

peer reviewed **ARTICLE OF INTEREST**

## Carbon dioxide angiography for peripheral vascular intervention

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### Abstract

Carbon dioxide angiography (CDA) is a relatively modern technique performed during interventional vascular procedures. Compared to traditional angiography using iodinated contrast media (ICM), CDA poses very little risk to a patient. Carbon dioxide (CO<sub>2</sub>), as an imaging agent, is particularly useful for those patients in whom ICM is contraindicated. It may also be used in combination with ICM in some cases. This paper provides insight into the basic principles of CDA and its contribution to modern day medical imaging for the treatment of peripheral vascular disease.

### Keywords

Imaging agent, interventional vascular procedures, femoral artery stents, abdominal aortic aneurysms.

### Introduction

Angiography can be defined as the radiographic imaging of blood vessels within the human body after the administration of iodinated contrast media (ICM).<sup>[1, 2]</sup> Angiograms are performed daily to diagnose and treat various vascular diseases. Interventional vascular procedures, in general, are minimally invasive and can be described as a non-surgical treatment applied in order to improve the blood flow within the vessels.<sup>[3]</sup>

Carbon dioxide angiography (CDA) was discovered in 1971 when 70cc of room air was accidentally administered intra-arterially instead of ICM during a diagnostic procedure. The surgeon was, however, able to view the vessels and its branches as a negative contrasted image without having imposed any adverse effects on the patient.<sup>[4]</sup> After this incident, the use of carbon dioxide (CO<sub>2</sub>) gas in medical imaging was explored and tested using animal models.<sup>[4, 5]</sup>

The use of intravenously administered, purified medical grade CO<sub>2</sub> gas, as an imaging agent, proved to be harmless compared to ICM.<sup>[4, 6]</sup> Due to the lack of modern technology during this era (1970s), the image quality was poor. A few years later, during the 1980s, digital subtraction angiography (DSA) was developed and the use of CO<sub>2</sub> became a sustainable vascular imaging agent.<sup>[4]</sup> DSA refers to the visualisation of blood vessels by removing the background anatomical structures to enhance the radiographic contrast of specific structures, in context, the blood vessels under investi-

gation.<sup>[1]</sup> The use of CO<sub>2</sub> as a contrast agent has been validated in numerous clinical studies, especially for the treatment of renal artery stenosis, abdominal aortic aneurysms (AAAs) and peripheral vascular disease.<sup>[7]</sup>

Although CO<sub>2</sub> was used primarily in patients with renal failure, and for those patients who were allergic to ICM, its application is being expanded. It can be used in combination with ICM for both

adults and children.<sup>[4]</sup> The use of CO<sub>2</sub> has numerous advantages compared to ICM. Since CO<sub>2</sub> is a natural byproduct, all possibilities of allergic reactions can be excluded.<sup>[5]</sup> Larger quantities of CO<sub>2</sub> may be administered during interventional vascular procedures as the gas is removed effortlessly during respiration. It is important to note, however, that sufficient time (30 to 60 seconds) must be allowed by the operator between CO<sub>2</sub> injections to allow for clearance of the gas.<sup>[5]</sup>

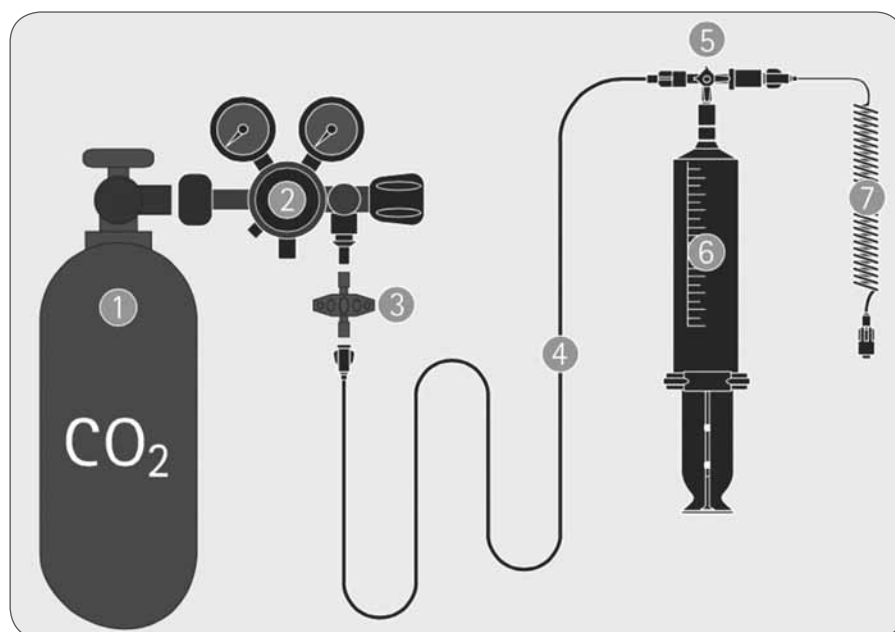


Figure 1. Basic illustration of a CO<sub>2</sub> delivery system.<sup>[12]</sup>

Key: 1. Medical grade CO<sub>2</sub> cylinder  
2. Regulation valve  
3. Filter  
4. Delivery tube  
5. Two-way tap  
6. Volume control syringe  
7. Connection to patient

## Basic working principles

The method for CO<sub>2</sub> delivery has improved over the years and there are various delivery systems on the market. It is delivered from a disposable source and requires a connective mechanism to deliver it from the source to a patient as illustrated in Figure 1. The gas is delivered by means of a closed system to prevent contamination with room air. There is no specific patient preparation required for CDA.

Once administered, the CO<sub>2</sub> gas combines with water (found within the blood plasma) which forms carbonic acid. Within the bloodstream, it becomes bicarbonate (HCO<sub>3</sub><sup>-</sup>) which reverts back to CO<sub>2</sub> before diffusing through the capillaries into the lungs. Carbon dioxide is transported in the blood in three ways: 85% as bicarbonate ions; 10% binds with the haemoglobin; and approximately 5% dissolve directly in the blood. It is highly unlikely that any vascular damage will occur due to the administration of CO<sub>2</sub>. However, minor discomfort (pain) may be experienced by a patient should excessive volumes of CO<sub>2</sub> be administered by the operator without allowing sufficient time for the clearance of the gas. It is less dense compared to blood plasma, therefore when a patient is positioned supine the gas floats on blood, especially when administered into the larger vessels.<sup>[4]</sup> It does not mix with the bloodstream whereas ICM does.<sup>[5]</sup> The quality of the images is therefore directly dependent on the amount of blood being displaced by the CO<sub>2</sub>.<sup>[4]</sup>

During the imaging process, increased frame rates are essential to acquire images due to the quick passage of CO<sub>2</sub> through the bloodstream. The majority of imaging systems function optimally with CDA by setting 7.5 frames per second (fps). The increased fps rate, unfortunately, increases the radiation dose delivered to a patient. Bowel gas may also obscure the images. It may demonstrate the same density as CO<sub>2</sub>.<sup>[8]</sup>

## Indications and contraindications

Indications for CO<sub>2</sub> varies. For example, risk of allergic reactions to ICM, patients in renal failure, procedures that may require high volumes of ICM, the evaluation of renal transplant patients, patients with peripheral artery occlusive disease, as well as the diagnosis and intervention in the venous system. Contraindications for the use of CO<sub>2</sub> may include, but are

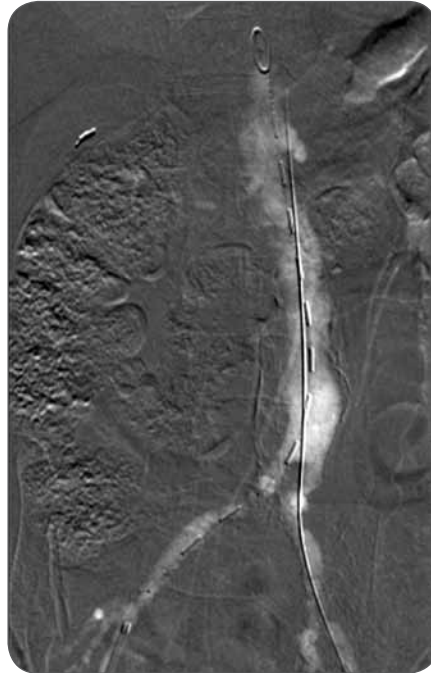


Figure 2a. Pre treatment.

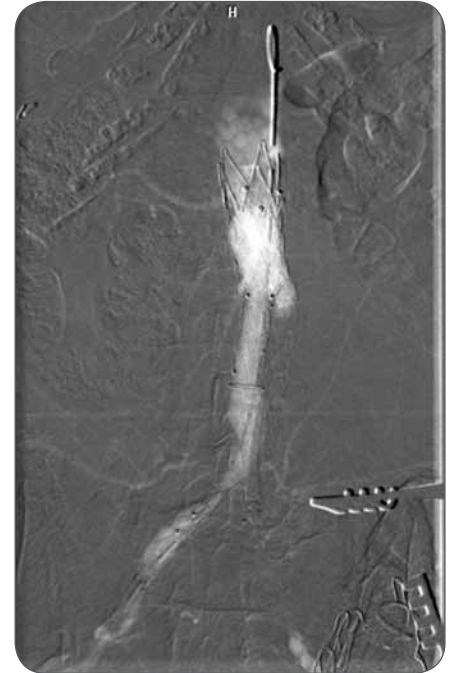


Figure 2b. Post treatment.



Figure 3a. Pre treatment.



Figure 3b. Post treatment.

not limited to patients with pulmonary insufficiency, patients with arteriovenous malformations as well as atrial and ventricular septal defects (ASD and VSD). A study of the vessels above the level of the diaphragm is contraindicated due to concern about possible air embolism to the brain.<sup>[4]</sup>

## Operator experience

To date, the co-author has successfully treated eight patients with AAAs, placed 11 iliac artery stents and 27 femoral artery

stents under the imaging guidance of CDA. Figures 2a and 2b are the pre and post treatment images of a patient who presented with an AAA. This patient urgently required an interventional endovascular aneurysm repair (EVAR) by placing a stent graft. The patient had compromised renal function. Therefore, CO<sub>2</sub>, in combination with a small volume of ICM, was used for imaging guidance. Traditionally, approximately 100-250 mL of ICM are used during EVAR procedures; however, only 10-20 mL were administered for this

patient. The reason for administering ICM in this patient was to improve the image quality due to the rapid blood flow within the abdominal aorta. Premedication in similar cases is advised to prevent the possibility of allergic reactions occurring. AAAs are common and life threatening due to the risk of rupture. Between 65% and 90% of patients with ruptured AAAs will die due to the consequences of massive blood loss. Men over the age of 65 years are at greater risk for the development of an AAA compared to women. Although an AAA can be asymptomatic, it may cause acute abdominal and back pain due to compression of the spine and enlarged nerve roots. AAAs may be identified upon palpation during routine physical examinations. In order to diagnose them, the use of ultrasound (US), computed tomography (CT), magnetic resonance imaging (MRI) and/or angiography, is recommended. Surgical repair is recommended for the treatment of AAAs: either by open surgery or by stent graft placement.<sup>[9]</sup> The treatment applied to this patient is in keeping with standard protocol: a stent graft was placed.

Figures 3a and 3b are the pre and post treatment images of a patient who presented with a distal femoral artery occlusion. The patient required urgent interventional treatment. Pure medical grade CO<sub>2</sub> was

used for imaging guidance. Vascular occlusion can be defined as the blockage of a vessel (arteries and/or veins). This blockage may be as a result of the rupture and thrombosis of atherosclerotic plaque, an embolus from the heart or large arteries, aortic dissection as well as acute compartment syndrome.<sup>[10]</sup> Occlusive artery disease (OAD) can be diagnosed by conducting a complete lower-extremity pulse examination, starting at the abdominal aorta all the way to the feet. Planar angiography, magnetic resonance angiography (MRA), computed tomography angiography (CTA), and duplex ultrasonography, are the recommended imaging investigations for evaluating the extent of an occlusion. Literature suggests that surgical treatment may be considered by open bypass surgery or by balloon dilatations and/or stents.<sup>[11]</sup> The applied treatment for this patient is in keeping with standard protocol as a stent was placed.

The co-author found that patients, undergoing peripheral vascular intervention utilising CO<sub>2</sub> as an imaging agent, may experience pain. The exact reason is however unknown. It is recommended that such patients should receive regional or light general anesthesia. The less pain experienced by a patient, the better his/her co-operation would be. Image quality would thus be increased as there would

be minimal patient movement. The co-author further recommends that the catheter, through which CO<sub>2</sub> is delivered, should be placed as close as possible to the area of interest to improve the quality of the images.

### Ethical considerations

Permission for publishing this paper with the patient images was obtained. No identifiable details of the patients, and the hospital where their treatment took place, have been revealed.

### Conclusion

This paper presents a literature review on CDA, as well as the experiences of the co-author with CDA. CDA is extremely useful, especially for those patients in whom ICM is contraindicated. It is the opinion of the author that radiographers need to be updated on the latest imaging agents and/or techniques. This paper thus should contribute to the knowledge of diagnostic radiographers who are practicing within this environment.

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