CO_2 DSA - POTENTIAL COMPLICATIONS AND PREVENTION

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At the University of Florida, CO_2 has been used as an intravascular imaging agent since the early 1970s. During that time period, we have examined greater than 120 animals and 1400 patients. The purpose of using CO_2 as an intravascular imaging agent is to utilize its specific advantages when compared to iodinated contrast. These include the lack of allergic potential and renal toxicity, the ability to use unlimited total volumes, its low viscosity, minimal discomfort, and insignificant cost. CO_2 affords these advantages in part because it is a gas. But as a gas, it is also buoyant, invisible, and compressible. These unique features must be well understood to avoid unusual, albeit rare, complications that can occur.

Because CO_2 is invisible, contamination can often go undetected. Contamination may arise from either the CO_2 source, or, more commonly, from room air. Early in our experience, we investigated CO_2 cylinders acquired from hospital stores. They were found to contain not only CO_2 but also rust, water, particulate matter, and even methane. Therefore, these could easily be inadvertently administered without detection. Similarly, room air can contaminate the system based on diffusivity, misdirected stopcocks, the Venturi effect, or inappropriate flushing of the delivery system. Considering diffusivity, anytime the delivery system is opened to room air, the differences in partial pressures of CO_2 and the constituents of room air will cause CO_2 to be replaced at approximately .2 cc/sec. In fact, in an open 20 cc syringe, 80% of CO_2 will be replaced within one hour. Additionally, room air can enter through misdirected stopcocks or with the stopcock in the correct position via the Venturi effect. The end result is air embolism with its associated high incidence of mortality (CO_2 is twenty times more soluable than O_2).

Unlike liquid contrast, CO_2 does not mix with blood, but must displace it to render a diagnostic image. Because of its buoyancy, it floats and assumes a nondependent position. This can work as an advantage in many instances in which the nondependent portion of a vessel is to be evaluated. However, under certain circumstances, e.g., if an excessive volume is injected with a single injection, this principle of buoyancy may cause CO_2 to trap anteriorly. This provides the potential for a vapor lock phenomena in which the trapped CO_2 precludes blood flow to that area. If uncorrected, ischemia can occur.

Unlike liquid contrast, CO_2 is compressible. Consequently, when receiving CO_2 from a source which is typically under pressure, the volume in the syringe may be much greater than the stated amount. When this is delivered, the gas compresses in such a manner that 95% will exit the catheter in the last ½ second of the injection. This results in an uncontrolled explosive delivery. In our experience, this has resulted in pain and abdominal cramping, as well as nausea and vomiting. The resulting excessive volumes may precipitate trapping, vapor lock and ischemia.

Other theoretical problems include the possibility of neurotoxicity, complications of nitrous oxide anesthesia, and its use in COPD. Considering neurotoxicity, animal studies and human experiences have been inconclusive. It is not certain whether the "neurotoxic" changes described are the result of CO_2, explosive delivery, or secondary to contamination by room air.

Regarding nitrous oxide anesthesia, the less soluble nitrous oxide will diffuse from the soft tissues and enter the CO_2 bubble causing it to enlarge as well as dilute. The gas bubble will therefore be larger and persist longer. It is estimated that it will become 5.5 times more occlusive than CO_2 alone. This can have serious repercussions if used intravenously and the gas bubble resides in the heart.

Finally, CO_2 has been used routinely in patients with COPD without any serious complications.

When employing CO_2 DSA, it is important to recognize the precipitating factors already described. Although extremely rare, when used casually they can precipitate potential complications. By following a few simple guidelines while using either the dedicated CO_2 injector or the non-compressed, closed plastic bag delivery system, these complications can be virtually eliminated.

Contamination in the cylinder can be eliminated by using disposable, medical grade pure CO_2. To eliminate room air contamination, a closed system, such as the dedicated injector or non-compressed plastic bag system, can be used. An attempt should be made to eliminate virtually all stopcocks by using one-way check valves. All connections should be glued to eliminate the Venturi effect. Finally, the system should be purged vigorously to remove any residual room air that may be present.

Delivery of a controlled volume is imperative when using CO_2. This can be accomplished by using a closed system which is not under pressure. Therefore, a known volume will be contained in the delivery syringe. To reduce compression of the gas during injection, the diagnostic or therapeutic catheter should be purged of blood or saline prior to injection. We also recommend that at least one sidehole be placed in the catheter in the event that explosive delivery does occur. This will prevent the undesirable complication of dissection if the catheter happens to be wedged.

If there is a concern for trapping, the area of potential involvement can be examined using fluoroscopy. If persistent gas is present, this site can be placed in the dependent position allowing CO_2 to exit and blood flow to resume. The best way to prevent trapping from occurring is to eliminate excessive volumes which can be the result of either one large or multiple small injections given in rapid succession.

The first and foremost means of preventing excessive volumes is NEVER connect directly to the CO_2 cylinder. Most CO_2 cylinders contain at least 3.3 million cc of pressurized CO_2 . If connecting stopcocks are misdirected, CO_2 can flood the vascular system, possibly resulting in occlusion. We therefore recommend a closed system with a limited potential volume. We also advise delivering known volumes of non compressed gas. We wait 1-2 minutes before each injection to allow for dissolution of the CO_2. Also, the volumes are limited to less than 100 cc per injection. This is more than sufficient for diagnostic and therapeutic applications. To reduce volumes even further, we employ "stacking" software which superimposes multiple exposures to generate a composite image.

Because of the uncertainty of neurotoxicity, we never use CO_2 in the arterial system above the diaphragm. A controlled nonexplosive delivery is performed to eliminate explosive delivery and reflux into the cerebral circulation. Moreover, CO_2 is never delivered in the prone position or with the patient's head elevated.

Minor side effects are eliminated by preventing explosive delivery. Selective injections at lower volumes also reduce rare but potential discomfort. The catheter position is also kept below the mesenteric vessels until that area is to be evaluated to limit the repetitive exposure of these anteriorly positioned vessels.

Although the use of CO_2 in patients with COPD has not been a problem, the potential may exist. Therefore, in these patients, we limit our volumes and increase the delay between injections. If necessary, in patients with extremely severe disease, blood gases can be obtained during the examination.

With the use of CO_2 DSA, the potential for complications is exceedingly rare when using a dedicated CO_2 delivery system and abiding by a few but significant guidelines. It is safe and efficacious with specific advantages when compared to iodinated contrast. It is imperative that its properties, potential problems, and prevention be well understood to avoid future complications that could limit its use.

Objectives:

1. To restate the advantages of CO_2 Digital Subtraction Angiography.
2. To describe those attributes which make CO_2 advantageous as an imaging agent, but also identify how these unique properties can potentially cause unusual complications.
3. To express how the employment of simple guidelines as well as the correct delivery system can virtually eliminate all potential complications.
4. To reiterate the safety and efficacy of CO_2 as an imaging agent as long as certain guidelines are followed.

References:

1. Caridi JG, Hawkins IF. CO2 Digital Subtraction Angiography: Potential Complications and Their Prevention. JVIR 1997; May - June (at press)
2. Hawkins IF. Carbon dioxide digital subrraction arteriography. AJR 1982; 139:19-24.
3. Kerns SR, Hawkins IF. Carbon dioxide digital subtraction angiography: expanding applications and technical evolution. AJR 1995; 735-741.
4. Yang X, Hannu M, Soimakallio S. Carbon dioxide in vascular imaging and intervention. Acta Radiologica 1995;36:330-337.5

5. Frankhouse JG, Ryan MG, Papanicolaou G, et al. Carbon dioxide/digital subtraction arteriography-assisted transluminal angioplasty. Annals of Vascular Surgery 1995; 9(5):448-452.

6. Hawkins If, Mladinich CRJ, Storm B, et al. Short-term effects of selective renal arterial carbon dioxide administration on the dog kidney. JVIR 1994; 5:149-154.

7. Weaver FA, Pentecost MJ, Yellin AE, et al. Clinical applications of carbon dioxide/digital subtraction arteriography. Journal of Vascular Surgery 1991; 13(2)266-272.

8. Coffey R, Quisling RG, Mickle JP, Hawkins IF Jr, Ballinger Wb. The cerebrovascular effects of intra-arterial CO2 on quantities required for diagnostic imaaging. Radiology 1984; 15:405-410.

9. Shifrin EG, Plich Wb, Verstandig AG, Comori M. Cerebral angiography with gaseous carbon dioxide CO3. J Cardiovasc Surg 1990; 31:603-606.

10. Ehrman KO, Taber TE, Gaylord GM, Brown PB, Hage JP. Comparison of Diagnostic Accuracy with Cargon Dioxide versus Iodinated Contrast Material in the Imaging of Hemodialysis Access Fistulas. JVIR 1994; 5:771-775.

11. Bettmann MA, D'agostino R, Juravsky LI, et al. Carbon dioxide as an angiographic contrast agent. A prospective randomized trial. Investigative Radiology 1994; 29:S45-S46.

12. Sullivan KL, Bonn J, Shapiro MJ, Gardiner GA Jr. Venography with carbon dioxide as a contrast agent. Cardiovasc Intervent Radiol 1995; 18:141-145.

13. Hawkins IF Jr, Caridi JG, Kerns JG. Plastic bag dilivery system for hand injection of carbon dioxide. AJR 1995; 165:1-3.

14. Steffey EP, Johnson BH, Eger EI. Nitrous oxide intensifies the pulmonary arterial pressure response to venous injection of carbon dioxide in the dog. Anesthesiology 1980; 52:52-55