

Angiography: Venography and Arteriography is performed traditionally with a liquid iodinated contrast (Dye). Unfortunately when used in large doses or smaller doses in patients with compromised kidney function it can lead to worsening of their function or at worst dialysis. These are devastating and expensive.

The ideal way to lessen or prevent this is to decrease the volume of contrast used. Hawkins showed in the late 70's and 80's that carbon dioxide could be supplanted as an imaging agent for angiography. It has absolutely no kidney toxic effects. In addition it 100 cc's costs 3 cents as opposed to 100 dollars of traditional contrast.

Carbon dioxide also has numerous other benefits in diagnosis and treatment when used in angiography.

Replacing traditional contrast with carbon dioxide would not only reduce morbidity and mortality but it would amount to a savings in the millions and even billions.

Figure 7 percent of all angiography results in an untoward effect on the kidneys leading to increased misery and cost.

Non-nephrotoxic (non kidney toxic) Quality of CO₂

Undoubtedly the best advantage of CO₂ DSA is its lack of nephrotoxicity.^{10,29-34} Contrast-induced nephropathy (CIN) is the third leading cause of hospital-acquired renal failure behind decreased renal perfusion and nephrotoxic medications.³⁵ The incidence of hospital-acquired contrast-induced nephropathy approximates 7%³⁶ based on the definition of CIN representing an increase of serum creatinine of 0.5mg/dL or a 25% elevation over baseline which usually occurs within the first 24 hours and peaks up to 5 days following the offending incident.

The significance of CIN was underscored by McCullough.³⁷ He compared individuals who developed hospital-acquired CIN to those who received contrast and maintained stable creatinine. Those with CIN had 5.5 times the incidence (34%) of in-hospital mortality. Those requiring dialysis had even higher rates of mortality. The duration of hospitalization was twice those without CIN accompanied by increased morbidity and cost. In addition, those developing CIN demonstrated chronic effects with increased (2 times) 1- and 2-year mortality. Cardiovascular events were the leading cause of increased morbidity and mortality in these patients.

Rihal et al prepared a retrospective analysis on approximately 7,500 in-hospital patients, of whom 3.3% developed CIN.³⁸ The in-hospital mortality was 22% for those developing CIN vs 1.4% who did not. The 1- and 5-year mortality rates were almost 4 times greater in the CIN group. Therefore the risk of death persists long after discharge. It must be stated that the

incidence of CIN in these two groups was all-inclusive and that the incidence of CIN was much higher proportionately in those with underlying renal insufficiency. The majority of patients with CIN do not undergo dialysis. Today with improved iodinated contrast the incidence of CIN requiring dialysis approximates 4% for those with renal insufficiency³⁹ and 3% for those undergoing percutaneous coronary intervention.⁴⁰

Early animal studies by Hawkins and others showed that CO₂ as an intravascular contrast agent did not affect renal function.⁹ Hawkins later went on to demonstrate this in humans as well. Comparing iodinated contrast, gadolinium, and CO₂ in renal insufficient patients, CO₂ was the only agent not demonstrating an elevation in creatinine.^{41,42} It should be the first-line imaging agent in patients with renal insufficiency requiring vascular evaluation or intervention. Even if there are limitations to the CO₂ imaging it can be used in conjunction with limited diluted doses of iodinated contrast.

Although hydration and cessation of nephrotoxic drugs are helpful, reducing the volume of iodinated contrast is by far the best method for eliminating CIN.⁴³ CO₂ DSA can usually accomplish this alone or as an adjunct to dilute liquid contrast. Moreover, because of the solubility of CO₂ and the fact that it is eliminated via one pass through the lungs when given IV, there is no limit to the total dose delivered. As a result, unlimited volumes can be given provided that individual doses are given as previously discussed.