DEVICE EMERGENCY

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هر بیشه گماه مبر که خالی است
باشد که پلنگ خفته باشد
Prevention rather than treatment
Devices

- Balloons
- Stents
- Amplatzers
- Coils
Balloons

- PS
- AS
- CoA
- Stent redilation
- Renal
- .......
Stents

- CoA
- PDA stents
- RVOT stents
- MAPCAs
- Other stenosis (SVC, PABs, ....)
Devices

- ASD
- VSD
- PDA
- MAPCA or shunt closure
- Other: (TAPVC, AVF, coronary fistulas, Malformations,.....)
Coils: (Detachable, Pushable)

- PDA
- MAPCAs
- AVF (Coronary, Gallen, .......
BALLOONS

- Rupture (Transvers, longitudinal)
- Perforation (stent)
- Air embolism (To prevent air embolism due to balloon rupture, the balloon is gently flushed with CO2 before the insertion.)
STENTS

- Bare, Covered,
- Migration (choose appropriate balloons, different techniques for prevention)
- Fracture
- Balloon perforation
ASD

Contraindications

Primum ASDs

Sinus venosus defects at the superior or inferior vena cava

Defects in the wall of the coronary sinus

Elevated pulmonary vascular resistance (>5 WU)

Pulmonary hypertension (PA pressure more than 50–70 mmHg)

associated other cardiac anomalies requiring surgical repair,

sepsis

contraindication to antiplatelet therapy

a deficient rim (<5 mm)
COMPLICATIONS/PROBLEMS ENCOUNTERED DURING ASD CLOSURE

- Device embolization/migration (<1%),

  Usually occurs in patients with a large ASD and deficient rims,

  most of these embolizations do not cause acute hemodynamic collapse (larger sheet >2 F needed to remove)

  surgical stand-by need
ASD

- Implanters must be familiar with risk factors for embolization, avoidance strategies, and retrieval techniques. Furthermore, the catheterization laboratory must be stocked with appropriate retrieval equipment including snare catheters, a variety of shaped catheters that will accommodate snares, bioptomes, and 12–18 F long sheaths.

- Cardiothoracic surgical services are available.

- Right or left atrium

- the ventricle, the aorta, or the branch pulmonary arteries.

- Obstruction of ventricular inflow or outflow

- Embolization events have been associated with Valsalva (emesis, cough), vigorous TEE probe manipulation, DC cardioversion, and cardiopulmonary resuscitation.

- Occur within 24 hours
ASD

• **Causes:**

  • Device undersizing
  • Septal rim deficiency
  • A thin, mobile septum primum
  • Septal aneurysm
  • Gross device misalignment with prolapse of the device
  • Careful echocardiographic assessment of rim capture (The inferior rim is typically the most difficult to assess.)
  • Color-flow Doppler imaging can aid in confirming rim capture.
  • Fluoroscopically, separation of the inferior device components
ASD

- Devices in the PA should be retrieved through a long sheath positioned across the pulmonary valve.
- Devices in the Ao should be retrieved through a retrograde arterial sheath.
- Devices in either the left or right ventricle should not be forcefully pulled across the mitral or tricuspid valve but should be retrieved in the ventricle or associated great artery.
- Retrieval from the great arteries is generally easier than from within a cardiac chamber.
- Frequent anticoagulation
- Device in mitral or Tricuspid corda should be removed surgical.
- Pin the device
COMPLICATIONS/PROBLEMS ENCOUNTERED DURING ASD CLOSURE

• Arrhythmia  (almost all of them resolved spontaneously)

  Supraventricular ectopy was noted in (63%) out of patients immediately after the device closure
  A complete AV block is a potential risk, but rare (<1%).
  Atrial tachycardia (most common), Beta blocker for 6-12 weeks,
  AF
  Cardioversion for prolonged arrythmia for prevention of clot
  WPW, AVRT, AVNRT
  Ventricular beat in emboli
  patients with arrhythmia symptoms prior to device implant should undergo formal rhythm assessment.
  Preexisting arrhythmia may require treatment before device implantation.

• Air emboli (prevention during dilator withdrawn)
ASD

• Cardiac erosion or perforation (0.1%)

• one in 10 erosion events are fatal

Which all occurred at the dome of the atria, near the aortic root.

The risks for erosions may be seen in patients with deficient rims or the use of oversized ASO. Most (66.6%) of the cardiac perforations occurred after a patient’s discharge.

Cardiac tamponade due to hemopericardium was present in 68 cases (70%) at the time of presentation.

Majority of erosions (57%) occurred <72 h after implant.
ASD

- An implanted device diameter >150% of the largest native (not balloon sized) ASD diameter as measured by echocardiography in any view.

- Device oversizing and aortic rim deficiency (< 5mm) independently, and in combination, increase erosion risk

- As 75% of erosion cases involved devices larger than 18 mm.

- devices <18 mm are formed from a 0.004 inch nitinol wire,

- devices of 18 mm and larger are formed from a 0.006 inch wire

- and devices of 26 mm and larger are formed from a 0.0075 inch wire.
COMPLICATIONS/PROBLEMS ENCOUNTERED DURING ASD CLOSURE

• Cobra-head formation,

The left disk maintains a high profile when deployed, mimicking a cobra head.

This can occur:

if the left disk is opened in the pulmonary vein

or the left atrial appendage,

or if the left atrium is too small to accommodate the device size.

If this occurs, check the site of deployment; if appropriate, recapture the device, remove it, and inspect it.
Complications/problems encountered during ASD closure
COMPLICATIONS/PROBLEMS ENCOUNTERED DURING ASD CLOSURE

- Malpositioned device
- Clot formation
  
  ASA 3 days before procedure
  
  monitoring during the procedure by echo
  
  ACT >225-250 s
  
  Frequent flushing the system
  
  Use other anticoagulant for 3 m in older patients
  
  TR, MR and antiproliferative drugs need prolong anticoagulant
- Groin complications
ASD

• Pulmonary edema

• Transcatheter ASD closure in patients with left ventricular diastolic dysfunction most commonly patients >60 years of age—can result in acute pulmonary edema and the need for emergent intubation and anticongestive therapy.

• Elimination of the atrial “pop-off” causes a sudden increase in LV preload, a rise in LA pressure, and the development of acute pulmonary edema.

• Balloon occlusion and pressure monitoring if LVEDP > 25 mmHg or increased >10 mmHg consideration should be given
VSD

• The commonly accepted indications for transcatheter VSD closure include:

• Clinical signs and symptoms:
  • Congestive heart failure, Failure to thrive, Recurrent respiratory tract infections, Shock or respiratory failure
  • Hemodynamically significant shunt (Qp:Qs > 1.5) measured by
  • Echocardiography, MRI, Cardiac catheterization
  • Evidence of left-side chamber by
  • Echocardiography, MRI
  • History of previous infective endocarditis
Immediate complications include

1. Embolization
2. Rhythm disturbances
3. Residual shunt
4. Hemolysis
5. Thromboembolism
6. Endocarditis
VSD

Device embolization/migration

The device can migrate to the LV, aorta, RV, or PA

Device embolization is not a common complication. (1%)

The device can be snared and retrieved percutaneously; however, a larger sheath may be needed.

The presence of a cardiovascular surgeon in house is essential for device closure of muscular VSD.
VSD

- **Arrhythmia:** Ventricular arrhythmia may be encountered during catheter manipulations and device deployment, which is usually benign and transient.

- **Conduction disturbances** can be seen and CHB is rare.

- **Air embolization:** A meticulous technique of catheter and wire exchanges can minimize this complication. It is important to let the sheath bleed back freely once it has entered the left-sided circulation.
VSD

• **Hemolysis:**
  - This complication is rare and usually associated with residual shunting.
  - You can preferably presoak the device with the patient’s own blood for about 15–20 min; this technique can reduce residual shunt and improve immediate complete closure.

• **Valvular regurgitation:**
  - Tricuspid, mitral, or aortic regurgitation may occur due to the impingement of the device on the valvular apparatus or subaortic septum.
  - Echocardiographic assessment of the valvular regurgitation prior to closure and prior to device release is extremely important.
  - If the device does appear to be entangled in the subvalvular apparatus, may be successful try in recapturing the device and repositioning it.

• **Pericardial effusion:** This is very rare complication that may result from catheter irritation or minute wire perforation during the procedure.
  - There have been no cases of tamponade or delayed pericardial effusion after 24 h.
VSD

Closure of PMVSD using PFM coil

- There were no serious complications and there was no mortality or major morbidity.
- Embolization rare
- Hemolysis
- CHB
I - Small infants with large PDA:

The indication to close a PDA in small infants is the presence of significant “cardiac failure” symptoms and failure to thrive due to a relatively large ductus.

Procedure need passing a large sheet in small heart.

As noted above, in these symptomatic infants, a relatively large device is often required, usually 8/6 mm or 10/8 mm.

Newer device reduced (ADOII, Picolo) these complications. (pressure on aortic wall and tension on vascular structures, or LPA stenosis, Arrhythmia) because of smaller sheets.
PDA
2. Undersizing and embolization to PA

Embolization of the ADO is rare. In the typical PDA morphology, this may be due to undersizing the device or positioning the device too deep within the ductus before its release.

When the device is pulled too deep, which may be partly due to undersizing, a “bump” caused by the retention disk is seen on the top part of the PDA. Although complete occlusion is achieved in the laboratory, the device may embolize later probably due to the “milking” action of the ductal wall.
PDA

3- Long tubular PDAs.

- May or may not have a constriction at the site of pulmonary insertion.
- ADO > is relatively short (7 or 8 mm) and only has one retention disk.

- USE:
  1- long devices
  2- AMVO (Amplatzer Muscular VSD Occluder)
  3- ASO (ASD devices)
  4- ADO II.
  5- Amplatzer vascular plugs (II and IV) in smaller infants
PDA

4- Large PDA in adults.

• May be Large and long PDA and ADO may be embolized or stents the duct and have a residual shunt.
• Use devices with 2 retention disks
PDA

• Large PDA with advanced pulmonary vascular disease

• The PDA may not be apparent on clinical and echo examination, and only diagnosed at cardiac catheterization in the course of an evaluation of a patient with pulmonary hypertension.

• with PA/Ao pressure ratio >0.8 and Qp:Qs <1.5:1.

• Surgical ligation is usually considered inappropriate.

• Use vasodilator for 6 m

• Subject to an observed fall in pulmonary vascular resistance

• Use ASO or an AMVO, where the device is deployed but not released.

• Stressed with dobutamine to achieve maximum heart rate while observing the hemodynamics (ABG & hemodynamic)

• Transfer to ICU and device not release. (immobile under full sedation)

• Release the device in stable patients and keep on Sildenafil
AS (NEONATES)

- Procedure-related mortality occurs in 3.0–4.5% of the patients.
- Acute moderate or severe aortic regurgitation has been reported in 15–30% of neonates following balloon dilatation.
- The use of balloon/annulus ratios larger than 0.9:1.0 increase the risk of aortic regurgitation.
- Interestingly, the antegrade approach has been associated with a lower incidence of aortic regurgitation.
- Femoral art. access in neonates is associated with arterial injury and pulse loss in 30–45% of procedures.
- However, the risk of serious vascular injury resulting in vascular surgery or long-term sequelae such as growth retardation of the affected extremity is low. (subcutaneous enoxaparin (1 mg/ kg/dose) twice daily.)
- If the extremity perfusion improves and pulses return within 12 hours, enoxaparin is discontinued. Otherwise, an arterial Doppler ultrasound of the affected extremity is performed and a 10-day course of enoxaparin is completed.
Aortic wall injury due to creation of an intimal flap has recently been described in 15% of neonates undergoing aortic balloon valvuloplasty via the retrograde approach as an often unrecognized and potentially lethal complication. The most common locations are the distal ascending aorta and transverse arch.

- Left ventricular wall or aortic valve cusp perforation,
- Arrhythmias including complete atrioventricular block,
- Mitral valve injury,
PS & PA

- Balloon/annulus ratio of 1.2–1.25 instead of 1.2–1.4.
- 20-mm-long balloons in neonates and infants,
- 30-mm-long balloons in children
- and 40- or 50-mm-long balloons in adolescents and adults.
PS & PA

Acute complications

Transient bradycardia,

Premature beats,

Atrial Tachycardia

and a fall in systemic pressure during balloon inflation
PS & PA

- Blood loss requiring transfusion
- Complete right bundle branch block,
- transient or permanent heart block,
- cerebrovascular accident,
- loss of consciousness,
- cardiac arrest,
- convulsions,
- balloon rupture at high balloon-inflation pressures,
- rupture of tricuspid valve papillary muscle,
- and pulmonary artery tears,
- Transient prolongation of the QTc
- and development of premature ventricular contractions
- Tamponade following perforation into the pericardial space (most operators replace the aspirated blood by autotransfusion)
PS & PA

- Use of appropriate diameter and length of the balloon,
- Avoiding high balloon-inflation pressures,
- And short inflation/deflation cycles may prevent or reduce the complications
The major immediate complication of balloon angioplasty is vascular damage or even disruption.

Disruption of the inner layers of the vessel, however, may result in the formation of vascular flaps that can cause severe stenosis or occlusions.

The balloon can be maintained with low-pressure inflation for at least 3–5 min and a repeat angiogram can be performed to see if the curtain reforms.

If the intimal flap persists, placement of a stent may be necessary.

Extension of the vascular disruption past the media may result in extreme thinning of the remaining circumference of the vessel.

An aneurysm is frequently seen in this circumstance.

Any aneurysm seen immediately after angioplasty should be reevaluated after 5–30 min to be certain that the aneurysm is not enlarging.

If an aneurysm is enlarging rapidly or if there is disruption, the balloon catheter should be immediately reinflated at or slightly proximal to the region of previous stenosis.

Tamponading the affected vessel will reduce the chance of an urgent catastrophe.

Aneurysms that remain stable during the procedure still require follow-up evaluation by repeat catheterization or CT/MRI.
BALLOON DILATION OF COA

Mortality: 0.7% for dilation of native coarctation and 2.5% for recoarctation.

Aortic wall damage: Aortic rupture is the most serious complication, with an incidence of 0–2%. Balloon diameters greater than three times the coarctation diameter produced vascular tears and mediastinal hemorrhage.

Cystic medial necrosis: is present in the aortic wall of patients with coarctation. It is more frequent in older patients, in whom there is a higher incidence of wall thinning, marked tortuous segments, and calcification.

Aneurysm formation: Most patients with small are managed conservatively, but larger aneurysms are usually referred for surgery or covered stent implantation.
Balloons Dilatation of COA

- **Femoral artery injury**: was reported in 2–10% of children. The use of low-profile balloons and arterial access through small introducers has significantly reduced this complication.

- **Paradoxical hypertension**: occurrence of less than 1.5%, in contrast with surgical patients with a reported incidence of 25–36%.

- **Persistent systemic hypertension**: was found at late follow-up in 15–50% of patients without residual stenosis after dilation of aortic coarctation. Systemic hypertension was also documented in 10–33% of patients after effective stent implantation and in 25–72% after surgery.

- **Cerebrovascular accidents**: have been reported in less than 2% of patients and are usually secondary to thromboembolic events.
STENTING OF COA
COMPLICATIONS OF STENTING

• Femoral artery disruption or thrombosis,

• **Stent migration at implantation (5%):** may be dealt with by implanting and dilating the stent in an alternative safe location

• Delayed stent migration,

• **Acute aortic rupture:** this can be managed conservatively, if small or by implanting a bare or a covered stent, if large. If aortic rupture occurs, then availability of covered stents, which can be rapidly inserted percutaneously, can save the day and avoid the need for emergency surgery.
COMPLICATIONS OF STENTING

- Paradoxical hypertension (aggressive medical treatment)
- Thrombotic occlusion of the stent (local thrombolysis)
- Endocarditis
- Deaths from stenting of aortic coarctation are rare (0–1.4%)
- Embolic strokes may occur in 0–3.7% of patients
COMPLICATIONS OF STENTING

• Aneurysm formation (bare stents) : Predilation may be a risk factor for subsequent aneurysm formation. The occurrence of an aneurysm can also be treated similarly.
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<th>Procedure type</th>
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<th>Risk category 2</th>
<th>Risk category 3</th>
<th>Risk category 4</th>
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<td>Diagnostic</td>
<td>Age &gt;1 year</td>
<td>Age &gt;1 month and &lt;1 year</td>
<td>Age &lt;1 month</td>
<td>Aortic valve, age &lt;1 month</td>
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<td>Balloon valvuloplasty</td>
<td>Pulmonary valve, age &gt;1 month</td>
<td>Aortic valve, age &gt;1 month</td>
<td>Pulmonary artery, &gt;4 vessels</td>
<td>Pulmonary vein</td>
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<td>Balloon angioplasty</td>
<td>Aorta &lt;8 atm RVOT</td>
<td>Pulmonary artery, &lt;4 vessels</td>
<td>Pulmonary artery, &gt;4 vessels, &lt;8 atm</td>
<td>Systemic artery, vein, surgical shunt, or AP collateral</td>
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<tr>
<td>Stent placement</td>
<td>Systemic vein</td>
<td>Aorta RVOT</td>
<td>Systemic artery</td>
<td>Pulmonary artery</td>
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<tr>
<td>Stent redilatation</td>
<td>Aorta Atrial septum RVOT</td>
<td>Pulmonary artery</td>
<td>Pulmonary vein</td>
<td>Pulmonary vein</td>
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<td>Device or coil closure</td>
<td>L-SVC Venous collateral</td>
<td>ASD or PFO PDA</td>
<td>Coronary fistula</td>
<td>Perivalvular leak</td>
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<td>Other</td>
<td>Myocardial biopsy Foreign body retrieval, snare Transseptal procedure</td>
<td>Recanalization of occluded or jailed vessel</td>
<td>Balloon atrial septostomy</td>
<td>Atrial septum dilation and stent</td>
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<td>Atretic valve perforation</td>
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<td>Cath &lt;4 days after surgery</td>
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<td>Major complications</td>
<td>How to avoid</td>
<td>How to treat</td>
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<tr>
<td>Access related</td>
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<td>Bleeding</td>
<td>Appropriate pressure, pressure dressing for appropriate time, bed rest for 6 h after arterial puncture.</td>
<td>Hold manual pressure for 10–20 min, apply appropriate pressure dressing, bed rest. Early detection, compress hematoma for 10 min to allow for it to diffuse. Replace pressure dressing, bed rest. Leeches may be used to relieve compartment syndrome.</td>
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<td>Hematoma</td>
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<td>Subcutaneous bleed (third space accumulation)</td>
<td>Identify cases in which puncture site of the vessel not the skin was high and hold above the inguinal ligament as well in those cases.</td>
<td>Early detection with CT scan if suspected. Observe for signs of deterioration. NPO. Vascular repair and evacuation if necessary. If pulse is not felt, start therapeutic heparin for 24 h. If no resolution in 24 h, then do ultrasound and give low-dose tPA. 0.05 μg/kg/h for the first hour as a test dose 0.1 μg/kg/h for 4–6 more hours. Stop before if pulses are felt and start therapeutic heparin. Keep heparin for 24 h after pulse is regained. May repeat 12 h later after checking fibrinogen. Do not allow fibrinogen to drop below 150 mg/dL.* Pressure and observation. May need to have surgery (may be difficult due to patient size).</td>
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<td>Retroperitoneal hematoma</td>
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<td>Thrombosis</td>
<td>Lidocaine subcutaneous around arterial sheath to relax the vessel. Allow sheath to bleed back briefly prior to removal. Appropriate pressure to the vessel (not too hard), feel pulse in the foot while compressing. Pressure dressing for &lt;3 h for patients less than 2 years of age. Start low-dose heparin 10 μg/kg/h without checking PT/PTT if foot is cool and pulse is felt.</td>
<td>Early detection with Doppler signal to palpate. Ultrasound and Doppler guided compression or thrombin injection.</td>
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<td>Vessel tear</td>
<td>Avoid deep skin cut with scalpel. Avoid wire mismatch. Do not use force. Dilate up the vessel using smaller-diameter dilator if needed prior to insertion of the sheath. Take out sheath slowly. If sheath feels tight, give lidocaine subcutaneous first and very slowly with slow steady pull in increments remove the sheath. Do not use force.</td>
<td>Early detection. Try compression &quot;flattening the pseudoaneurysm&quot; while barely feeling the pulse. Ultrasound with Doppler if &gt;1 cm would try ultrasound-guided compression or thrombin injection. Early detection. Local prolonged compression. Ultrasound localization of the fistula with selective compression at the exact connection between the vessels.</td>
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<tr>
<td>Pseudoaneurysm</td>
<td>Avoid posterior vessel puncture (obtain access on the way in). Appropriate pressure during sheath removal. Use more caution when patient is on aspirin and plavix or has vascular.</td>
<td>Early detection. Try compression &quot;flattening the pseudoaneurysm&quot; while barely feeling the pulse. Ultrasound with Doppler if &gt;1 cm would try ultrasound-guided compression or thrombin injection. Early detection. Local prolonged compression. Ultrasound localization of the fistula with selective compression at the exact connection between the vessels.</td>
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<td>AV fistula</td>
<td>Avoid through and through access of artery and vein. Avoid puncturing the vein and artery in close proximity. Avoid prolonged access of artery and vein on the same side. Appropriate pressure during sheath removal.</td>
<td>Early detection. Try compression &quot;flattening the pseudoaneurysm&quot; while barely feeling the pulse. Ultrasound with Doppler if &gt;1 cm would try ultrasound-guided compression or thrombin injection. Early detection. Local prolonged compression. Ultrasound localization of the fistula with selective compression at the exact connection between the vessels.</td>
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<td>Anesthesia related</td>
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<td>Airway obstruction</td>
<td>Monitor saturation and end-tidal CO₂ and proper management of ETT with suction</td>
<td>Reintubation, tube reposition, positive pressure ventilation.</td>
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<td>Acidosis</td>
<td>Follow arterial blood pressure during the procedure.</td>
<td>Sodium bicarbonate, hyperventilation.</td>
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<tr>
<td>Hypoxia</td>
<td>Monitor saturation and proper management of ETT with suction, and so on</td>
<td>Oxygen, airway management.</td>
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<tr>
<td>Low cardiac output</td>
<td>Avoid sedation or anesthetics that cause myocardial depression and peripheral vasodilatation.</td>
<td>Inotrope support (dopamine, milrinone, epinephrine).</td>
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<tr>
<td>Hypothermia (low COP/acidosis)</td>
<td>Heating pad. Temperature probe. Warm flush if possible.</td>
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<tr>
<td>Major complications</td>
<td>How to avoid</td>
<td>How to treat</td>
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<td>Malignant hyperthermia</td>
<td>Autonomic dominate disorder. Reaction to halothane and succinyl choline with hyperthermia and rigidity.</td>
<td>Dantrium (start at 1 mg/kg and increase to 10 mg/kg).</td>
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<td>Peripheral nerve injury (brachial plexus)</td>
<td>Proper arm positioning. Avoid overextension or abduction of the arms.</td>
<td>Usually reversible.</td>
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<td>Infection</td>
<td>Sterile conditions should be followed. Antibiotic prophylaxis for 24 h with device/stent placement or prolonged procedures. Fever that starts after or lasts beyond 12 h should be worked up. Patients that are in the ICU prior to cath are at higher risk.</td>
<td>Early recognition. 3–5 blood cultures are drawn and antibiotics started pending cultures. Implanted device may need to be removed in resistant cases.</td>
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<td>CNS complications</td>
<td>Air embolus</td>
<td>Fluid-filled catheter. Passive bleed back of the sheath (air can be trapped in the hub). Do not aspirate when wire is in the sheath. CO₂ should be used in balloon catheters not air. Injector pointing down during injection.</td>
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<td>Thrombus, stroke</td>
<td>Heparin 100 µg/kg/h. Keep ACT at 230–280, check hourly. Flush long sheaths frequently. Hydrate especially with polyethylene.</td>
<td>If air is collected in a chamber, then direction of the catheter to this area with suction of the air can be performed. If it has dispersed, then there is not much you can do at this point.</td>
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<td>Wire perforation of vessels</td>
<td>Do not place wire in the carotid. Monitor wire in the jugular vein.</td>
<td>Therapeutic heparin and possibly tPA.</td>
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<tr>
<td>General hemodynamic complications</td>
<td>Pulmonary edema</td>
<td>Monitor IV fluid and contrast given.</td>
<td>Diurese.</td>
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<td>Pulmonary hemorhage</td>
<td>Avoid implanting large stents to severely stenotic pulmonary vessels. Gentle manipulation of wires, catheters, and sheaths in branch pulmonary arteries.</td>
<td>Increase PEEP, prolonged ventilation, transfusion.</td>
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<td>Pulmonary hypertensive crisis</td>
<td>Anticipate patients with reactive pulmonary bed and elevated PVR.</td>
<td>Oxygen, diuresis, iNO readily available.</td>
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<td>Hypotension</td>
<td>Avoid procedures that cause prolonged mitral or tricuspid regurgitation.</td>
<td>NS, LR, packed red blood cells, dopamine, epinephrine.</td>
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<td>Cardiac arrest</td>
<td>Use light sedation or anxiolytic prior to procedure.</td>
<td>CPR.</td>
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<tr>
<td>Angiography complication</td>
<td>Myocardial stain</td>
<td>Large catheter with multiple holes. Test injection. Lower pressure for intracavitary injections.</td>
<td>Antihistaminic (benadryl 1–1.5 mg/kg), steroids (decadron 0.5 mg/kg), epinephrine (0.1 mg/kg), IV fluids and manage bronchospasm.</td>
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<td></td>
<td>Allergic reaction (hypotension, bronchospasm)</td>
<td>Awareness of the possibility. Premedication in suspected or known cases of allergy.</td>
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<td>Condition</td>
<td>Recommendation</td>
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<td>Renal toxicity/CNS toxicity</td>
<td>Caution in valuable/predisposed cases. Avoid too much contrast in a short time. Maximum contrast for ionic 4 mg/kg for non-ionic 8-10 mg/kg. With larger doses, give a dose of lax (0.5 mg) and IV fluid. Fenoldopam before and after the cath (0.03-0.1 mcg/kg/min). IV fluid and diuretics. Hemodialysis.</td>
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<td>Electricity</td>
<td>Asystole: Echo for EF, avoid hypoxia, avoid prolonged iatrogenic AV valve regurgitation, obtain blood gas frequently, careful coronary angiography/intervention. Atropine, isoproterenol, epinephrine, pacing, CPR.</td>
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<td>Bradycardia: Careful device selection and positioning with ASD or VSD closure. Pacing, atropine, isoproterenol, CPR.</td>
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<td>AV block: Awareness of underlying CHD: ccTGA, DILV, AVSD, heterotaxy. Careful device selection and positioning with ASD or VSD closure.</td>
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<td>Atrial flutter: Review of medications. Digiex, sotalol, DC cardioversion.</td>
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<td>Ventricular tachycardia: Lidocaine, amiodarone.</td>
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<td>Ventricular fibrillation: Defibrillation.</td>
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<td>Pacemaker or ICD malfunction: Awareness of programming, device interrogation within 30 days of the procedure. Programmer and magnet in cath lab.</td>
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<td>Balloon atrial septostomy</td>
<td>Balloon rupture/air embolism: Ensure that balloon is deflated. Controlled jerk of the catheter and avoid follow through.</td>
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<td>Injury to mitral valve, pulmonary vein, or IVC: Have a clear understanding of where the catheter is. May use echo guidance to better visualize mitral valve and pulmonary vein. Catastrophic event (prevention is the only therapy).</td>
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<td>Tricuspid valve injury: Cross the valve with a balloon wedge when possible. Use a short balloon (infants 2 cm, older children 3 cm). Damage is done, surgical correction if severe or hemodynamically significant.</td>
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<td>RVOT perforation: Cross with a soft floppy tipped wire (e.g., Wholly wire). For tight stenosis, use JR catheter to direct the wire away from RVOT. Early recognition of wrong wire position prior to introducing the catheter or balloon. Withdraw wire and tap effusion. If not controlled, it is a surgical emergency.</td>
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<td>Aortic valve balloon</td>
<td>Aortic regurgitation: Avoid valve perforation with use of floppy tipped wire. Adequate wire position. Avoid over dilation. Be happy with some residual stenosis and minimal or no regurgitation. Avoid dilation of mild aortic regurgitation with no LVH. Mild to moderate regurgitation is well tolerated in hypertrophied ventricle. May need ECMO or urgent surgery of not tolerated.</td>
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<td>Stunned ventricle: Recognition of this rare association and do not dilate the valve. Surgical emergency. Likely needs ECMO.</td>
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<td>&quot;Hooded coronary&quot; with ischemia postdilatation: Inotropic support prior to dilation.</td>
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<tr>
<td>Major complications</td>
<td>How to avoid</td>
<td>How to treat</td>
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<td>Pulmonary artery</td>
<td>Wire perforation of distal vessel/pulmonary hemorrhage or</td>
<td>Use appropriate wire with a soft tip and avoid inadvertently pushing the wire in.</td>
<td>Usually self-limited. Tape pleural effusion. Pull wire slightly out of the opening, but still in the vessel. May need to tamponade with a balloon.</td>
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<tr>
<td>balloon</td>
<td>hemorrhage or hemoptysis</td>
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<tr>
<td>Vessel rupture</td>
<td>Avoid overdilation. For postoperative &gt;6 months can go up to 50% of normal vessel. For congenital stenosis use only 10% more than normal vessel. For fresh postsurgical cases, dilation should only be done within the first 2 weeks or after the first 6–8 weeks (sutures are still intact in the first 2 weeks, healing occurs at 6–8 weeks).</td>
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<td>Do not lose wire position. Tamponade with the same balloon. Covered stent if available.</td>
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<tr>
<td>Balloon rupture and loss of fragments</td>
<td>Do not exceed burst atmospheres for balloon. Beware of calcification.</td>
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<tr>
<td>Pulmonary artery</td>
<td>Balloon rupture with incomplete inflation of the stent</td>
<td>Avoid Palmaz stents with sharp edges. Use BIB balloon or balloon shorter than the stent.</td>
<td>Forceful injection of saline rather than contrast. Use pressure injector to inject 50% more than filling volume of the balloon. Be prepared to deal with a torn balloon as above.</td>
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<td>stent</td>
<td>Slippage of the stent over the balloon</td>
<td>Cover the stent as it passes through the hub of the sheath. Do not extrude the stent from the sheath if the marks are not centered.</td>
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<td>Coronary compression</td>
<td>Beware of the proximity of the RCA to the origin of the LPA in TOF and variants. Test the vessel with balloon only and injection of the aortic root prior to placement of the stent.</td>
<td>Place a wire in the coronary to prop it open. Chest compression may flatten the stent some. Consider coronary stent placement. Alert the operating room.</td>
<td>Surgical removal of the stent if significant compression.</td>
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<tr>
<td>Bronchial compression</td>
<td>Beware of the proximity of the left bronchus to the LPA when the geometry of the region has been altered by an arch repair as in Norwood. Consider CT scan prior to intervention to better understand their relationship.</td>
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<td>Reperfusion injury</td>
<td>Avoid complete relief of the stenosis if very tight (stage it). Distribute the wealth and dilate various segments especially with high PA pressure.</td>
<td>Medical management with mechanical ventilation and diuretics usually suffices.</td>
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<td>Coarctation balloon/stent</td>
<td>Do not exceed the size of the smallest adjacent normal aorta or more than 3x the stenotic segment. Superstiff wire with a long floppy tip. Wire in the subclavian artery. Shortest balloon possible. Use BIB balloon when possible.</td>
<td>Place a stent, preferably a covered one.</td>
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<tr>
<td>Vessel rupture</td>
<td></td>
<td>Inflate the balloon to tamponade the vessel. Place a covered stent. Surgical emergency if not controlled. Covered stent or surgical correction.</td>
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<tr>
<td>Aortic aneurysm</td>
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*Consider CT scan prior to intervention to better understand their relationship.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Treatment</th>
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<tbody>
<tr>
<td>Exaggerated vagal response</td>
<td>IV hydration for 24 h after the procedure.</td>
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<tr>
<td>Pericardial tamponade</td>
<td>Avoid stiff wires. Gentle catheter manipulation.</td>
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<tr>
<td>Residual leak/hemolysis</td>
<td>Do not leave the lab with a residual jet.</td>
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<td>Embolization (especially with coils)</td>
<td>Use appropriate coil or device for the shape and size of the PDA. Avoid free-hand delivery of coils in larger PDAs. Avoid undersizing of the device (PDA may distensible), balloon size if not sure.</td>
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<tr>
<td>ASD closure</td>
<td>Appropriate sizing and visualization prior to release.</td>
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<tr>
<td>Erosion</td>
<td>Avoid over- or undersizing. True cause unknown. Make family aware as it can happen up to many months to 2 years after the procedure.</td>
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<tr>
<td>Heart block</td>
<td>Avoid oversizing of the device. Be cautious with an absent inferior rim.</td>
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<tr>
<td>Coronary fistula</td>
<td>Adequate assessment of branches with a balloon angio catheter if needed.</td>
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<td>Ischemia due to occlusion of important side branches</td>
<td>Gentle handling of the vessel, avoid roughing it back, place on anticoagulation, even Coumadin in large fistulae.</td>
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<tr>
<td>Thrombosis of dilated coronary artery after closure</td>
<td>Tap effusion and autotransfuse. Surgical emergency if not controlled.</td>
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<tr>
<td>Endomyocardial biopsy</td>
<td>Take biopsy from interventricular septum or the apex. Avoid biting from the same site.</td>
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<tr>
<td>Cardiac perforation</td>
<td>Use a long sheath with a curve. Use a balloon wedge catheter to position the long sheath. RV angiogram prior to biopsy.</td>
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<tr>
<td>TV injury</td>
<td>Early detection and echo confirmation. Tap effusion and if needed autotransfuse.</td>
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<td>IV fluid. Try to closure residual leak. Surgery.</td>
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<td>Snare the embolized coil or device.</td>
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<td>Snare if in an appropriate site. Surgery may be preferred to avoid injury of valves.</td>
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<td>Surgical emergency.</td>
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<td>Change to a smaller device if still in the lab. Steroids and observation. Remove device if not reversed.</td>
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