Embolization of Shotgun Pellets to the Cerebral Circulation: Imaging and Management

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Disclosures

None of the authors nor their immediate family members have a financial relationship with a commercial organization that may have direct or indirect interest in the content.

Teaching Points

Discuss	Discuss the pathophysiology of shotgun pellet embolization to the cerebral circulation
Review	Review clinical & imaging findings of shotgun pellet embolizations to the cerebral circulation
Present	Present cases of shotgun pellet embolization to the cerebral circulation

Background

- **Shotguns** are versatile firearms used for targeting small and fast-moving targets, particularly for hunting waterfowl and other small birds
  - Other uses: skeet shooting, military applications, home defense
- **Shotgun shells** contain small metallic **pellets**, which burst and fan out to hit the target
  - **Size** of the pellets depends on use
    - Range of 1.27mm to 9.14 mm in diameter
- Average vessel diameter[1-3]:
  - Terminal ICA (C7): 3.3 mm
  - MCA: M1: 2.3 mm, M2: 1.7 mm
  - Basilar: 2.96 +/- 0.52 PCA: P1: 2.4 mm

Multiple shotgun casing and pellet sizes.
Source: Getty Images

1. Halama D, Merkel H, Werdehausen R, et al. Reference Values of Cerebral Artery Diameters of the Anterior Circulation by Digital Subtraction Angiography: A Retrospective Study. Diagnostics (Basel). 2022 Oct 12;12(10):2471.
2. Mahmood M, Kummer K, Touchette J, et al. Variability in Intracranial Vessel Diameters and Considerations for Neurovascular Models: A Systematic Review and Meta-Analysis. Stroke. 2024;4(4).
3. Iqbal, S.. Average dimensions of the vessels at the base of the brain and the embryological basis of its variations. National Journal of Clinical Anatomy 2(4):p 180-189, Oct–Dec 2013.

Background

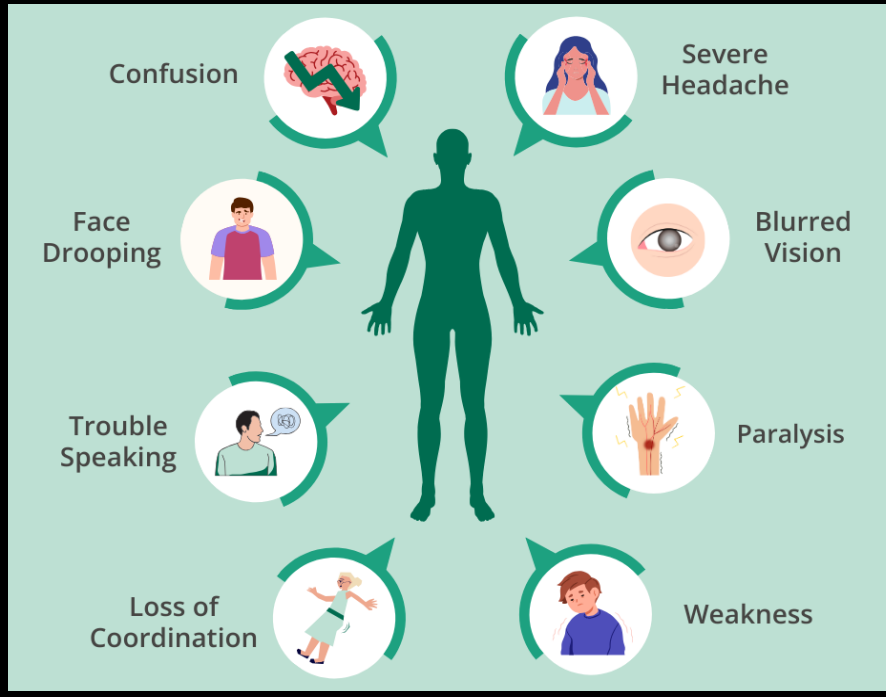
- Shotgun pellets can embolize via two main routes:
  - **Direct embolization** occurs following direct penetration of vessel by a pellet
  - **Indirect embolization** occurs due to the erosion of a pellet from peripheral tissue into vasculature
- The final target of the embolized pellets depends on where the injury occurred
  - Injuries at the aortic arch or the arterial system of the head and neck can migrate to the cerebral circulation
  - Injuries to the left-sided heart chambers or pulmonary venous system can migrate to the systemic (typically right side) circulation

Epidemiology and Demographics

- **Incidence**
  - Shotgun wounds make up a small percentage of all gunshot wounds
  - Embolization of lodged shotgun pellets to the cerebral circulation is also a rare occurrence
- **Risk Factors**
  - Shotgun wounds to the head, neck, and/or chest
    - Low-velocity pellets do not fully penetrate vessels and can easily get lodged
    - These locations are particularly susceptible to embolization to the cerebral circulation

Clinical Findings

- Emboli have greater propensity for right side of circulation than left
- Cerebral infarction caused by emboli result in **neurological deficits** with ranging severity:
  - Hemiparesis/hemiplegia
  - Aphasia
  - Gait disturbance/ataxia
  - Headache
  - Dizziness
  - Seizures
  - Vision disturbances
  - Behavioral changes

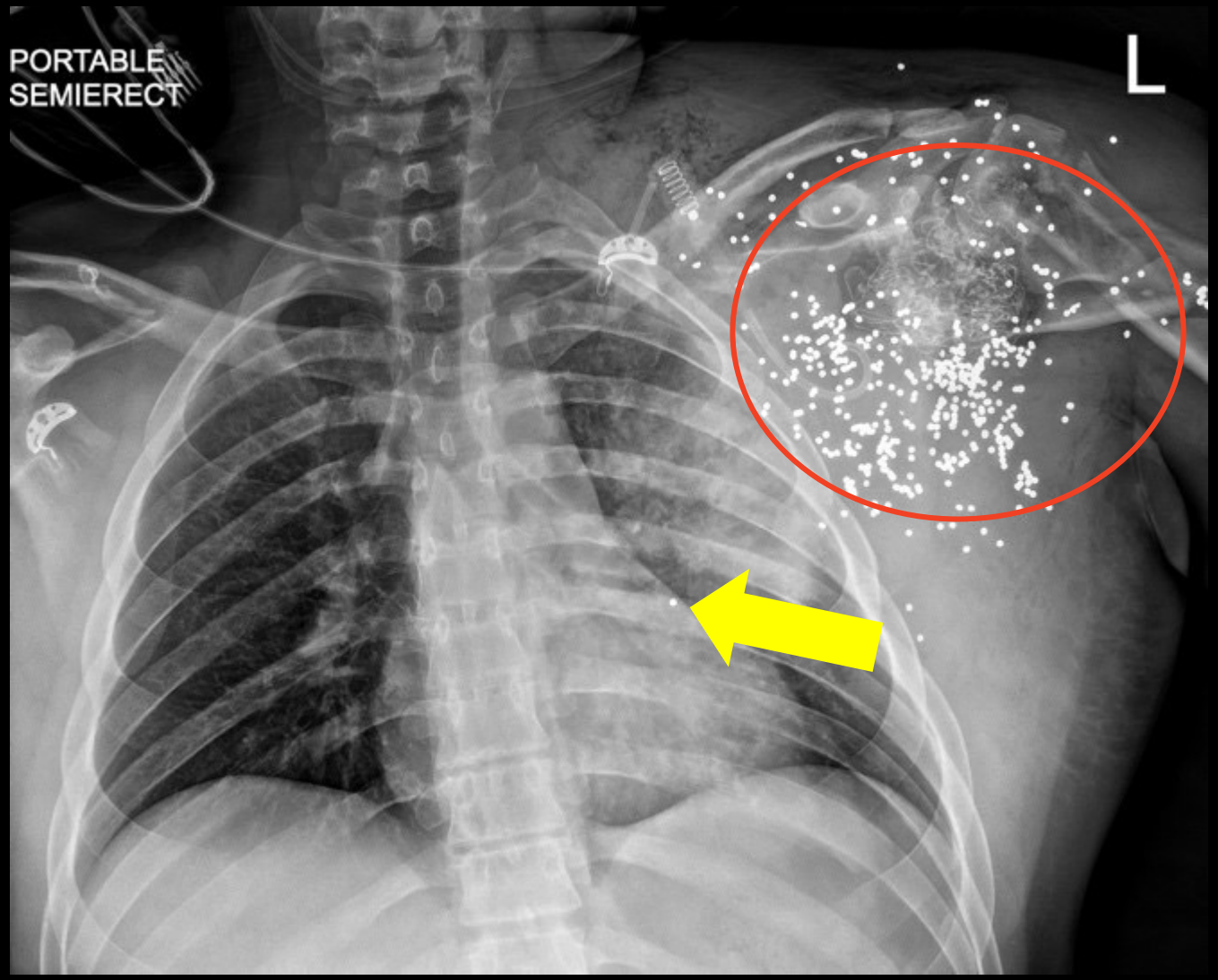


Range of neurological deficits caused by cerebral infarction
Source: Everyday Health, Inc.

Preferred Imaging Modalities

- **CT head and neck without contrast**
  - Used to identify/locate pellet embolus in the brain
  - Used to identify whether infarcts have occurred due to occlusion caused by the embolus
- **CTA head and neck**
  - Used to locate the vessel where the pellet is lodged
  - Used to assess flow distal to the embolus
- **MRI**
  - Potentially hazardous due to risk of the movement of pellet fragments
  - Depending on pellet composition, likely to be nondiagnostic due to large susceptibility artifact

Case 1:
25 y.o. with a shotgun wound to the axilla



Multiple shotgun pellets (2.3 mm) are present in the left axilla with large surrounding soft tissue edema.

Pulmonary contusions and a pellet at the left heart border (located in the pleural space on subsequent CT) indicate penetrating injury to the thorax

Case 1:

4 days later, sedation was weaned and was found to have left sided weakness and sensory symptoms

CT head: Small/moderate sized acute infarct in the right MCA territory

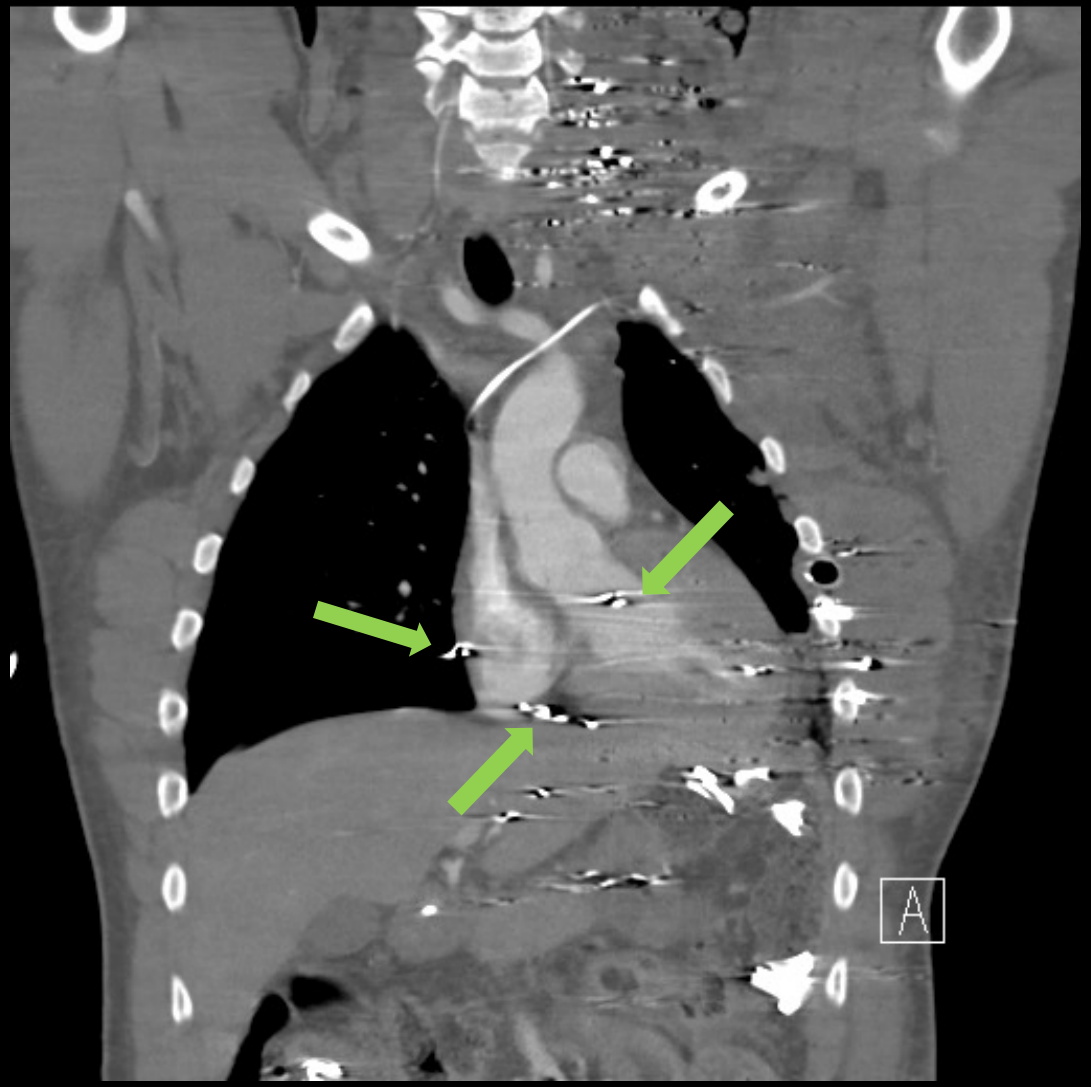
CTA head: Embolized shotgun pellet in a distal left M2 MCA branch with infarct of the distal territory

Case 1:
Embolized Shotgun Pellet to the Right MCA with Acute Infarct

- A bubble study was negative for a left-to-right shunt, so this pellet did not enter through the systemic venous circulation from the axillary vein
- Radiographs at injury and post-stroke failed to identify a pellet that had moved
- **Hypothesis**: Entry into the left heart through direct injury to a pulmonary vein with embolization at the time of injury, not discovered until sedation was weaned

Case 2:

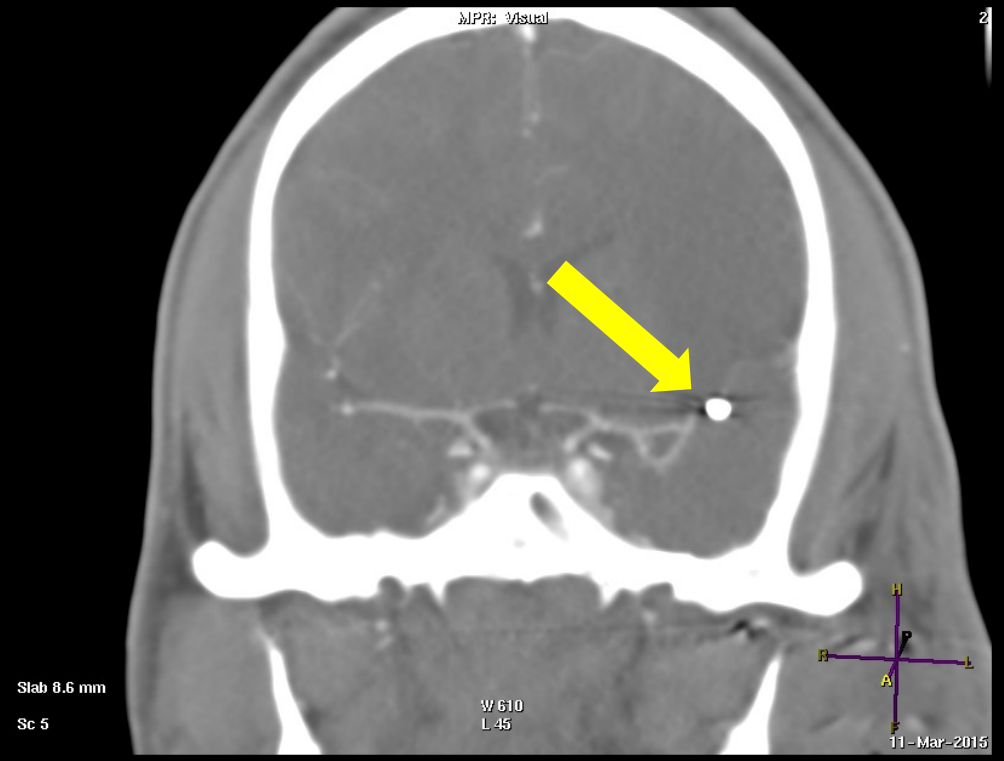
32 y.o. paraplegic from prior GSW with a shotgun wound to the left face, neck, and chest



- **Multiple left ventricle and LV outflow tract pellets, 2.8mm diameter**
- **Not imaged, but there is a pellet in a pulmonary vein**

Case 2:

32 y.o. with a shotgun wound to the left face, neck, and chest



CTA head:
Acute left MCA infarct

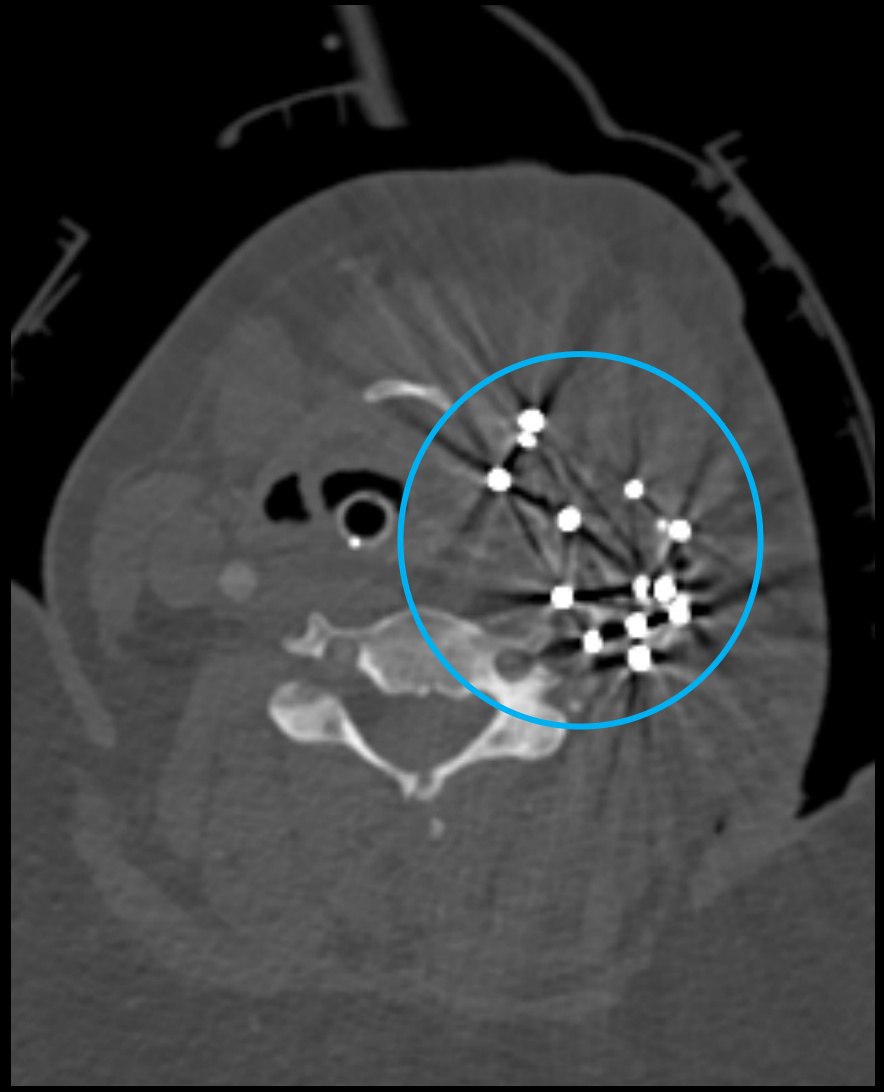
CTA head:
Pellet in proximal left M2 MCA

Case 2: Embolized Shotgun Pellet to the Left MCA with Acute Infarct

- Patient suffered multiple injuries to the left neck, chest, & abdomen requiring tracheal repair, tracheostomy, ex lap and neck exploration with left IJ ligation and L carotid repair
- No endovascular or surgical intervention due to comorbid injuries
- **Hypothesis**: Embolus migrated from direct injury to the left common carotid artery (most likely – a pellet hole was repaired in the CCA on neck exploration), left ventricle, or left pulmonary vein to L M1 MCA branch

Case 3:

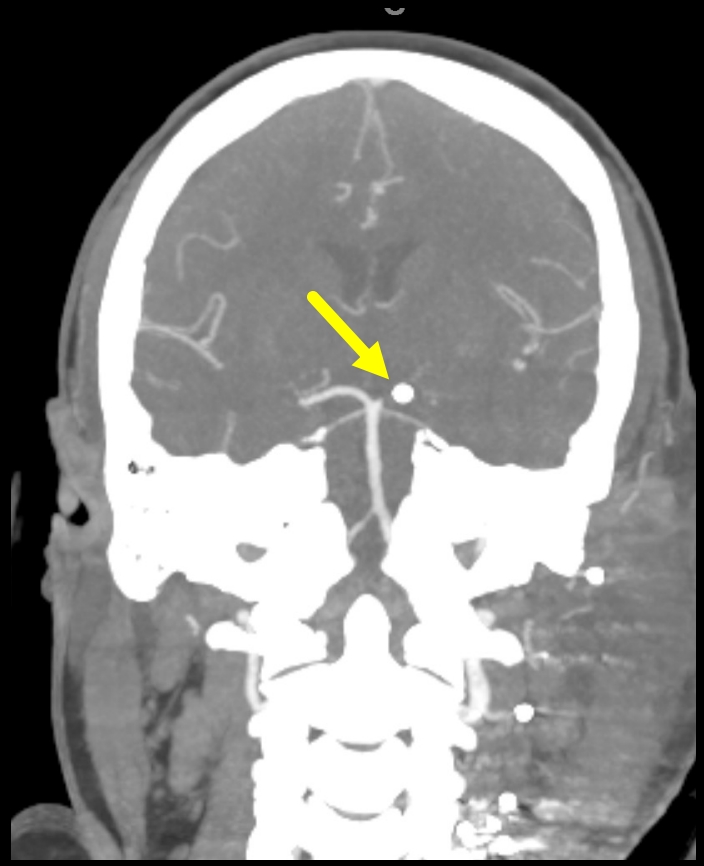
35 y.o. pregnant (31 weeks) female with shotgun wound to the left face and neck

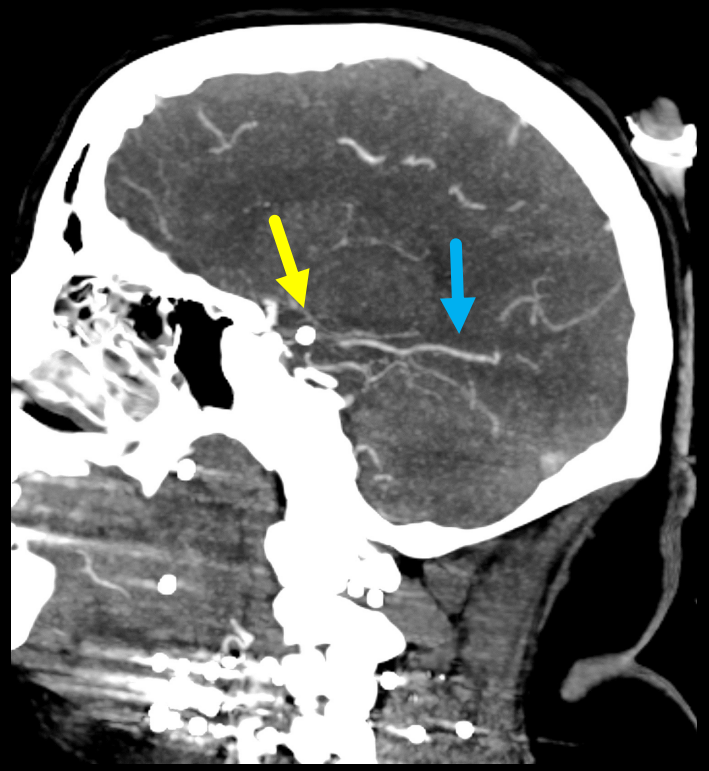


CT head: Multiple shotgun pellets (3.1 mm) in the left neck in close proximity to the left foramen transversarium

Case 3:

35 y.o. female with shotgun wound to the left face and neck





CT head: Pellet in the interpeduncular cistern without surrounding hemorrhage

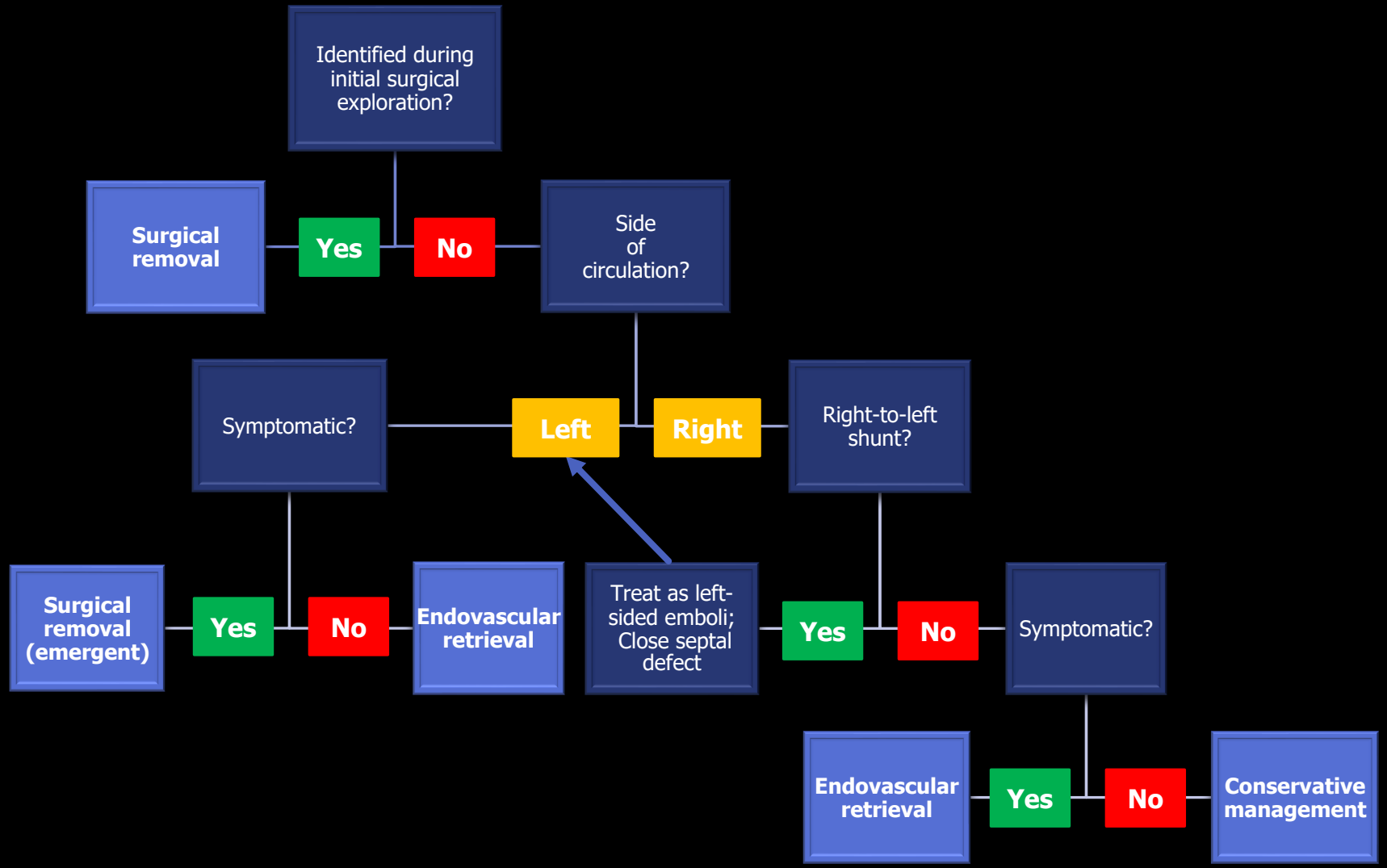
CTA head: Pellet in the left PCA P1 segment with distal reconstitution

Case 3: Embolized Shotgun Pellet to the PCA

- Patient ultimately underwent debridement of the left neck wound and C-section at 33 weeks due to preeclampsia
- Neurovascular intervention was not pursued. Small volume infarct in the midbrain and thalamus
- **Hypothesis**: Pellet likely entered into cervical vertebral artery and embolized to left PCA

Management

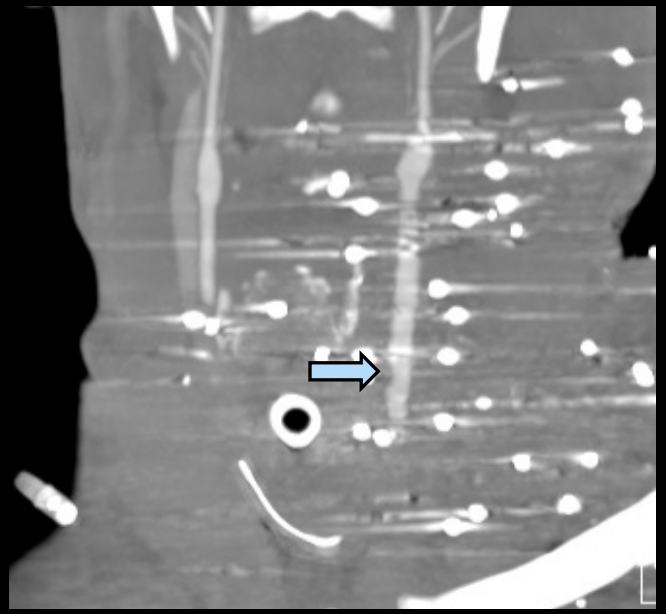
- Options
  - Surgical removal
  - Endovascular retrieval
  - Conservative management



Adapted from Kuo AH, Gregorat AE, Restrepo CS, Vinu-Nair S. Systematic review of civilian intravascular ballistic embolism reports during the last 30 years. J Vasc Surg. 2019;70:298–306.

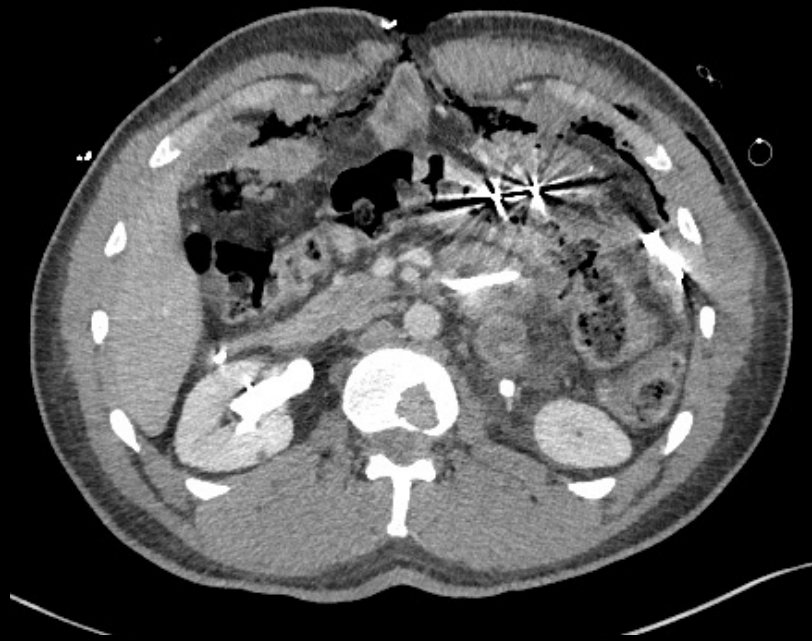
Management:
Additional Considerations

Is the vessel to access the embolized pellet injured/occluded?
Large surrounding hematoma and mural filling defect in the left CCA wall.
Injury confirmed at surgery.



Age and potential size of infarct:
This was likely a few days old when discovered.

Comorbid conditions and injuries:
This patient required emergency ex-lap for bowel injury.



Prognosis

- Varies based on timing of intervention and severity of infarction
  - Early intervention can prevent neurological deficits from worsening
  - Delayed treatment can lead to permanent deficits or death
- Surgical removal can improve neurological outcomes, but it is not guaranteed (full recovery is rare)
- Non-operative management usually results in stable or mildly worse neurological deficits
  - Follow up with serial imaging to assess stability of pellet over time

References

- Alsofrom DJ, Marcus NH, Seigel RS, Talbot WA, Akl BF, Schiller WR, Sklar DP. Shotgun pellet embolization from the chest to the middle cerebral arteries. J Trauma. 1982;22:155–157.
- Chao J, Barnard J, deJong JL, Prahlow JA. A case series of anterograde and retrograde vascular projectile embolization. Acad Forensic Pathol. 2018;8:392–406.
- Cogbill TH, Sullivan HG. Carotid artery pseudoaneurysm and pellet embolism to the middle cerebral artery following a shotgun wound of the neck. J Trauma. 1995;39:763–767.
- da Costa LB, Wallace MC, Montanera W. Shotgun pellet embolization to the posterior cerebral circulation. AJNR Am J Neuroradiol. 2006;27:261–263.
- Dadsetan MR, Jinkins, JR. Peripheral vascular gunshot bullet embolus migration to the cerebral circulation. Neuroradiology. 1990;32:516–519.
- Gipe BT, Acker B, Smith R. Delayed cerebral embolization of a shotgun pellet with fatal consequences. J Trauma. 1981;21:326–329.
- Konkel L, Cutler M. Stroke Symptoms and Causes. EverydayHealth.com. August 7, 2022. https://www.everydayhealth.com/stroke/guide/symptoms/.
- Kuo AH, Gregorat AE, Restrepo CS, Vinu-Nair S. Systematic review of civilian intravascular ballistic embolism reports during the last 30 years. J Vasc Surg. 2019;70:298–306.
- McCague A, Kelly S, Wong DT. Shotgun pellet embolization to the middle cerebral artery. Am Surg. 2013;79:322–323.
- Mingo M, Cao D, Ezepue C, Massaquoi R, Sehi M. Embolic Shotgun Pellet to the Left Middle Cerebral Artery Causing Hemiplegia and Aphasia With Near Complete Clinical Recovery on Nonoperative Management. Cureus. 2020 Nov 24;12(11):e11677. doi: 10.7759/cureus.11677.
- Monterey M, Kerr K, Dannenbaum M, Chen PR, Blackburn S. Open Surgery for Extraction of an Embolized Pellet in the Middle Cerebral Artery From a Shotgun Injury. Oper Neurosurg. 2019;17:E119-E123. doi: 10.1093/ons/opy312.
- Stein M, Mirvis SE, Wiles CE III. Delayed embolization of a shotgun pellet from the chest to the middle cerebral artery. J Trauma. 1995;39:1006–1009.
- Vakil MT, Singh AK. A review of penetrating brain trauma: epidemiology, pathophysiology, imaging assessment, complications, and treatment. Emerg Radiol. 2017;24:301–309.
- Vaquero-Puerta C, San Norberto EM, Merino B, González-Fajardo JA, Taylor J. Shotgun wound and pellet embolism to the intracranial carotid artery. J Vasc Surg. 2012;55:535–537.
- Vedelago J, Dick E, Thomas R, Jones B, Kirmi O, Becker J, Alavi A, Gedroyc W. Look away: arterial and venous intravascular embolisation following shotgun injury. J Trauma Manag Outcomes. 2014;15:19–10.