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

Carelli HH and Sordelli E. Un Nuevo procedimento para explorar el ninon Rev Assoc Med Argent 34:424-425, 1921

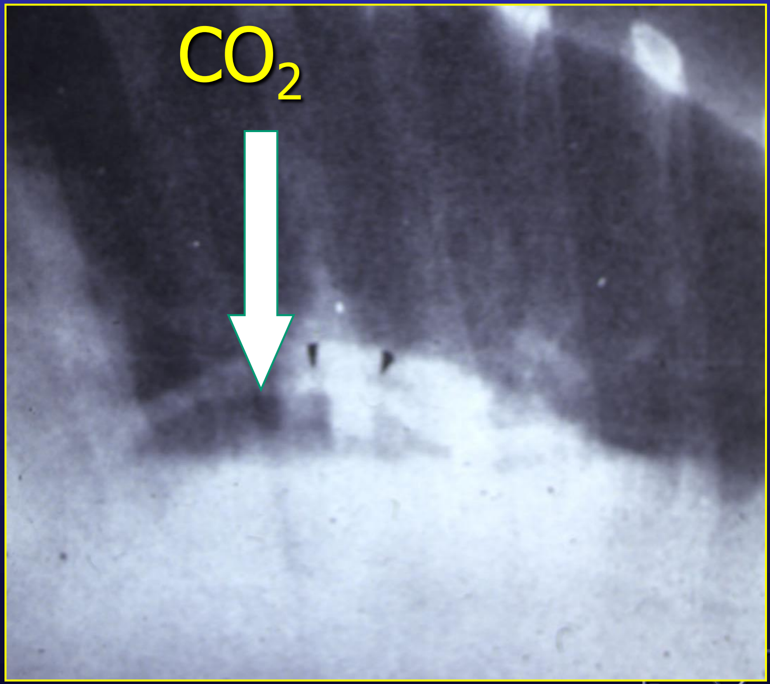
CO_2 Angiocardiogram 1950s to 1970s

Antecubital vein injection of 100 cc of CO_2 with pt in LLD

Radiolucent gas trapped in right atrium

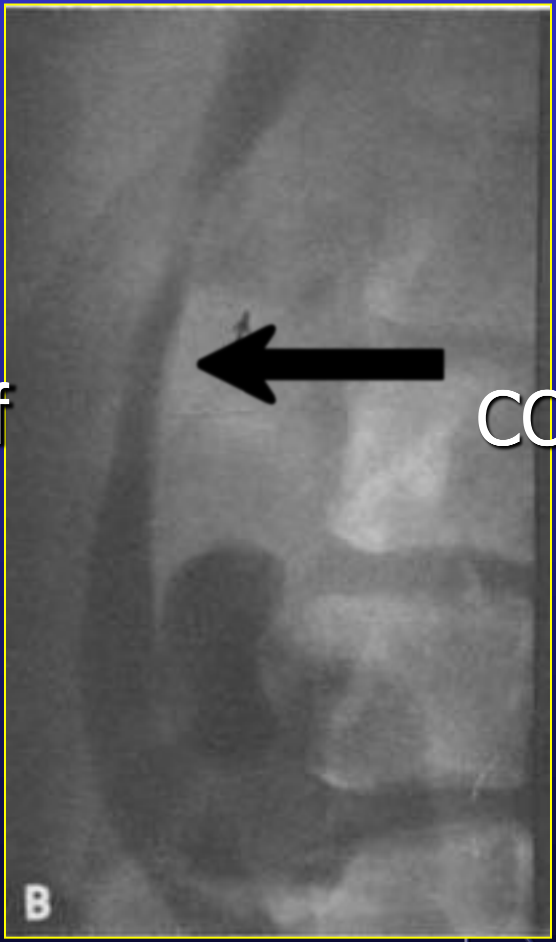
Opaque band above gas represents pericardial space

Normal band thickness is 3 mm



CO_2 Capnocavography

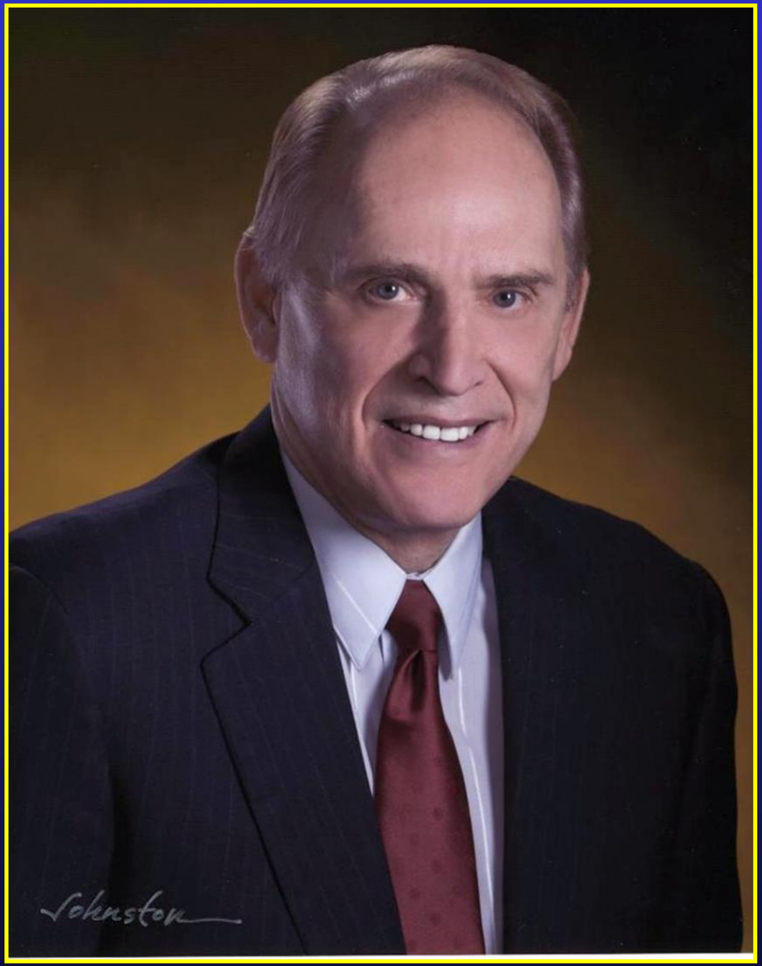
CO_2 inferior venacavography with the intravenous injection of 80 cc of CO_2



Radiology 92:606,1969

Pioneer of CO_2 Angiography

Dick Hawkins, M.D.

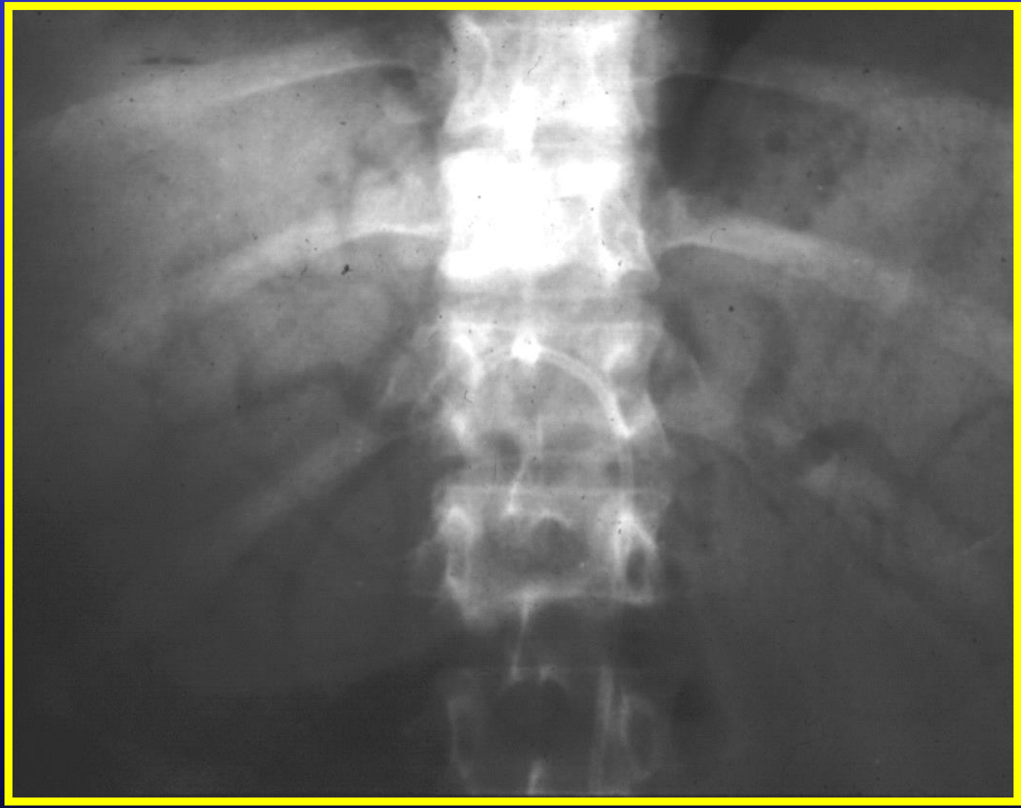


1936-2011

CO_2 Aortogram

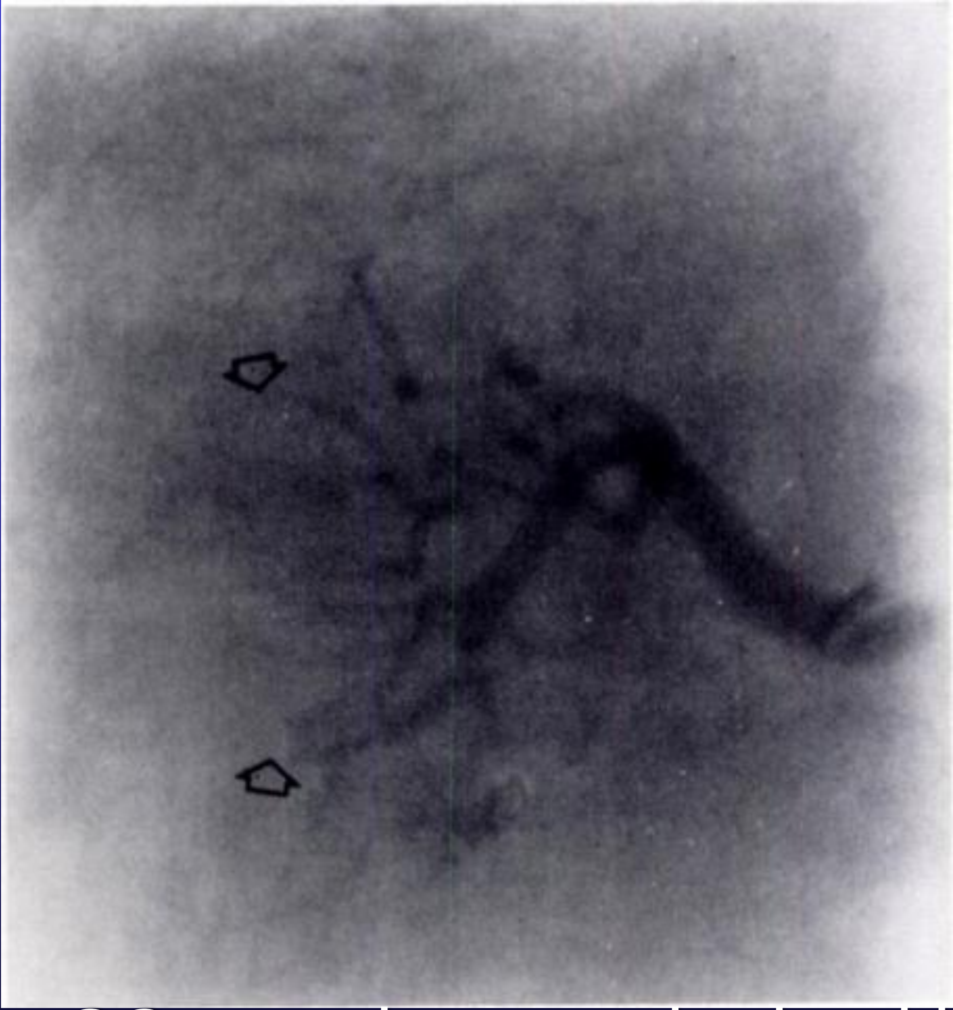
Celiac Arteriogram with Air

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



AJR 139:19,1982

Renal CO_2 Arteriogram

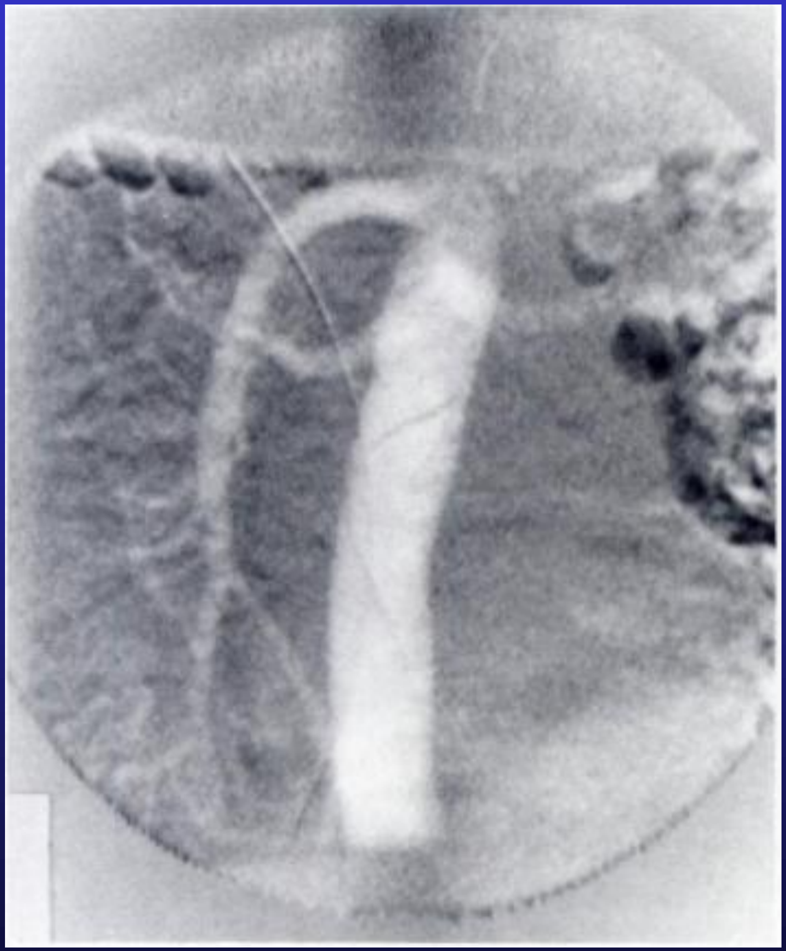


AJR139:19, 1982

CO_2 arteriogram obtained in 1971 with 20 cc of CO_2.

Renal CO_2 DSA

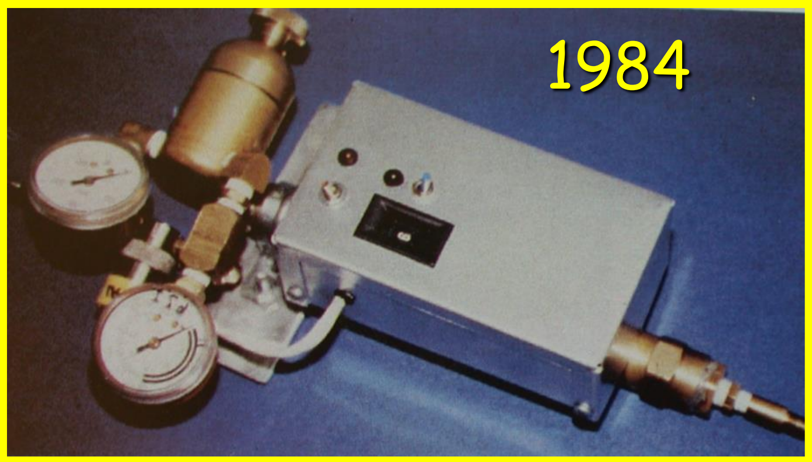
CO_2 aortogram in severely hypertensive man. Aortic injection of 35 cc/sec for a total of 75 cc. Digital subtraction imaging

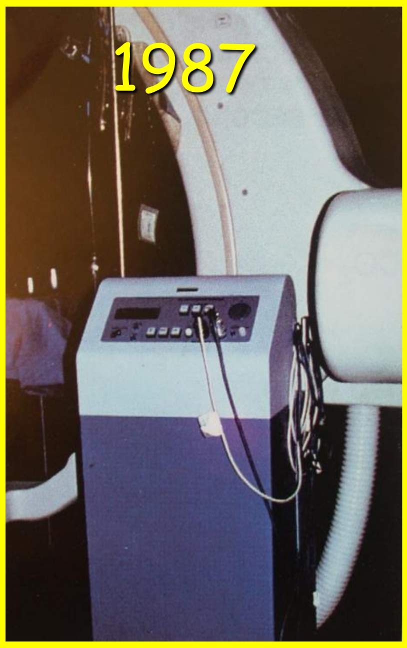


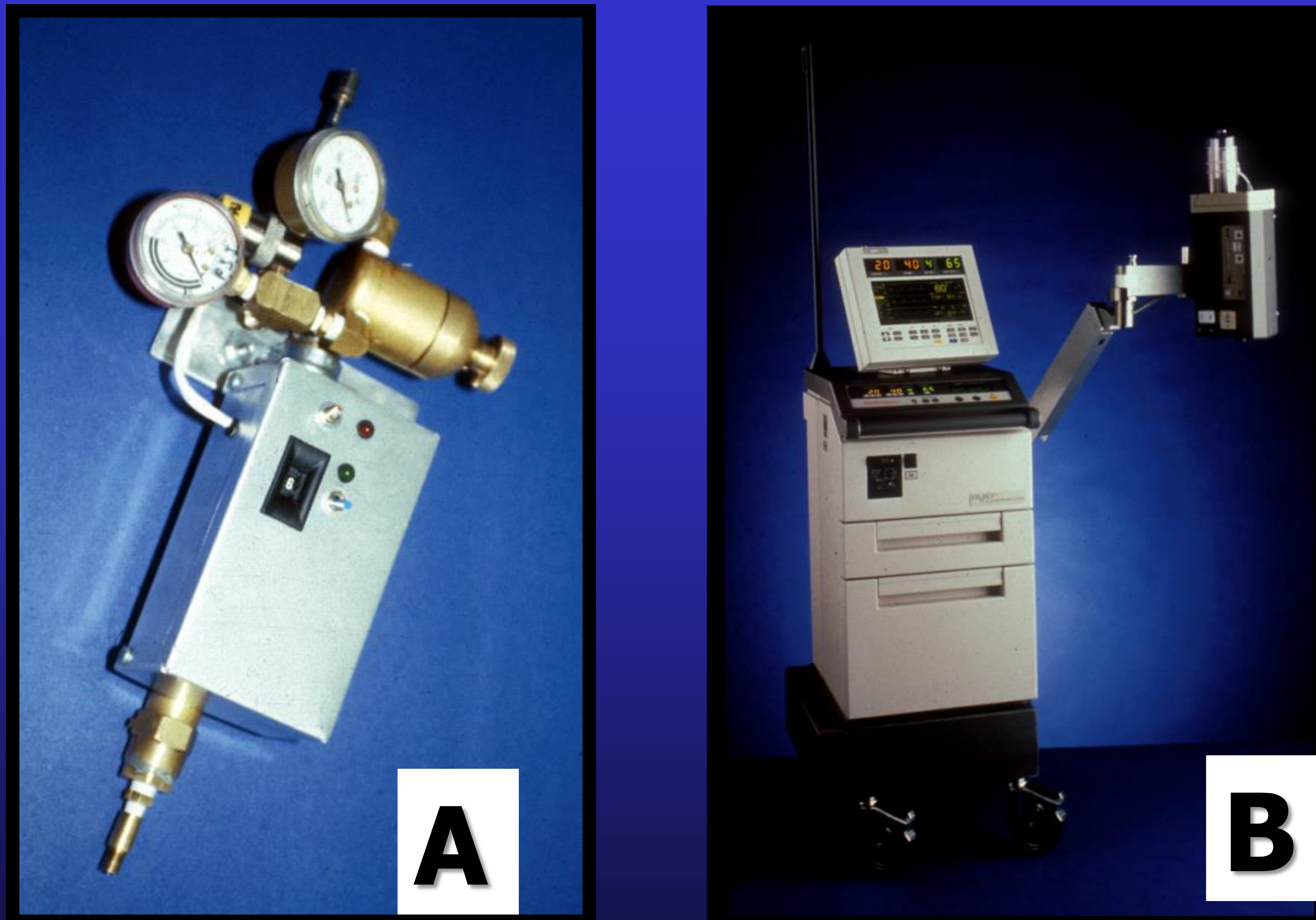
AJR 139:19, 1982

The Evolution of CO_2 Delivery Techniques

- 1971 - Hand held Syringe
- 1972 - Standard Angio Injector
- 1973 - CO_2 Cylinder (animals only)
- 1984-87 - 6 different dedicated models

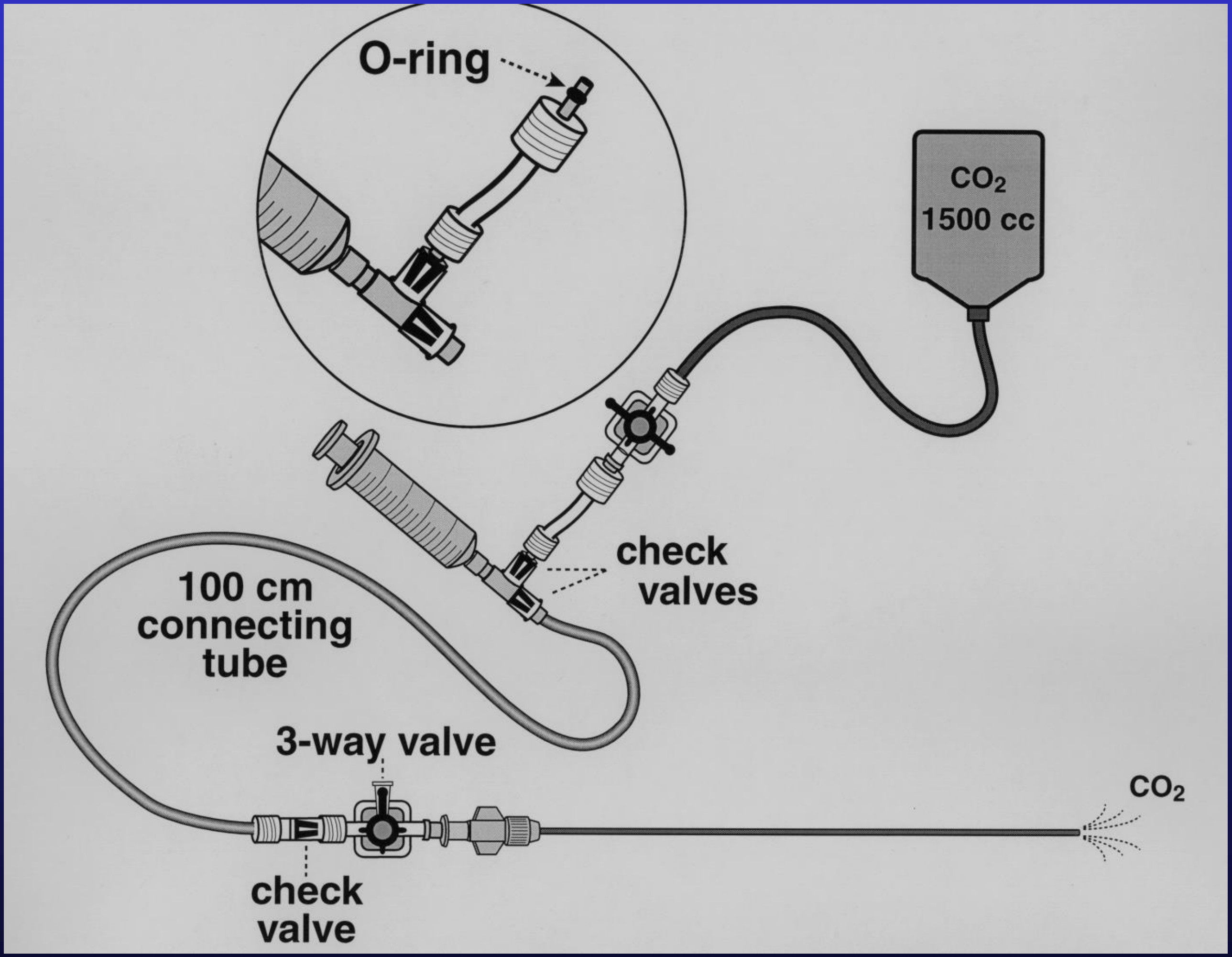






(A) Early model hand-held CO_2 injector. (B) Angiojet computerized CO_2 injector (Angiodynamics)

The plastic bag CO_2 delivery system



AJR 176:229, 2001

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

	CO2	O2	N2
Molecular wt	**44**	**32**	**28**
solubility	**0.87**	**0.03**	**0.016**

	Atomic Number
CO_2	C = 6, O =8
Iodine	53
Gd	64

Comparative Radiopacity of Saline, Iodine, Gd and CO_2

Saline Omnipaque 240 Gd

CO_2 in arm vein

CO_2 Angioscopy

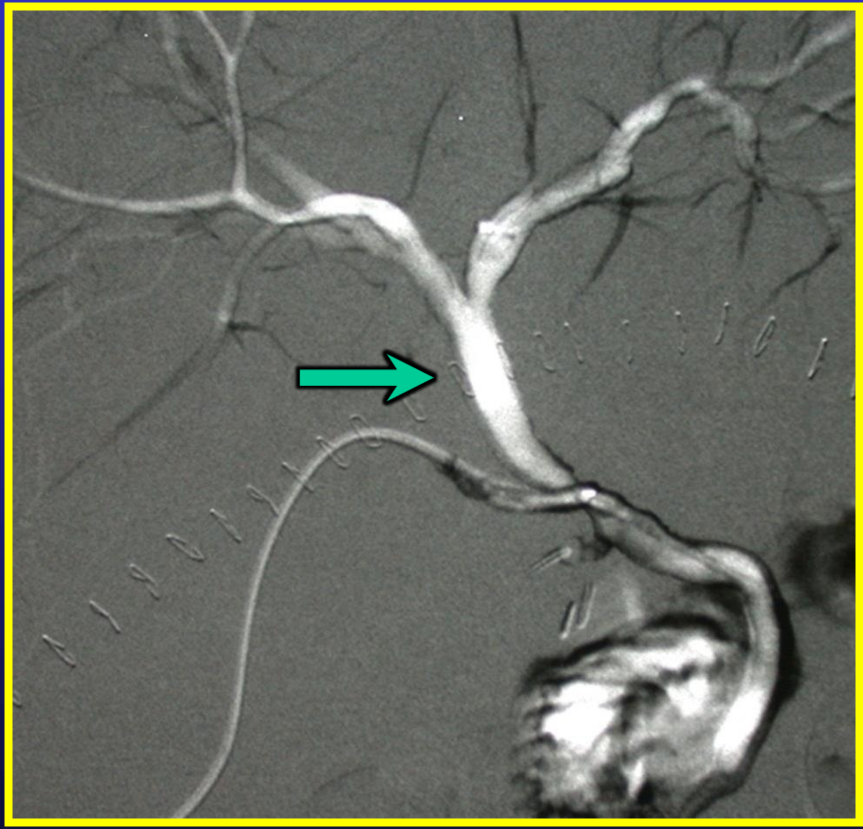
CO_2 angioscopy shows origin of right renal artery

Total displacement of blood without arterial flow from branches

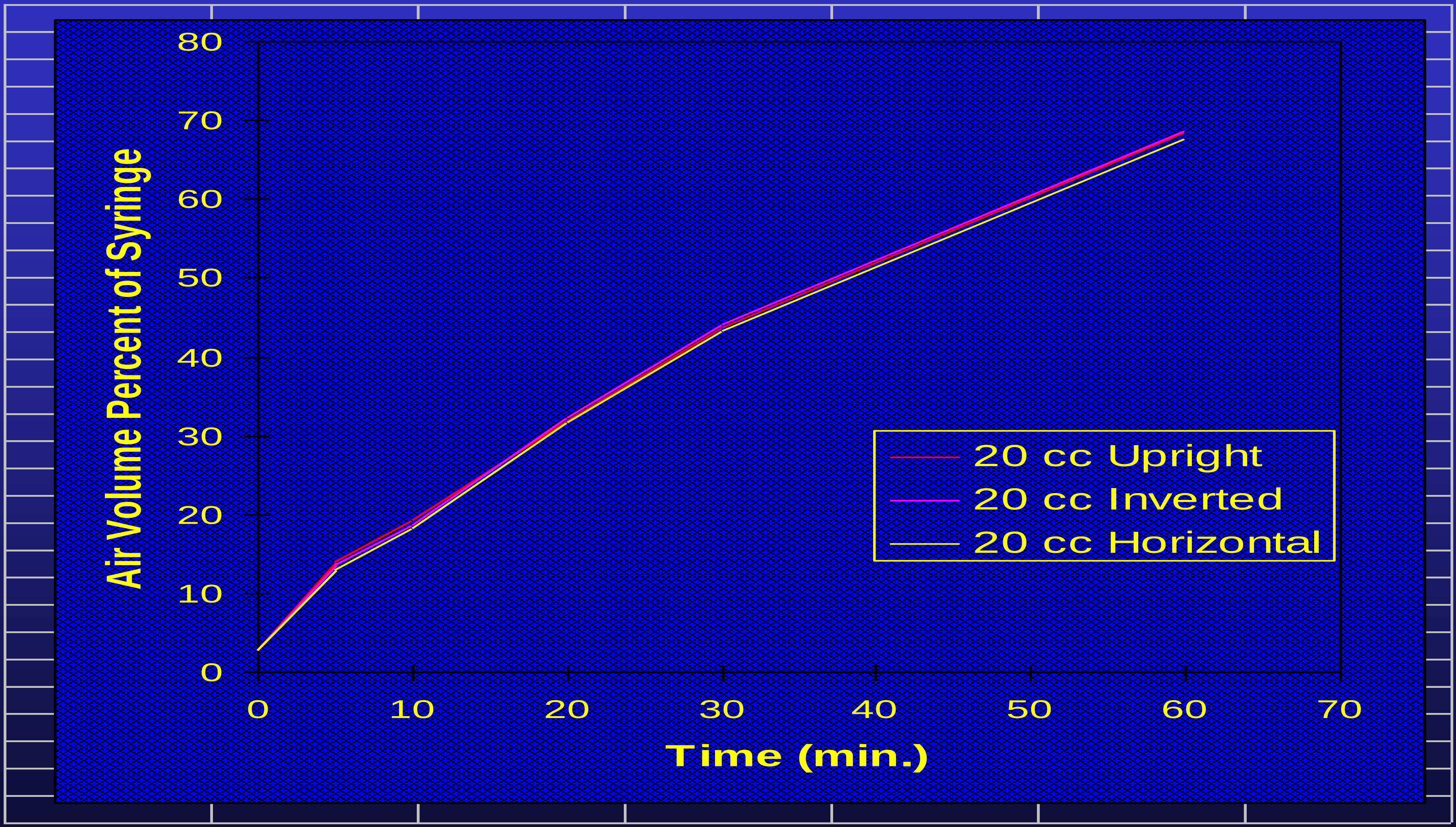
CO_2 Cholangiogram

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



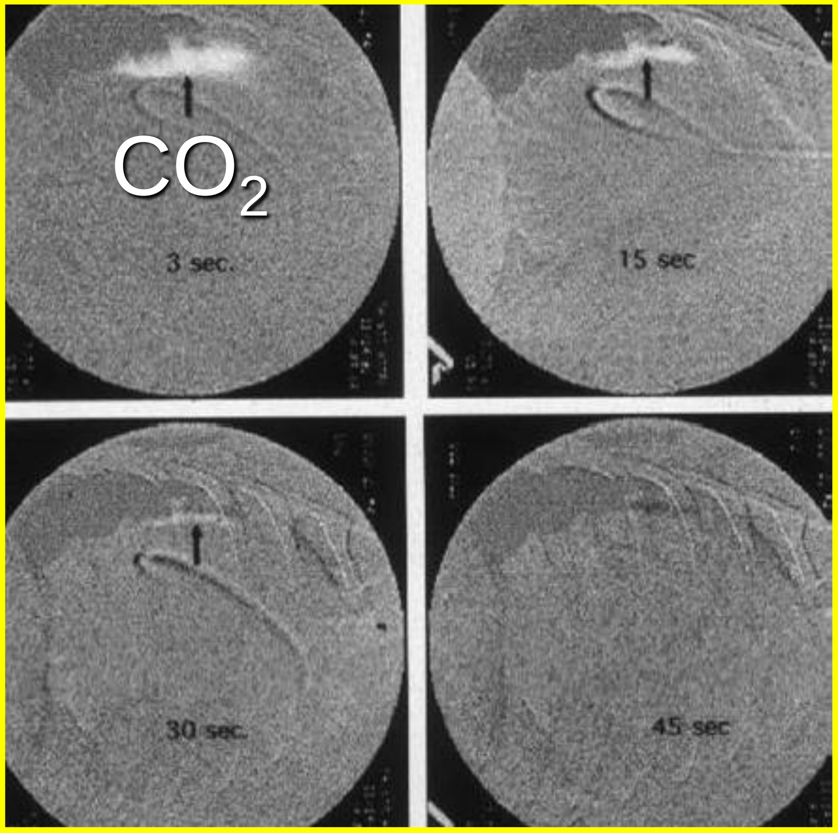
CVIR;29:637,2006

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



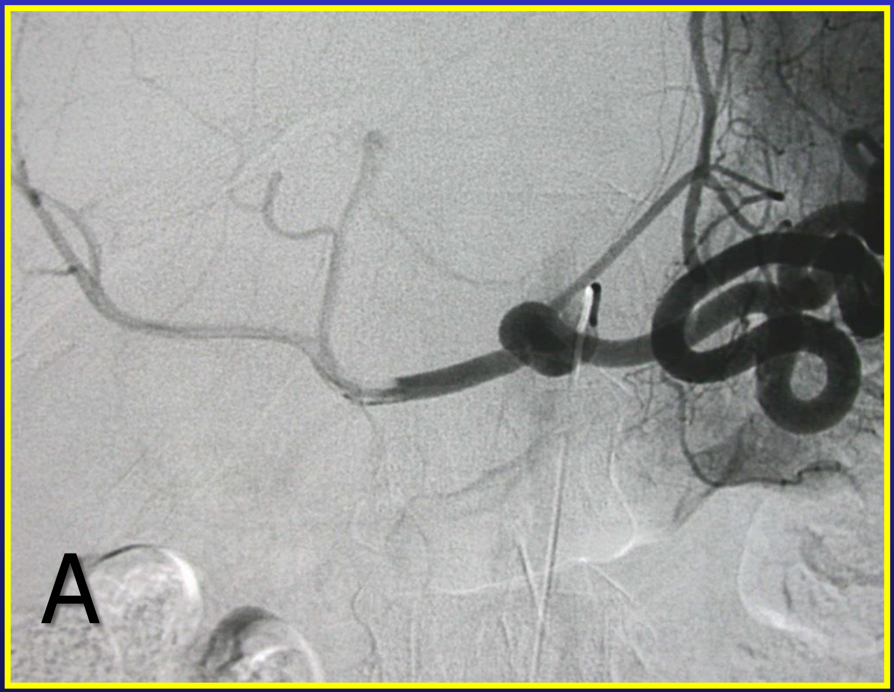
Aortoiliac Occlusive Disease: CO_2 DSA

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

Injection of 30 cc of CO_2 in L external iliac artery

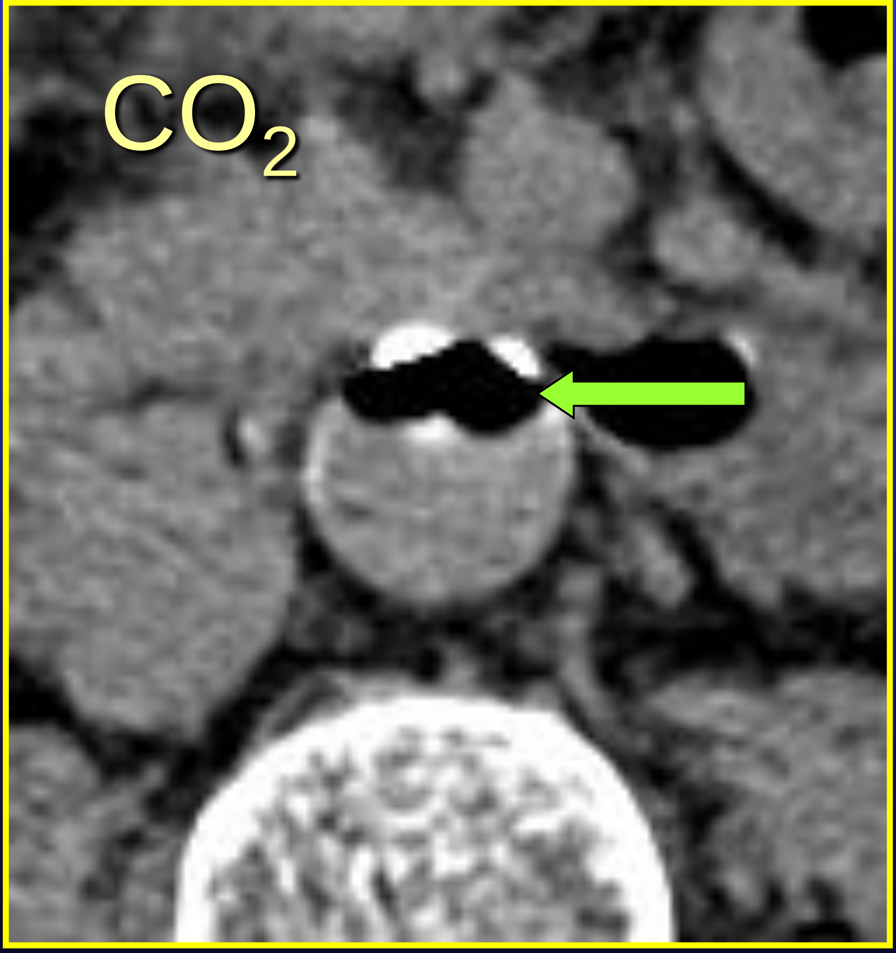
CO_2 filling iliac, collaterals, inflow and outflow vessels

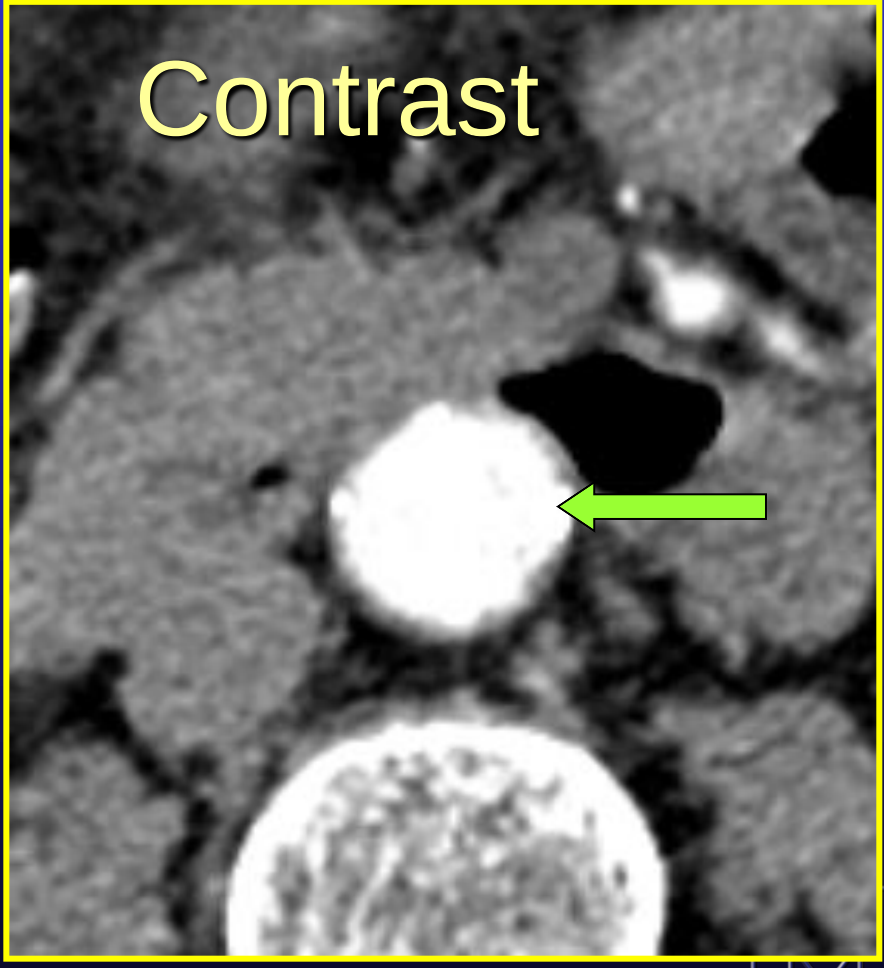
Celiac Stenosis: Median Arcuate Ligament Compression



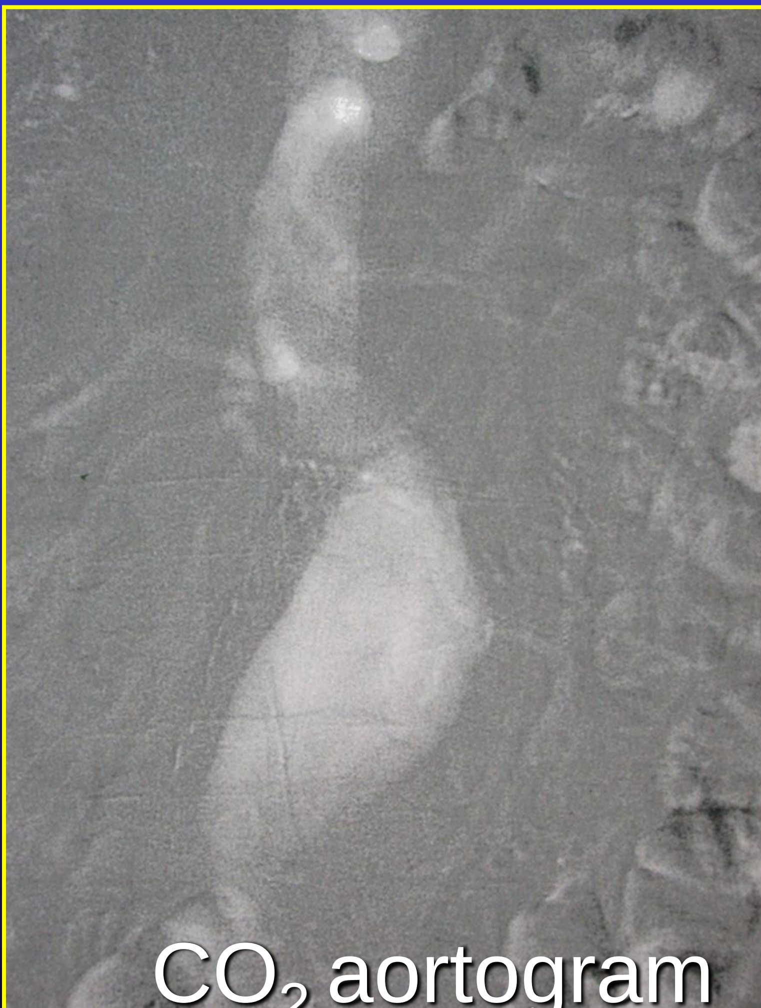
(A) Celiac DSA with contrast medium showing flow defect at origin of GDA. (B) CO_2 injection fills both celiac and SMA branches

CT with intra-aortic injection of CO_2 and contrast medium: CO_2 displaces blood whereas contrast is mixed with blood

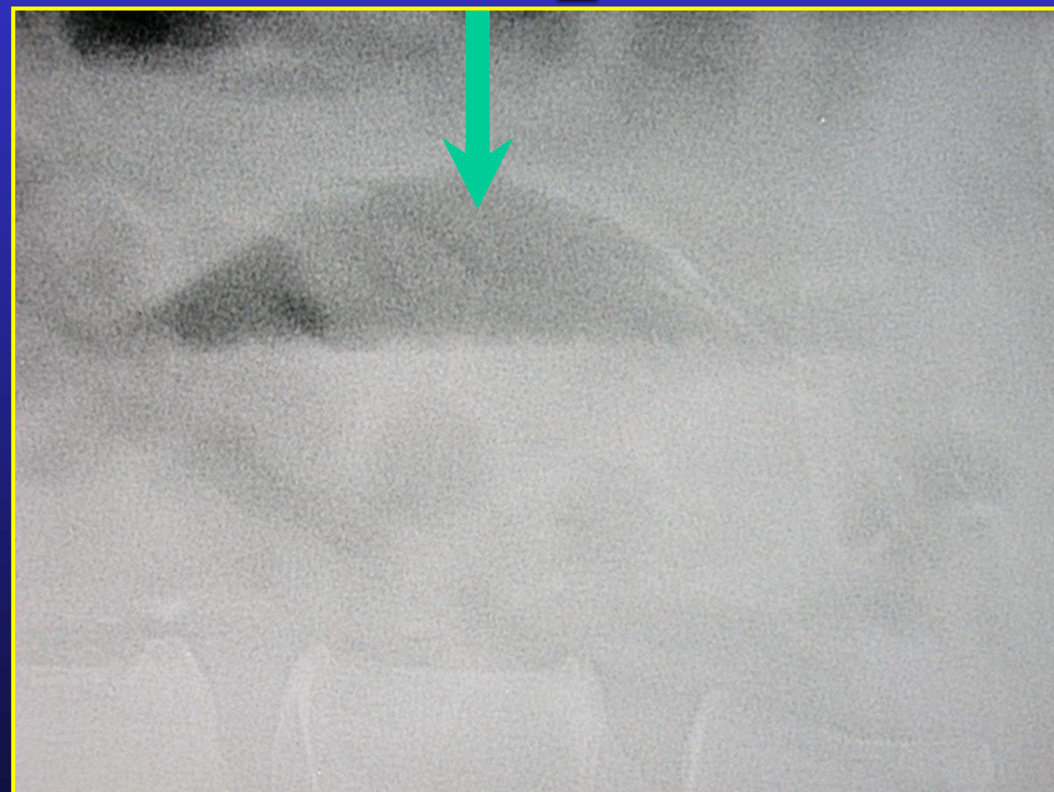




Buoyant CO_2 is trapped in AAA



CO_2

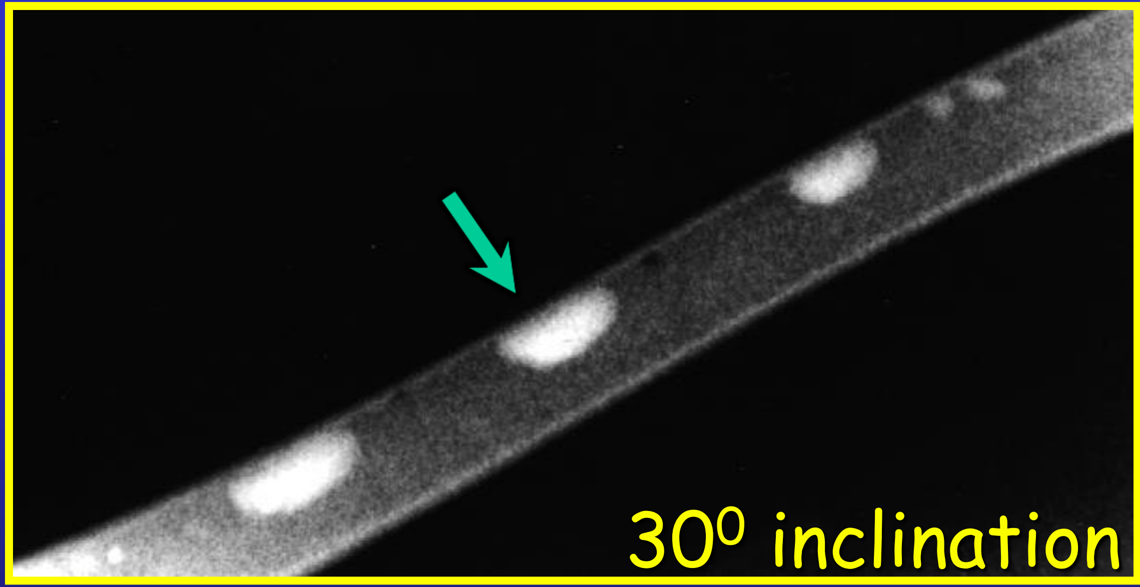


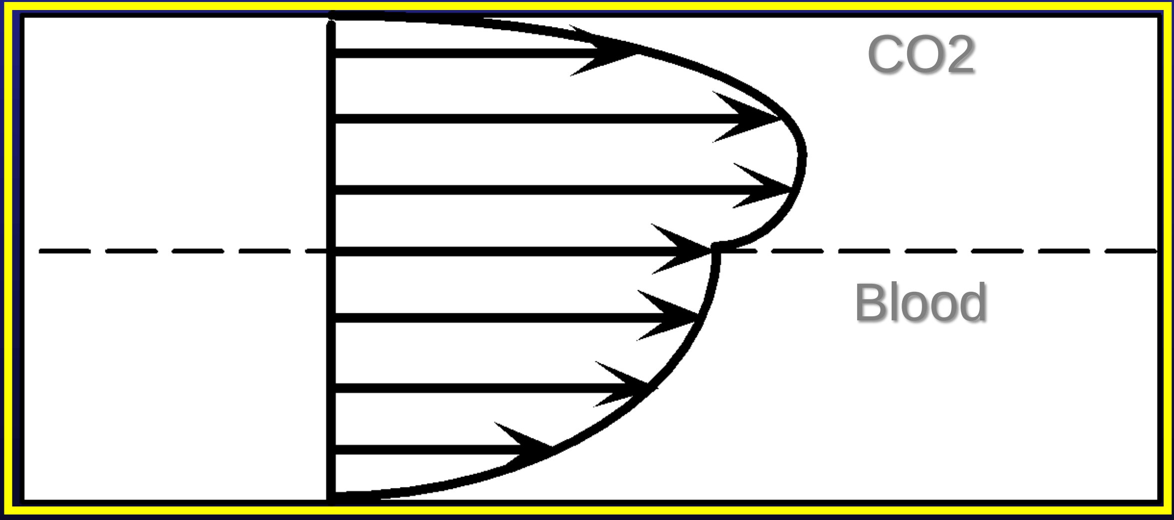
X-table Lat

Lateral CO_2 Aortogram:Median Arcuate Ligament Compression

X-table lateral

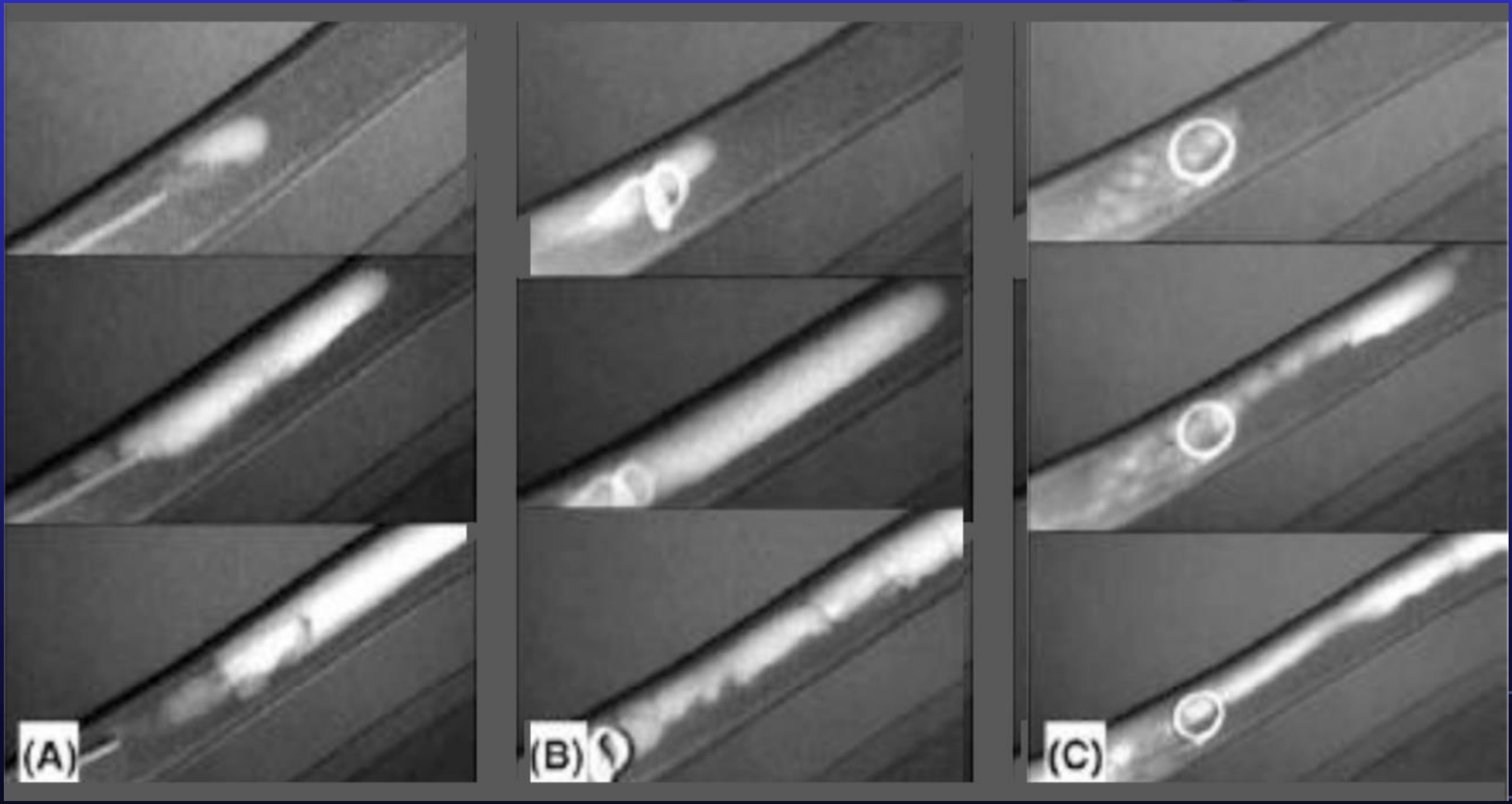
CO_2 Bubble Flow in a 9.5 mm Tube of a Pulsatile Flow Model



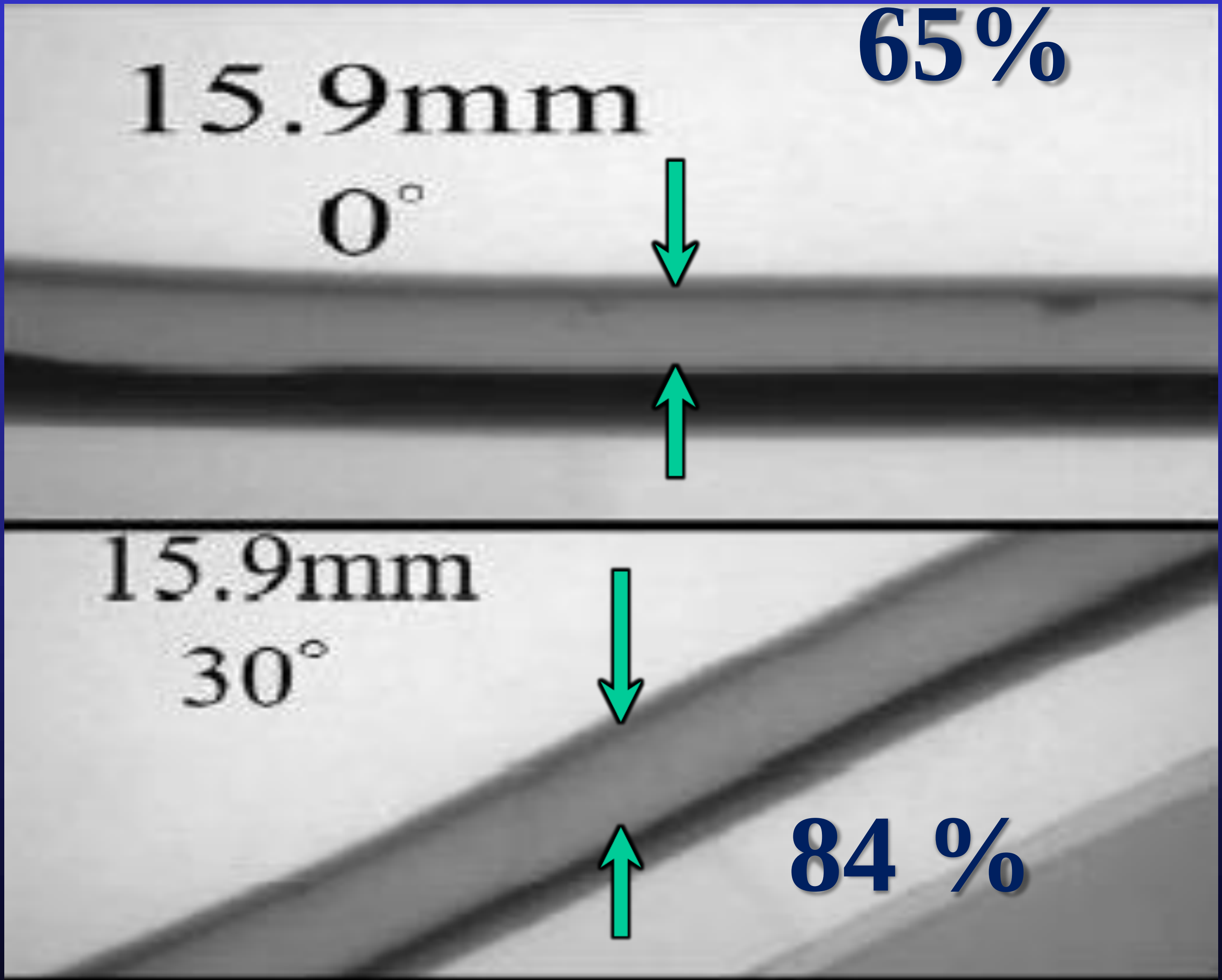


CO_2 Dispersal from Different Catheter Design

Endhole Halo Pigtail



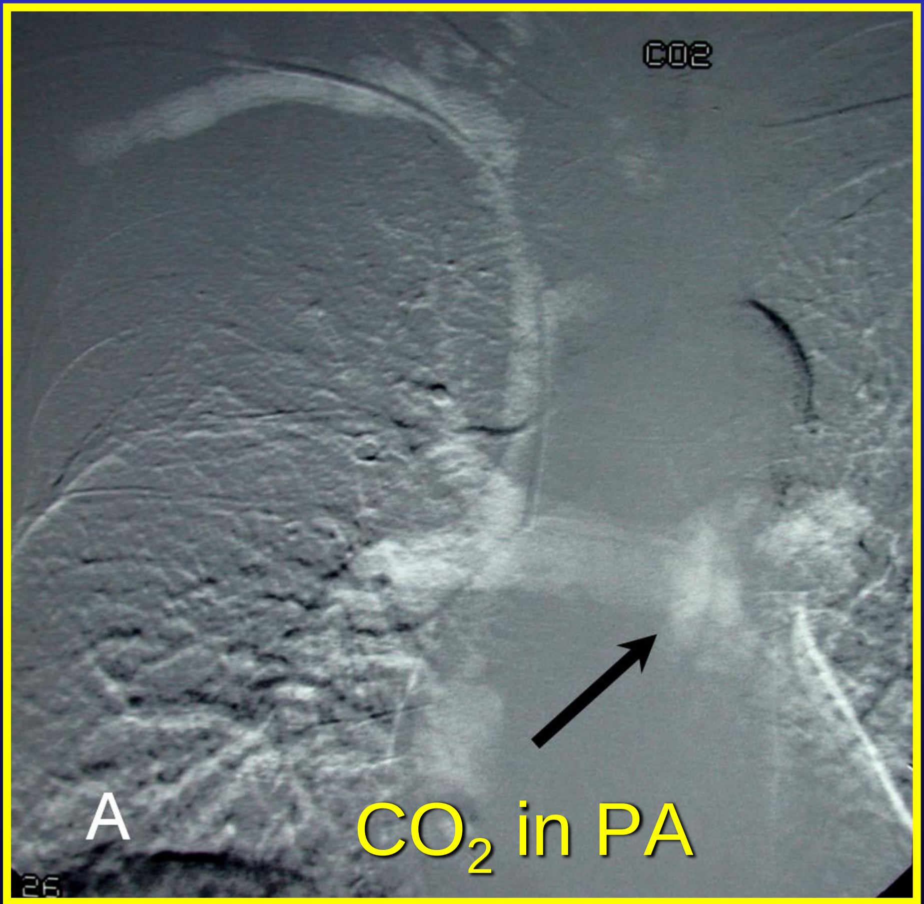
CO_2 Filling of 15.9 mm Tube in Supine vs 30^0 elevation

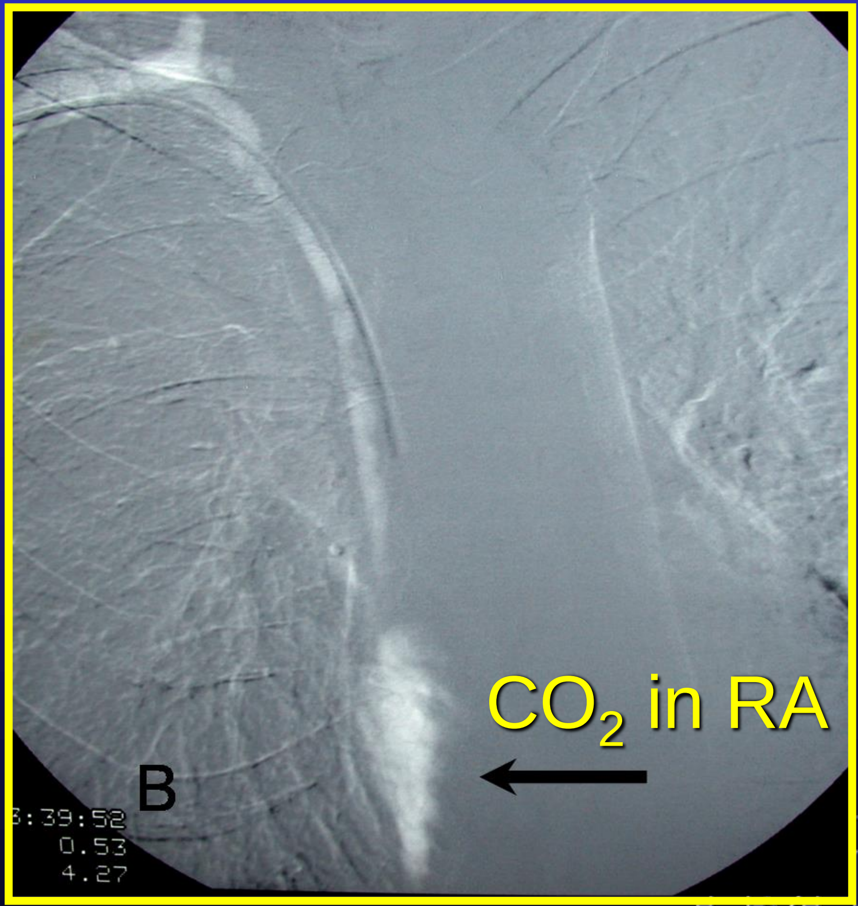


Superior venacavogram with intravenous CO_2 injection

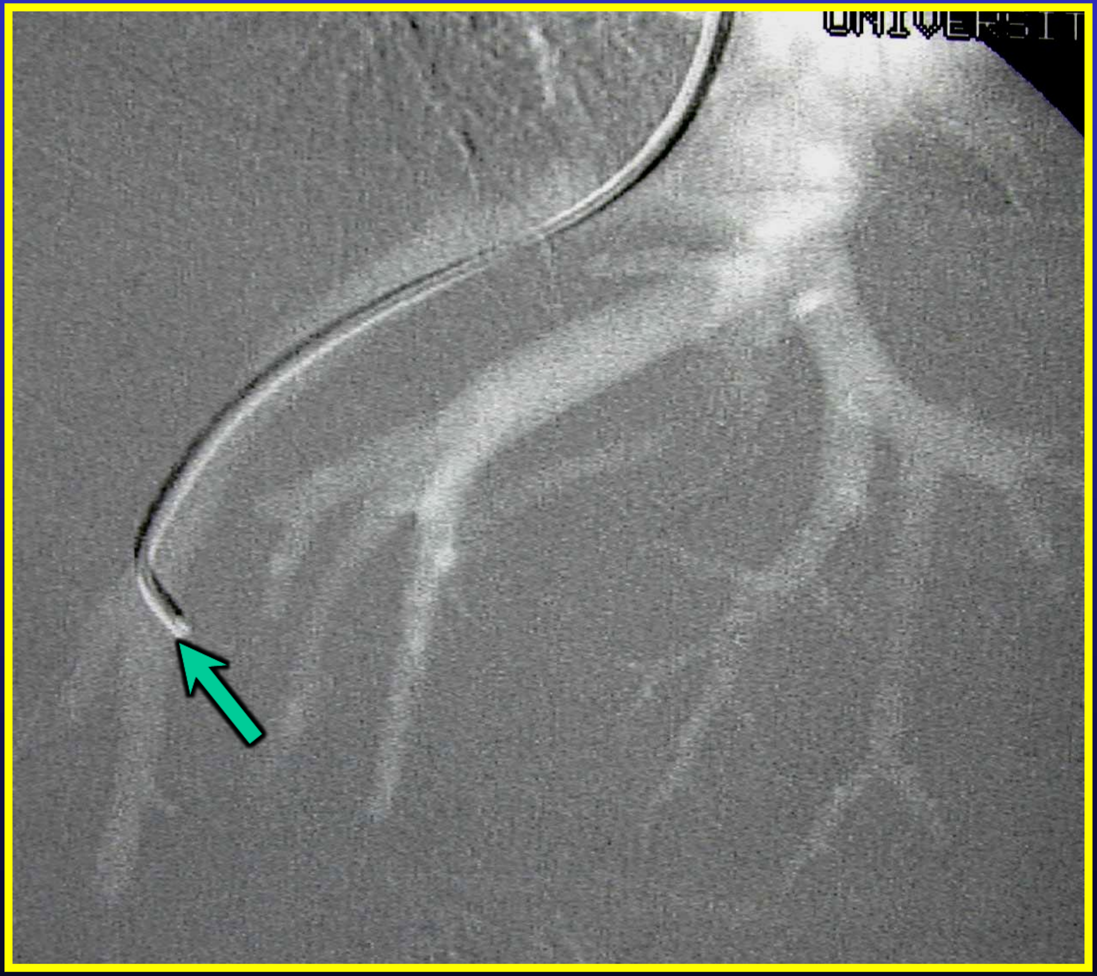
Supine

LLD: X-table Lat

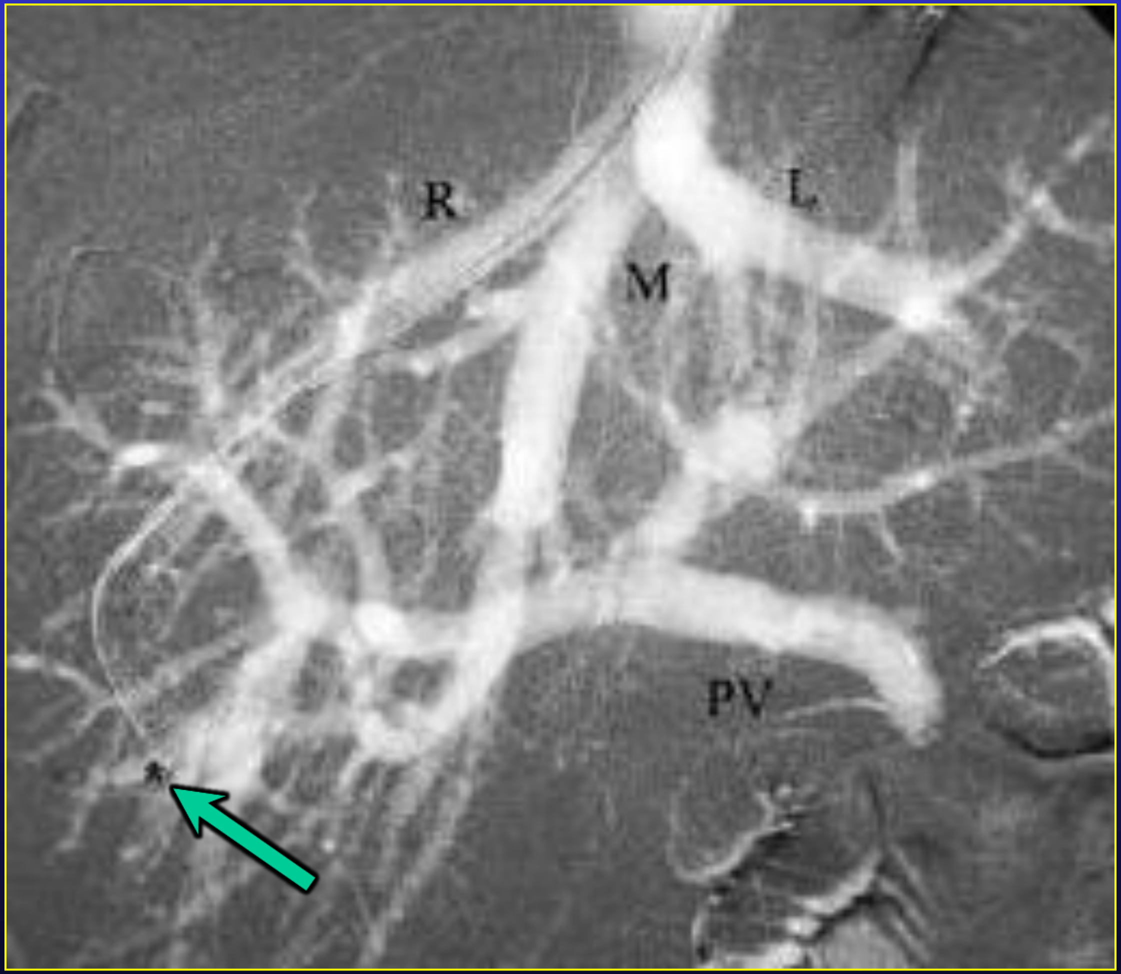




Buoyant CO_2 injected into right hepatic vein filling anterior middle and left hepatic veins



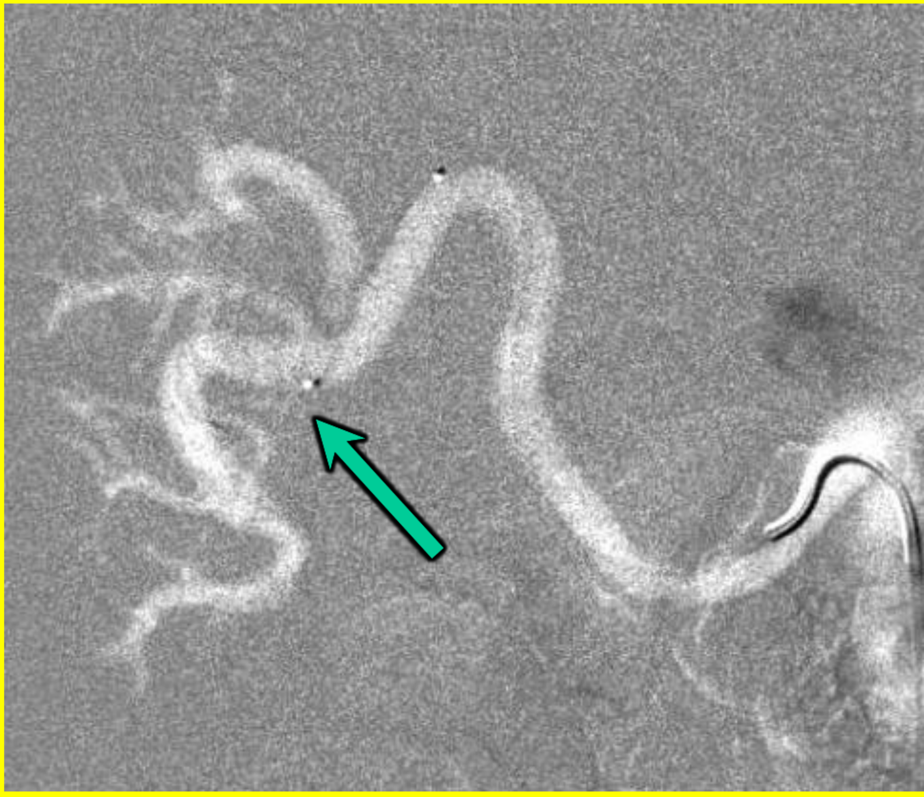
Buoyant, less viscous CO_2 injected into wedged right hepatic vein fills the portal, right, middle and left hepatic veins



Buoyant, compressible CO_2 injected into celiac artery flows backwards, filling the aorta, superior mesenteric and renal arteries

CO_2 Renal DSA

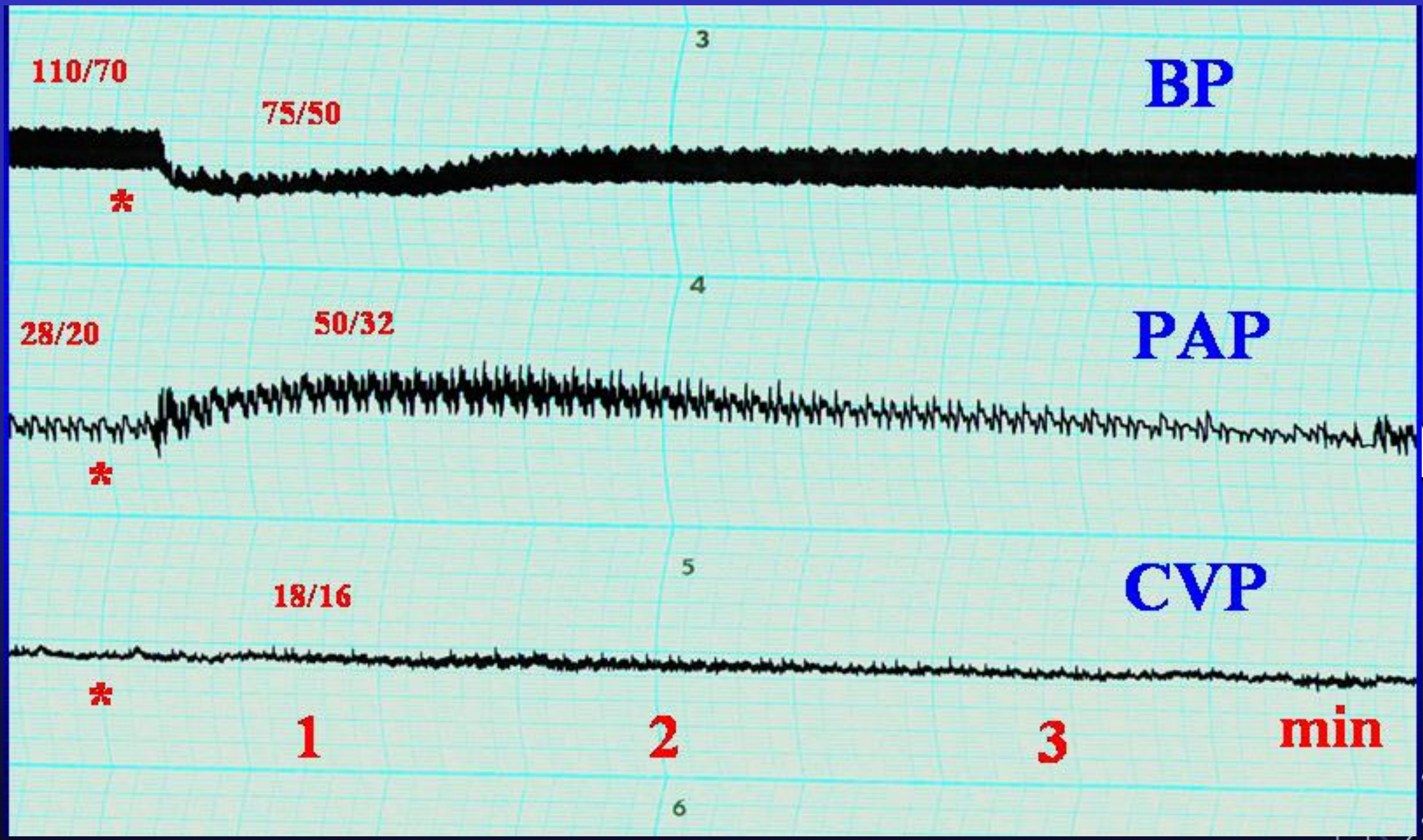
Renal artery aneurysm



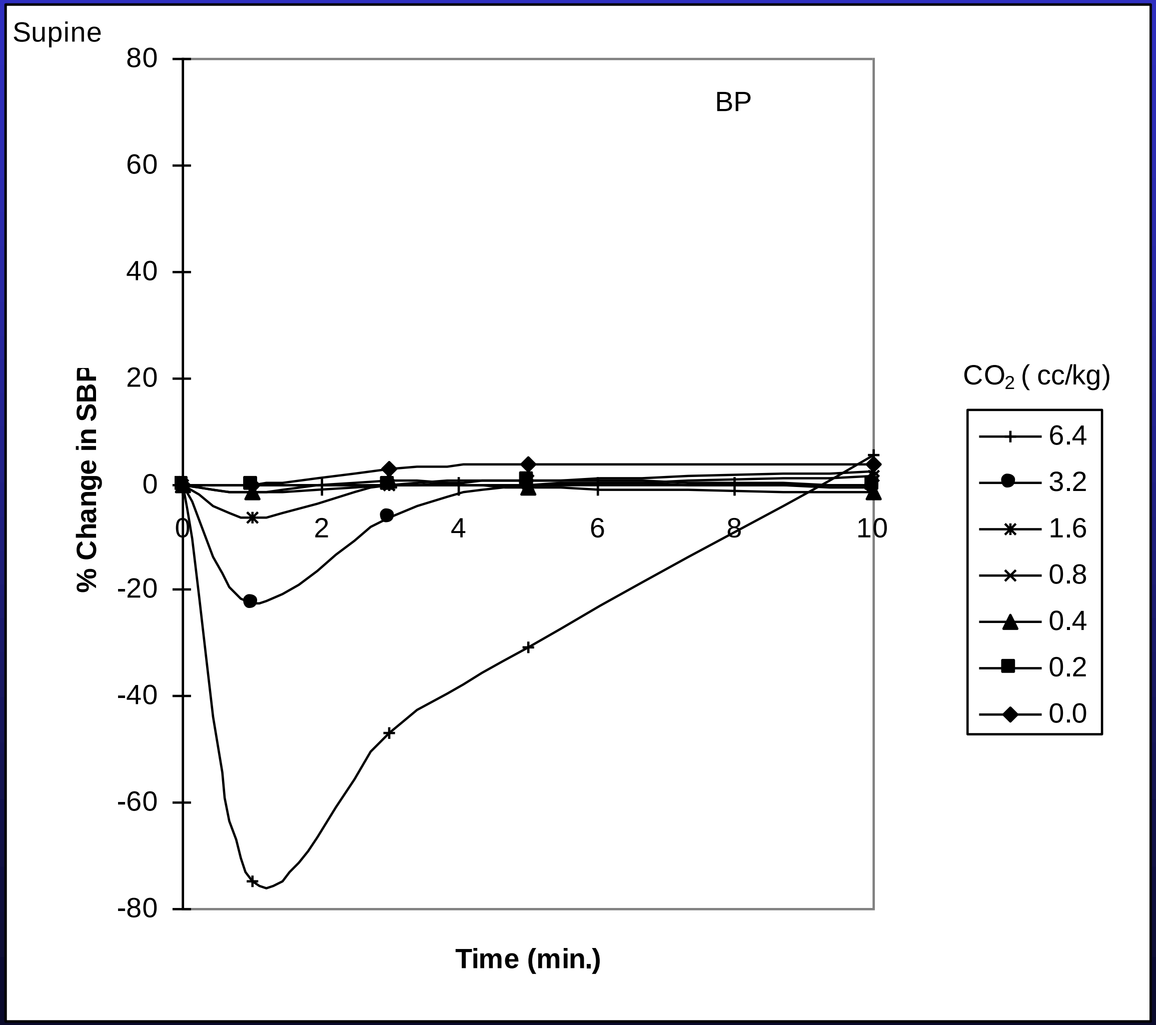
CO_2 injection via microcatheter

The hemodynamic and ventilatory responses to intracaval injections of ascending doses of CO_2

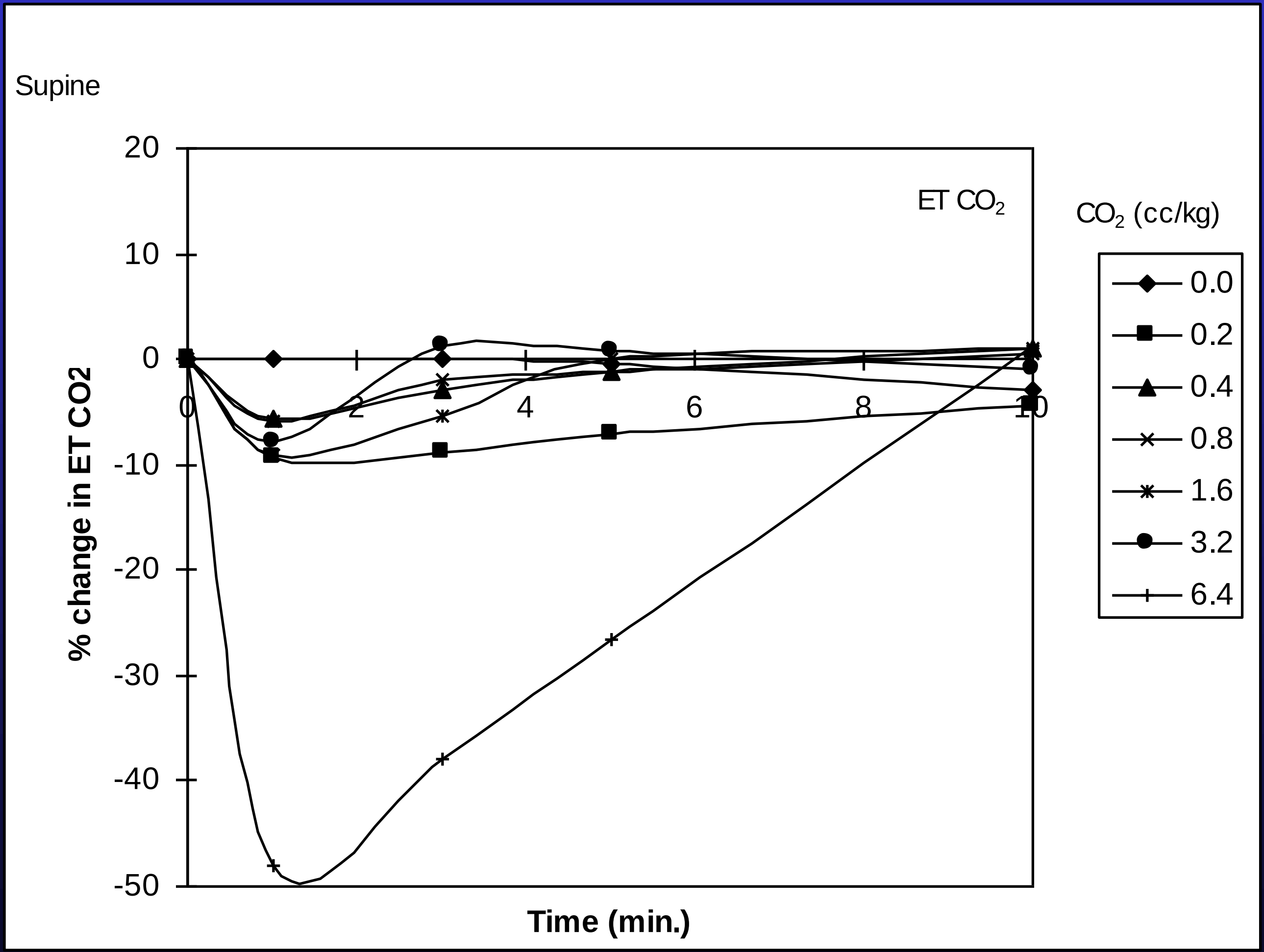
Polygraph tracing of blood pressure, pulmonary artery pressure and CVP following intracaval injection of CO_2 at 3.2 cc/kg in swine



Average percent changes in systemic blood pressure following intracaval injections of ascending doses of CO_2 in swine



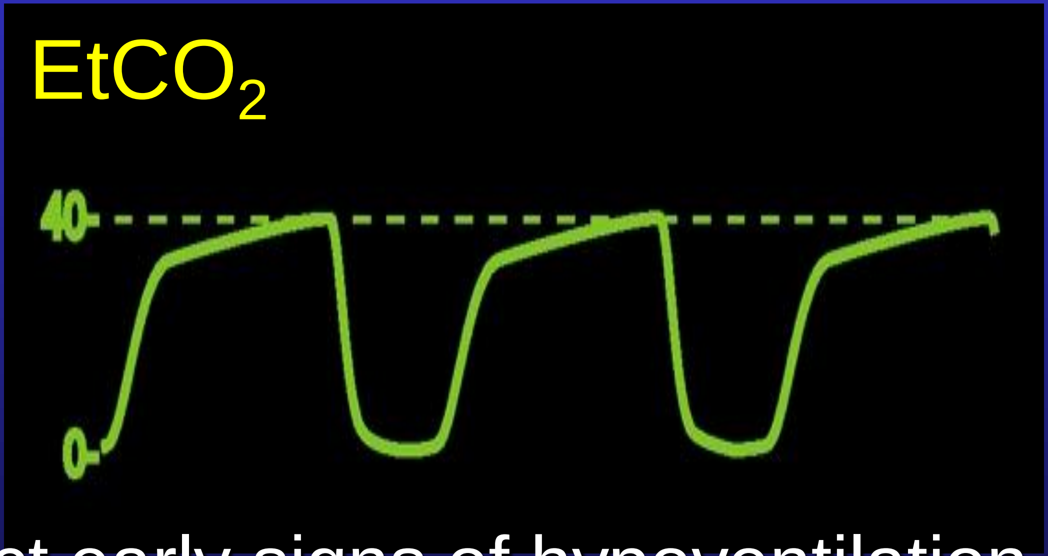
Average percent changes of $ETCO_2$ following intracaval injections of ascending doses of CO_2 in swine



Continuous Monitoring during CO_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

- CO_2 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 CO_2 in doses of 0.2-1.6 cc/kg caused no cardiopulmonary effects in swine.

- CO_2 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.