History and Science of CO$_2$ Angiography

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The First Use of CO$_2$ as a Nonvascular Contrast Agent

- 1920s Carelli and Sordelli of Buenos Aires performed retroperitoneal pneumography with CO$_2$ for visualization of the kidneys and adrenal masses.

- Presacral insufflation with CO$_2$ has replaced air or oxygen insufflation, thus eliminating the hazard of air emboli.

CO₂ Angiocardiogram
1950s to 1970s

Antecubital vein injection of 100 cc of CO₂ with pt in LLD

Radiolucent gas trapped in right atrium

Opaque band above gas represents pericardial space

Normal band thickness is 3 mm
CO$_2$ Capnocavography

CO$_2$ inferior venacavography with the intravenous injection of 80 cc of CO$_2$

Radiology 92:606, 1969
Pioneer of CO$_2$ Angiography
Dick Hawkins, M.D.

1936-2011

CO$_2$ Aortogram
Inadvertent room air injection (70 cc) in celiac artery with good visualization of major arteries.

AJR 139:19, 1982
Renal CO$_2$ Arteriogram

CO$_2$ arteriogram obtained in 1971 with 20 cc of CO$_2$.

AJR139:19, 1982
CO$_2$ aortogram in severely hypertensive man. Aortic injection of 35 cc/sec for a total of 75 cc. Digital subtraction imaging

AJR 139:19, 1982
The Evolution of CO₂ Delivery Techniques

- 1971 - Hand held Syringe
- 1972 - Standard Angio Injector
- 1973 - CO₂ Cylinder (animals only)
- 1984-87 - 6 different dedicated models
(A) Early model hand-held CO₂ injector. (B) Angiojet computerized CO₂ injector (Angiodynamics)
The plastic bag CO\textsubscript{2} delivery system
Science of CO$_2$
Angiography
Unique CO$_2$ Properties

• Negative contrast
• High solubility
• Low viscosity
• Buoyancy
• Compressibility
## Properties of CO$_2$, O$_2$, N$_2$, Iodine and Gd

<table>
<thead>
<tr>
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<th>CO$_2$</th>
<th>O$_2$</th>
<th>N$_2$</th>
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<tbody>
<tr>
<td>Molecular wt</td>
<td>44</td>
<td>32</td>
<td>28</td>
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<tr>
<td>solubility</td>
<td>0.87</td>
<td>0.03</td>
<td>0.016</td>
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**Atomic Number**

- CO$_2$: C = 6, O = 8
- Iodine: 53
- Gd: 64
Comparative Radiopacity of Saline, Iodine, Gd and CO₂
CO\textsubscript{2} Angioscopy

CO\textsubscript{2} angioscopy shows origin of right renal artery

Total displacement of blood without arterial flow from branches
CO$_2$ Cholangiogram

CO$_2$ injection in bile duct fills intra- and extrahepatic ducts

Peripheral displacement of contrast medium
Air Volume Percent Changes over Time in 20 cc CO$_2$-filled Syringes

CVIR;29:637,2006
The Solubility of CO$_2$

5 cc of CO$_2$ injected into IVC in L lateral decubitus

Cross-table lateral DSA of CO$_2$ trapped in right atrium

Complete gas absorption in 45 sec
Aortoiliac Occlusive Disease: CO₂ DSA

3F dilator inserted into L external iliac artery (arrow)

Injection of 30 cc of CO₂ in L external iliac artery

CO₂ filling iliac, collaterals, inflow and outflow vessels
Celiac Stenosis: Median Arcuate Ligament Compression

(A) Celiac DSA with contrast medium showing flow defect at origin of GDA. (B) CO$_2$ injection fills both celiac and SMA branches
CT with intra-aortic injection of CO₂ and contrast medium: CO₂ displaces blood whereas contrast is mixed with blood

CO₂

Contrast
Buoyant CO$_2$ is trapped in AAA
Lateral CO$_2$ Aortogram: Median Arcuate Ligament Compression
CO\textsubscript{2} Bubble Flow in a 9.5 mm Tube of a Pulsatile Flow Model

30° inclination
CO$_2$ Dispersal from Different Catheter Design

- **Endhole**
- **Halo**
- **Pigtail**
CO₂ Filling of 15.9 mm Tube in Supine vs 30° elevation

15.9mm 0°

15.9mm 30°

65%

84 %
Superior venacavogram with intravenous CO$_2$ injection

Supine

CO$_2$ in PA

LLD: X-table Lat

CO$_2$ in RA
Buoyant CO$_2$ injected into right hepatic vein filling anterior middle and left hepatic veins
Buoyant, less viscous \( \text{CO}_2 \) injected into wedged right hepatic vein fills the portal, right, middle and left hepatic veins.
Buoyant, compressible CO$_2$ injected into celiac artery flows backwards, filling the aorta, superior mesenteric and renal arteries
CO$_2$ Renal DSA

Renal artery aneurysm

CO$_2$ injection via microcatheter
The hemodynamic and ventilatory responses to intracaval injections of ascending doses of CO$_2$
Polygraph tracing of blood pressure, pulmonary artery pressure and CVP following intracaval injection of CO$_2$ at 3.2 cc/kg in swine
Average percent changes in systemic blood pressure following intracaval injections of ascending doses of CO₂ in swine
Average percent changes of ETCO$_2$ following intracaval injections of ascending doses of CO$_2$ in swine
Continuous Monitoring during CO\textsubscript{2} Angiography

- Pulse oximetry (oxygenation)
- ECG/HR (Circulation)
- BP (Circulation)
- Respirations (oxygenation)
- Capnography (Ventilation & Perfusion)
End-tidal CO$_2$ monitoring: Increasing Patient Safety during Procedural Sedation and CO$_2$ angiography

Detect early signs of hypoventilation
Information on RR, depth, & apnea
Desaturation (SpO$_2$)-a late sign of respiratory compromise in hypoventilation.
Conclusions

• CO₂ has been used as a contrast agent in the nonvascular system since 1920s, in the venous system since 1950s and in the arterial system since 1970s.

• Intravenous CO₂ in doses of 0.2-1.6 cc/kg caused no cardiopulmonary effects in swine.

• CO₂ is the only safe, proven contrast agent in patients with contrast allergy and renal failure.
• A thorough knowledge of CO$_2$ properties, and facile catheterization and imaging techniques are essential in obtaining a successful CO$_2$ angiogram for the vascular diagnosis and intervention.

• Blood pressure monitoring and capnography provide the earliest sign of “vapor lock” in the pulmonary artery from the inadvertent injection of large volume of CO$_2$ or air.
• CO$_2$ is useful as a contrast agent in various vascular diagnosis and interventions, including angioplasty, stenting, thrombolysis, embolization, filter placement, TIPS, and EVAR.

• Both the plastic bag system and CO$_2$ mmander with AngiAssist allow for a safe, simple CO$_2$ delivery for CO$_2$ angiography.