **Vasoconstrictor or inotrope infusions may be needed** to support patients with low EF during tachycardia or rapid pacing.

- Once the initial electrophysiological study is completed the sedation may be deepened for the subsequent ablation, even GA perhaps. Always communicate with the EP team regarding the necessity or permissibility of deeper sedation.

- **Supplemental oxygen** can be provided with **nasal cannula with CO2 monitoring**. Alternatives include oral/nasal airway, simple face mask, non-rebreather, or anesthesia mask with straps to provide PEEP (it is time to reassess your "MAC").

- The **emergence** should be straight forward, which involves discontinuing the sedation and monitoring for any airway obstruction before leaving the EP lab. The EP staff will remove the sheaths, hold pressure for at least 15 minutes, and they prefer a relatively cooperative patient.

- **Recovery** of a patient after general anesthesia will be in the 4th floor PACU, while the patient who had **MAC will be recovered in the EP holding room** unless the anesthesia provider felt that a higher level of care (PACU or ICU) is necessary due to co-morbidities or intra-operative events, or if the length of recovery is expected to exceed the hours of EP staff. The patient will need to keep the legs unflexed for at least 4 to 6 hours to minimize the risk of bleeding.

KEY PROCEDURE-RELATED POINTS

- Those patients referred to tertiary medical centers such as UCSF may have had recurrent arrhythmias and prior ablations. The subsequent study/ablation procedure may be time-consuming.

- Access is primarily through sheaths placed in the femoral veins and RIJ sheath for a CS catheter, which are usually placed by the proceduralist. Local anesthetic is used even for patients under GA. This is performed by the EP fellow, usually prior to attending time out.

- Pre-procedural transthoracic echocardiogram may be necessary in patients with end stage systolic heart failure with dilated LV to rule out LV thrombus. Alternatively, TEE can be used, which has better sensitivity to detect LA thrombus.

- ****If left sided study is necessary, heparinization is required** to reduce the risk of thromboembolism from left side catheters. The anesthesia provider will be asked to give heparin boluses, while the EP staff will manage the infusion and check ACT. If transseptal puncture is performed, extreme caution should be used to avoid venous air and paradoxical embolism.

- Hemodynamic fluctuation is often seen, usually associated with induced tachycardia and pacing. While some patients may tolerate the prolonged tachycardia, many patients with structured heart diseases may not. Frequent BP measurements or invasive arterial pressure may be necessary.

- **Infusion of isoproterenol**, a non-selective beta agonist with chronotropic, dromotropic, inotropic and vasodilatory effects, is commonly used for elicit/evaluate tachyarrythmias and is administered by the EP nurse. Phenylephrine infusion may be needed to counteract the vasodiation.

POTENTIAL COMPLICATIONS

- **Arrhythmia** that is hemodynamically significant is always a risk. **Unstable VT will require defibrillation,** and a deeper plan of anesthesia is needed.

- **Vascular complications** at the access site are not uncommon and range from self-limited site hematoma to retroperitoneal bleeding requiring urgent/emergent vascular surgery interventions. Resuscitation with fluids, blood products, and vasoactive medications may be necessary.

- **Cardiac perforation** may occur due to catheter manipulation, during Trans-septal puncture or as a result of ablation. This may result in pericardial effusion, and potentially causing tamponade. This is usually indicated by persistent hemodynamic instability unrelated to the induced arrhythmia and refractory to routine vasoconstrictors and fluid. The EP team should be informed when this is suspected. Blood products should be ordered immediately. Consider reversing anticoagulation in consultation with the proceduralist. One or more of the femoral sheaths can be used for volume resuscitation. The management varies:
  - "Wait-and-watch" approach when the effusion is small and self-limiting,
  - Emergent pericardial drain placement,
  - Rapid mobilization for surgical decompression of the tamponade.

- **Stroke** is possible due to the risk of thromboembolism with left sided catheters or in patients with PFOs.

- Aortic perforation is a relatively rare complication that can occur during trans-septal puncture or retrograde catheter.

SPECIAL ERGONOMIC CONSIDERATIONS

- **Extensions** on breathing circuit, oxygen supply, IV tubing, and infusion tubing are necessary to allow the unobstructed movement of the fluoroscopy equipment. Consider consolidating and securing monitors, circuits, and tubing such that they clear the C-arm, biplane and avoid tangling. Tourniquets and blue clamps are often useful. The patient's arms will be secured, padded and tucked, limiting our access. One should consider attaching two pre-flushed infusion lines that can be used for anesthetic agents such as propofol or remifentanil, and vasoactive agents.

- **Hazards to the anesthesia provider**
  - **Equipment is in motion**
    Be aware of the c-arm when it is in motion as it can move quickly and endanger heads and shins and may snag loose wires and tubings.
  - **Ionizing radiation**
    Consider time (limiting exposure), distance (inverse square law), and shielding (both garments and barriers) when in ionizing radiation environments. Particular attention should be granted to protecting the lens of the eye, thyroid, hematopoietic centers in long bones, and reproductive organs as these are particularly sensitive to ionizing radiation. The exposure is greatest as it exits the collimator (the part below the table) in path to the image intensifier (the part above the patient). However, scatter radiation is produced as the X ray encounters items in its path (the patient). Areas on the body that are often overlooked ("weak spots") include neck, shoulder/arm pits, and back. Lead (radiation protective) garments should cover the neck to the knees and are designed to be worn when facing the source.
  - **Magnetic fields**
    At UCSF, one of the EP rooms (EP1) is equipped with the Siemens Stereotaxis NIOBE® magnetic navigation system that can be used to manipulate wires and catheters in the patient's body. The magnets are material and cannot be turned off, but the magnetic field is tempered when in the stored position. The magnetic field is not on par with the electromagnet used in MRI; however, MRI precautions are recommended.

DURATION 4 - 8 hours

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