

# NEUROLOGIC COMPLICATIONS OF CARDIAC SURGERIES AND PROCEDURES

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## Clinical Findings and Mechanisms

### 1. CABG

- a. Signs and symptoms can be divided into (1) cerebrovascular events, (2) encephalopathy or coma, (3) early or delayed cognitive impairment (4) peripheral nervous system injury, and (5) other neurologic events (Table 1).
- b. Table 1: Etiologies and Potential Mechanisms of Neurologic Complications Following CABG

Ischemic infarction of the brain or spinal cord	Thromboembolism, air embolism, atherosclerosis, vasospasm, vessel trauma, hypotension, underlying coagulopathy or factors related to use of IABP
Hemorrhagic stroke	Mechanism unknown
Pituitary apoplexy	Proposed mechanisms include: factors related to the extracorporeal bypass apparatus, anticoagulation, low cerebral blood flow, anesthetic agents or presence of subclinical pituitary tumor
Seizure	Medication toxicity, cerebral thromboembolism, cerebral air embolism
Hypoxic-ischemic encephalopathy (HIE)	Acute low cardiac output, hypotension, shock, hypoglycemia
Encephalopathy	Sedatives, analgesics, showers of microemboli
Delayed cognitive dysfunction	Mechanism unknown
Visual loss	Optic nerve ischemia, retinal artery embolism
Subclavian steal syndrome	Atherosclerotic disease of the proximal subclavian artery
Horner syndrome	Injury to the cervical sympathetic chain
Brachial plexopathy	Stretching, direct trauma or compression
Phrenic nerve injury	Stretching, direct trauma, ischemia or topical hypothermia
Ulnar nerve injury	Compression
Recurrent laryngeal nerve injury	Stretching, direct trauma or hypothermia
Saphenous nerve injury	Direct trauma
Common peroneal nerve injury	Ischemia due to stretching or compression

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### 2. Cardiac Catheterization and PCI

- a. Signs and symptoms can be divided into (1) ischemic and hemorrhagic cerebrovascular events, (2) global cerebral anoxic ischemic insults, (3) seizures, (4) transient global amnesia, (5) peripheral nervous system injury including brachial plexopathy, peripheral mononeuropathies, complex regional pain syndrome (CRPS), and (6) cortical blindness (Table 2).
- b. Table 2: Etiologies and Potential Mechanisms of Neurologic Complications Following Cardiac Catheterization and PCI

Ischemic stroke	Thromboembolism, air embolism, atherosclerosis, vasospasm, vessel trauma, hypotension
Hemorrhagic stroke	Pharmacotherapy, vessel trauma, catecholamine surge
Seizure	Ischemic infarction, subdural hemorrhage, air embolism, contrast administration
Cortical blindness	Contrast
Hypoxic-ischemic encephalopathy	Acute low cardiac output, hypotension, shock, hypoglycemia
Transient global amnesia	Mechanism unknown
Brachial plexus injury	Direct compression, or hematoma or pseudoaneurysm formation with axillary angiography
Median nerve injury	Direct injury, hematoma formation
Lateral femoral cutaneous nerve injury	Trauma
Femoral nerve injury	Direct injury, compression by groin hematoma, arteriovenous fistula or pseudoaneurysm, superficial or common femoral artery occlusion
Complex regional pain syndrome	With transradial approach

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### 3. Valvular Surgery

- a. Complications include (1) both ischemic and hemorrhagic strokes, (2) seizures, (3) coma, (4) cognitive dysfunction, (5) migraine-like phenomena, (6) brachial plexopathy and peripheral mononeuropathies (Table 3).
- b. Table 3: Etiologies and Potential Mechanisms of Neurologic Complications Following Valvular Surgery

Ischemic stroke	Intraoperative	Postoperative
	Atherosclerotic emboli Hypoperfusion Air embolism Fat embolism Vessel clamping	Valve thrombosis Left-atrial thrombi Septic emboli
Intracranial and spinal hemorrhage	Anticoagulation	
Seizure	Cerebral air embolism	
Coma	Cerebral air embolism	
Cognitive dysfunction	Possibly due to showers of microemboli to the bilateral subcortical white matter.	
Migraine-like phenomena	Mechanism unknown	
Brachial plexopathy	Stretching, direct trauma or compression	
Peripheral nerve injury (see above with CABG)	Stretching, direct trauma or compression	

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4. Patent Foramen Ovale/Atrial Septal Aneurysm Surgery
  - a. Rarely transient ischemic attacks occur following percutaneous PFO closure
5. Surgery for Cardiac Tumors
  - a. Complications include (1) ischemic or hemorrhagic stroke, (2) delayed intracerebral or subarachnoid hemorrhage, or rarely (3) ischemic oculopathy
  - b. Pathophysiology
    - i. Myxomas account for 40% to 50% of primary cardiac tumors, and they typically arise from left-sided cardiac structures, predominantly the left atrium.
    - ii. Ischemic and hemorrhagic strokes may occur in the peri-procedural period as a result of embolism of myxomatous material or thrombus.
    - iii. Intracerebral or subarachnoid hemorrhage may develop in a delayed manner as a result of tumor recurrence after embolization, aneurysm formation and rupture or parenchymal metastasis
6. Mechanical Circulatory Devices
  - a. Signs and symptoms may be divided into (1) cerebrovascular events including ischemic stroke, HIE, transient ischemic attack (TIA) and intracranial hemorrhage, (2) seizures, (3) delirium, (4) visual loss, (5) hearing loss, (6) neuropsychological deficits, and (7) peripheral neurologic deficits (Table 4).
  - b. Table 4: Etiologies and Potential Mechanisms of Neurologic Complications Following Implantation of Mechanical Circulatory Devices

IABP		
	Ischemic stroke and TIA	Cerebral air embolism due to IABP rupture Thromboembolism
	Hemorrhagic stroke	Anticoagulation
	Neurological deficits in one or both legs ranging from foot drop to complete paralysis	Obstruction to blood flow, or thromboembolism in the femoral artery
Ventricular assist devices	Ischemic stroke	Thromboembolism
	Seizure	Secondary to stroke
	Delirium	Multifactorial
	Sciatic nerve injury	Compression due to posterior compartment syndrome of the thigh
ECMO		
	Ischemic stroke	Thromboembolism, air embolism, ligation of the carotid artery and internal jugular vein
	Hemorrhagic stroke	Anticoagulation, thrombocytopenia, systolic hypertension
	Hypoxic-ischemic encephalopathy	Changes in cerebral blood flow and arterial oxygen pressure
	Seizure	Mechanism unclear
	Sensorineural hearing loss	Mechanism unclear
	Visual loss	Anterior ischemic optic neuropathy
	Neuropsychological deficits	Mechanism unclear, probably related to hypoxia
	ICU acquired weakness	Microvascular, electrical, metabolic, and bioenergetic alterations to nerve and muscle

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7. Atrial Ablation
  - a. Signs and symptoms can be divided into (1) cerebrovascular events, (2) neuropsychological dysfunction, and (3) a combination of seizures, fever and stroke symptoms

- b. Pathophysiology
  - i. Thromboembolic events are rare and mostly occur within the 1st 48 hours
  - ii. Subtle, global, neuropsychological dysfunction may occur but data is mixed
  - iii. The constellation of symptoms including seizures, fevers and stroke symptoms should prompt an expedited search for atrio-esophageal fistula, a rare complication which allows air and food emboli to reach the brain

## Natural History

1. Stroke
  - a. Outcomes are affected by the underlying pathology, the type of procedure, the experience of the surgeon, differences in the surgery itself, and whether anticoagulation is used.
  - b. Extensive follow-up data is not available for outcomes of patients with ischemic stroke following cardiac surgery however favorable recoveries can be expected in the majority of cases, with only a minority dying from cerebral edema or withdrawal of care in the acute period following stroke.
    - i. ECMO is an exception, in which of patients who experienced neurological events, 59% die while on ECMO or within 7 days of discontinuation of ECMO
2. Seizures
  - a. Seizures following cardiac surgery are typically self limiting or easily controlled with benzodiazepines.
  - b. Rarely, status epilepticus has been reported with associated findings of diffuse cerebral edema on neuroimaging
3. Visual Loss
  - a. Outcome is dependent on mechanism
    - i. When induced by contrast administration with normal appearing optic nerves, the deficit is usually transient with return of vision within 24-48 hours
    - ii. Visual loss due to anterior or posterior ischemic optic neuropathy following cardiac surgery is typically permanent.
4. Delirium
  - a. Mixed outcomes, reflecting the multifactorial nature of delirium
    - i. Neurocognitive decline is common after cardiac surgery, varying from 7% - 49% at 3 months and up to 33% after 1 year
5. Peripheral Complications
  - a. Patients with brachial or lumbosacral plexopathy can in the majority of cases expect full recovery with conservative management
  - b. While the severity of mononeuropathies following cardiac surgery can range from mild transient sensory neuropathy to disabling paralysis, symptoms almost always resolve completely.

## Laboratory and Neuroimaging Investigations

1. Coma, encephalopathy or seizures
  - a. Laboratory evaluation should focus on ruling out a metabolic cause and should include at the minimum complete blood count, coagulation studies, chemistry panel, liver function tests, lactate and ammonia levels.
  - b. An EEG is appropriate in patients suspected of having seizures.
  - c. Those with seizures should be further evaluated for stroke or air embolism
  - d. Lumbar puncture should be performed for CSF analysis in unexplained coma or encephalopathy or when the patient is known to be immunosuppressed.
2. Suspected Stroke
  - a. Focal neurologic deficits raising concern for ischemic stroke or convulsions occurring during cardiac catheterization should alert the clinician to look for air in the tubing.
  - b. Neuroimaging
    - i. A non-contrast CT of the head should be obtained before considering thrombolysis or endovascular therapy. An MRI of the brain with diffusion-weighted images may be indicated if the CT scan does not show the suspected stroke
    - ii. For most devices, if there is a good clinical indication for an MRI scan, then the benefits probably outweigh the risks. The exception is patients who have implantable cardiac defibrillators (ICDs) and pacemakers, in which MRI scanning should be performed only at a very experienced center and only when there is a strong indication for MRI (Levine 2007)

- iii. Neuroimaging is undertaken to exclude hemorrhage and to identify the pattern of infarction. The most common pattern encountered is multiple embolic infarcts however large artery territorial or watershed infarcts can also occur.
  - c. Serum glucose, CBC, and coagulation studies
  - d. Trans-esophageal echocardiography may be indicated in selected cases, particularly those having undergone cardiac valve surgery to evaluate for the presence of left-atrial or valvular thrombus or infective vegetations.
  - e. ECG should be obtained and telemetry data reviewed to evaluate for arrhythmias.
- 3. Peripheral nervous system injury
  - a. EMG/NCV may help to localize the lesion and to provide prognostic information
  - b. Lumbosacral plexopathy or femoral neuropathy
    - i. Exclude retroperitoneal hemorrhage with CT scan of the pelvis in cases of lumbosacral plexopathy or femoral neuropathy following administration of thrombolytic agents during cardiac catheterization and PCI procedures.
- 4. Generalized weakness with or without myalgia
  - a. CK and aldolase should be obtained to assist in the evaluation of myopathy

## Management

- 1. Perioperative ischemic stroke in the setting of cardiac surgery
  - a. Similar to that in other settings except that use of intravenous r-tPA is contraindicated in patients within 2 weeks of cardiac surgery
  - b. TPA may be considered after cardiac catheterization (head CT is still required prior to TPA administration in this setting even if the embolism is detected by angiography)
  - c. Select patients may be considered for mechanical endovascular embolectomy
  - d. If the etiology of the stroke is an air embolism, hyperbaric oxygen therapy should be administered early
- 2. Seizures
  - a. Seizures can be managed acutely with benzodiazepines.
  - b. Long term treatment with an anti-seizure drug if focal or if an associated structural lesion is identified no pharmacologic mechanism is identified
- 3. Peripheral nervous system injury
  - a. Conservative management remains the mainstay of therapy for peripheral nerve or muscle injury associated with cardiac surgeries and procedures.
  - b. Surgery is only recommended when there are coexisting complications (e.g., development of a large hematoma)

## Conclusions

- Neurologic complications of cardiac surgery and cardiac procedures are not rare and remain an important cause of morbidity and mortality.
- Evaluation of these complications requires a systematic approach.
- Prompt identification of these deficits is important in order to plan appropriate evaluation and initiate possible treatments in a timely manner.

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