CO2mmander® and the AngiAssist®

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CARBON DIOXIDE

DIGITAL SUBTRACTION

ANGIOGRAPHY

&

INTERVENTION

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EVOLUTION OF CO₂ IMAGING

- 1914 - Peritoneal evaluation
- 1920’s - Retroperitoneal evaluation
- 1960’s - Hepatic veins and pericardial eval.
- 1970’s - UF Intraarterial trials began
- 1980’s - DSA improved imaging techniques
- 1990’s - CO₂ delivery improved
UF CO$_2$ EXPERIENCE

• 1971 → Present

• > 150 animals

• > 10,000 patients
CO₂ ADVANTAGES

* Non-allergic
* Non-nephrotoxic (unlimited volumes)
* Rapidly absorbed (20-30X O₂)
* Low viscosity (1/400 iodinated contrast)
  * Easier to use with microcatheters
  * Can inject in-between catheter and wire
  * Detection of bleeding, AVF
  * Portal vein visualization
* Central reflux
  * Ability to identify vessel (ostium) central to catheter tip
* Cost (1cc = .005)
CO$_2$ IS THE ONLY PROVEN “SAFE” CONTRAST FOR ALLERGY AND RENAL FAILURE


CO$_2$ UNIQUE PROPERTIES

- Endogenous gas
- Invisible
- Buoyant
- Compressible
### PHYSICAL PROPERTIES OF CO₂ AND PHYSIOLOGICALLY RELATED GASES

<table>
<thead>
<tr>
<th></th>
<th>CO₂</th>
<th>O₂</th>
<th>N₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular wt</td>
<td>44</td>
<td>32</td>
<td>28</td>
</tr>
<tr>
<td>Solubility</td>
<td>0.87</td>
<td>0.03</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Solubility of CO₂ is 29 x that of O₂
SAFETY!!
**THE HEMODYNAMIC AND VENTILATORY RESPONSES TO INTRACAVAL ADMINISTRATION OF ASCENDING DOSES OF GASEOUS CARBON DIOXIDE:**

* Experimental study in 20 swine – Kyung Cho

- CO₂: 0.2 - 6.4 cc/kg
- Position in supine, LLD, RLD
- Monitoring:
  - HR, RR, BP, PA, SaO₂, pCO₂,
  - pO₂, pH, HCO₃⁻,
  - ETCO₂ at 1, 3, 5, & 10 min post CO₂
- Histology of lungs
CONCLUSIONS

* Higher volumes showed various changes in recorded parameters

* $\text{CO}_2$ in doses of 0.2-1.6 cc/kg (112 cc in 70Kg) caused no cardiopulmonary effects.

* Intravenous diagnostic $\text{CO}_2$ DSA may increase PA pressure, $\text{CO}_2$ should be used cautiously in patients with pulmonary hypertension.
**CO\textsubscript{2} INDICATIONS**

- Iodinated contrast allergy
- Renal insufficiency
- High volume contrast procedures
- Detection of arterial bleeding
- Intervention
DELIVERY
Plastic Bag Delivery System

Plastic Bag Delivery System for Hand Injection of Carbon Dioxide

Irvin F. Hawkins, Jr.¹, James G. Caridi, Scott R. Kerns

Digital subtraction angiography with carbon dioxide as a contrast agent provides images useful in making a diagnosis and occasionally gives information not obtainable with use of iodinated contrast material. However, delivery of the gas is difficult because carbon dioxide is compressible and invisible [1, 2]. Over the past 10 years, we have developed a reliable, user-friendly, computer-controlled injector, which is not yet approved by the Food and Drug Administration. We describe a hand-delivery system designed on the basis of principles learned from the development of the computer-controlled injector system.

Materials and Methods

The system has two major components (Fig. 1): a plastic bag (AngioFill Bag Collection System, AngioDynamics, Queensbury, NY) that is used as a reservoir for the carbon dioxide and a closed fluid (or gas) delivery system (AngioFlush II, AngioDynamics) consisting of multiple check valves, stopcocks, and a connecting tube. The reservoir is a 1500-ml plastic bag with a 100-cm connecting tube. In order to remove residual air from the connecting tubing and the bag, a special female-to-female adaptor is connected to the one-way stopcock. After air is removed from the bag, the stopcock is

AngioFill Bag Collection System and Angioflush 11. AngioDynamics
FLACCID CO2 RECEPTACLE

DELIVERY SYRINGE
MEDICAL CUSTOM WASTE BAG AND CONTRAST DELIVERY SET
AngiAssist® Medical Gas Management System

CO₂, Embolics, Thrombolytics, Contrast

One way valve

Proprietary valve
AngiAssist® ADVANTAGES

* Lower profile
* More user friendly
* One component already assembled and sterile
* Can not be connected improperly
* Multipurpose
  * Chemical compounding – chemotherapy, embolics, thrombolytics
  * Tumescent anesthesia
  * Drainage
* Lower cost
ARTERIAL DIAGNOSIS
DETECTION OF BLEEDING / FISTULA

1. CO₂ - low viscosity
2. CO₂ exits the vessel and expands
3. Little or no capillary phase to obscure CO₂
4. CO₂ is not diluted by blood
5. Double the sensitivity and diagnosis of contrast

Hashimoto et al, Sem Interven Rad 1997; 14:163-173
Hawkins et al, Sem Interven Rad 1997; 14:173-180
VENOUS DX & TREATMENT

- Slow gentle injection of 15-30 cc
- CO2 is not diluted by blood and can opacify central veins more readily from a peripheral approach
- Venous PTA and stent placement
- IVC filter placement
- Ultra fine needle splenoportography
- Portal vein access
INTERVENTION
ARTERIAL INTERVENTION

- Reflux - can opacify the entire vessel including ostium for more precise stent placement

- Can inject between guide cath and catheter or wire and catheter to check placement without compromising position for PTA and stenting

- Microcatheter injections for easy opacification

- Can perform repeated injections without the fear of renal failure
<table>
<thead>
<tr>
<th>Condition</th>
<th>Increase</th>
<th>Factor</th>
</tr>
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<tbody>
<tr>
<td>Risk of death</td>
<td></td>
<td>6 x</td>
</tr>
<tr>
<td>Hospitalization</td>
<td></td>
<td>2 x</td>
</tr>
<tr>
<td>1 and 2 year mortality</td>
<td></td>
<td>2 x</td>
</tr>
<tr>
<td>Increase comorbid complications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased cost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

McCullough P. Contrast Induced Acute Kidney Injury. J. Am.Coll. Cardiol 2008; 51:1419-1428
http://content.onlinejacc.org/cgi/content/full/51/15/1419
• Predisposition for renal dysfunction > open

• Occurs in pts with & without renal insufficiency

• ARF = 7 – 25% with & 2.5% without

• Associated mortality is 30 – 50%
Use of CO2 Angiography for Complex EVAR

J Cross, D Smith, L Morgan Rowe, K Hranec, P Hams, T Richards

Introduction:
- Incidence of contrast induced nephropathy is proportional to volume of iodinated contrast used
- Complex EVAR: technically challenging requiring multiple images and larger volume of contrast
- Higher incidence of post op renal dysfunction

Aim:
- To assess role of CO2 as primary contrast agent in complex EVAR

Methods:
- Two Cohorts undergoing branched or fenestrated EVAR were compared:
  - Endpoint: Renal function, Contrast volume, Radiation dose
  - Cohort 1: Iodinated contrast only
  - Cohort 2: CO2 primary contrast

<table>
<thead>
<tr>
<th>Endpoint</th>
<th>Iodinated contrast</th>
<th>CO2</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in creatinine (median)</td>
<td>28.5</td>
<td>9.5</td>
<td>0.048</td>
</tr>
<tr>
<td>Post op renal dysfunction*</td>
<td>13/41</td>
<td>8/27</td>
<td>N/S</td>
</tr>
<tr>
<td>Temporary dialysis</td>
<td>7/41</td>
<td>3/27</td>
<td>N/S</td>
</tr>
<tr>
<td>Vol. iodinated contrast (median)</td>
<td>226.25mls</td>
<td>75mls</td>
<td>N/S</td>
</tr>
<tr>
<td>Radiation dose</td>
<td>52005 Gy</td>
<td>41836 Gy</td>
<td>N/S</td>
</tr>
</tbody>
</table>

CONCLUSION
- Useful adjunct for complex EVAR
- Allows 'unlimited' images
- Renal dysfunction likely to be multifactorial
- Significant reduction in the median creatinine difference

Technique
- Lab grade CO2
- Standard cylinder attached to filter and 3 way tap
- Attach 50 ml syringe with flaswitch to 3 way tap
- Avoid air contamination and fill using cylinder pressure
- Manually compress syringe of CO2
- Rapidly inject gaseous CO2 into aorta in 30-50ml aliquots

<table>
<thead>
<tr>
<th>DEMOGRAPHICS</th>
<th>Iodinated contrast</th>
<th>Primary CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Median age</td>
<td>75 yrs</td>
<td>74 yrs (P=0.15)</td>
</tr>
<tr>
<td>Age range</td>
<td>60-85</td>
<td>69-85</td>
</tr>
<tr>
<td>Median baseline creatinine</td>
<td>96</td>
<td>180 (P&lt;0.01)</td>
</tr>
</tbody>
</table>
CLASSIC CONTRAST ASSOCIATED NEPHROPATHY RISKS

* Diabetic nephropathy
* Myeloma
* Large volume contrast
* Intravascular volume depletion
Comorbid conditions predisposing to CIN
- Renal insufficiency, Diabetes, Hepatic insufficiency

- Peri-procedural medications can predispose to renal failure
  - NSAIDS

- Post embolization syndrome can deplete intravascular volume

- Many embolization procedures require high volume contrast

- Tumor lysis syndrome can induce renal failure

- Rare - non-target embolization of kidneys
- Prospective study 140 patients for HCC
- Pre procedure creatinine 1.1 +/- .2
- 8.6% developed ARF
- 2.8% irreversible renal failure (all diabetics)
- ARF correlated with the number of procedures, severity of liver disease and presence of post-embolization syndrome

Huo et al, Liver International 2004: 24;210-215
Portal vein embolization
Portal vein thrombosis
Portal vein stricture
TIPS
GELATIN BLOCK WITH 1 CM CONDUIT

I- Contrast: 12CC/SEC
GELATIN BLOCK WITH 1 CM CONDUIT

MULTI SIDEHOLE CATHETER: CO2 CC 225 CC/SEC
CO$_2$ GUIDED TIPS

- Hepatic vein evaluation
- Intraparenchymal portal venogram
- Entry site verification
- Portal venogram
- Post procedure portogram
DIRECT INTRAPARENCHYMAL CO₂
- \( \text{CO}_2 \) angiography is safe when used appropriately

- The delivery system is simple and user friendly

- \( \text{CO}_2 \) has unique properties as a contrast agent

- These properties make it a useful tool in both diagnosis and intervention