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The use of carbon dioxide as a contrast agent in critical ischemia lower extremities

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Abstract

The purpose of the study was to evaluate the possibility of clinical use of medical carbon dioxide as an alternative contrast agent for visualization of the arteries of the lower extremities in patients with critical ischemia of the lower extremities. During the period from January 2018 to December 2022, 153 patients aged 37 to 75 years (mean 56.2±12.5 years) underwent 39 arteriographies using medical carbon dioxide as a contrast agent. This use of medical carbon dioxide makes it possible to get high-quality contrast of the vascular bed in the lower extremities and in some cases has advantages over the use of water-soluble or iodine containing contrast agents in patients with critically ischemia of the lower extremities.

Keywords: Contrast Agent; Carbon Dioxide; Critical Ischemia Lower Extremities; Diabetes Mellitus; Atherosclerosis.

1. Introduction

During an angiographic examination, contrast agents (CMs) and surrounding tissues absorb X-rays to varying degrees, thereby achieving radiopacity. Depending on density and atomic weight, all materials can be divided into positive and negative contrast media. Iodine-containing contrast agents are positive, and carbon dioxide is a negative contrast agent [1]. The X-ray contrast of HF increases with increasing its atomic number and density.

At room temperature, CO2 is a colorless, odorless gas. Its concentration in the atmospheric environment is normally 0.03%. Carbon dioxide has high buoyancy, as well as 400 times lower viscosity than iodine-containing HF. Carbon dioxide is safe for intravascular infusion. It does not cause distal peripheral embolism, since the solubility of this gas in liquids is 20 times greater than that of oxygen.

Carbonic anhydrase catalyzes the formation of carbonic acid from carbon dioxide and water. Carbonic acid, in turn, quickly dissociates into hydrogen ions and bicarbonates. Bicarbonates move into the plasma and quickly dissolve. Carbon dioxide at high partial pressure in the capillary part of the alveoli is quickly utilized by diffusion through their membrane and removed through exhalation [2].

Contrast agents mix with the blood, while carbon dioxide displaces it. Despite the insignificant difference in density between CO2 and the surrounding soft tissues, it can be verified using the digital subtraction angiography (DSA) mode.

2. Material and methods

From January 2018 to December 2022, 153 patients aged 37 to 75 years (mean 56.2±12.5 years years) underwent angiographic studies using carbon dioxide as a contrast agent. The studies were carried out on a modern angiograph in DSA mode. To perform carboxyangiography, a special syringe-supercharger and certified medical carbon dioxide were used (Figure 1). The system components included: a syringe dispenser with a volume of 100 ml, a catheter to the patient

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with a length of 1.5 m, a special three-position tap with a valve that can be rotated counterclockwise by 900° for injection and carrying out the procedure, a gas supply line with a length of 1 .0 m with connection to the gas cylinder pressure regulation valve. For abdominal aortoarteriography, a standard Pigtail 6.5 F catheter was used, installed according to the standard method above the renal arteries and above the aortic bifurcation. For selective catheterization, catheters such as Cobra 5 F and JR 3.5 were used. Carbon dioxide was injected into the vascular bed at a pressure of 1.3 bar (according to the recommendation of the syringe-supercharger manufacturer).

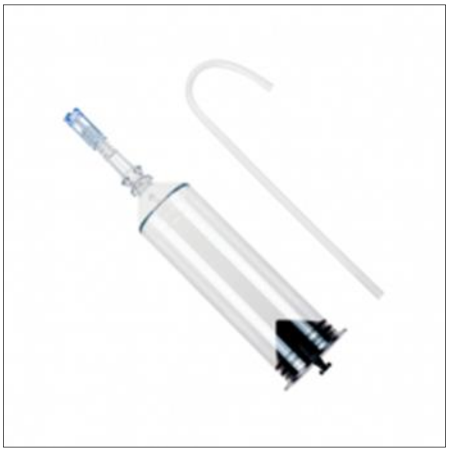

Figure 1 Syringe-supercharger for carboxy-angiography.

3. Research results and discussion

When carbon dioxide was introduced into the infrarenal aorta, due to the high buoyancy of the gas, in all cases it spread to varying degrees in a retrograde direction into the thoracic aorta, which was the reason for refusing to use CO2 in angioplasty - graphic studies above the diaphragm (Figure 2). When carbon dioxide was injected into the right external iliac artery, retrograde propagation of gas was revealed with simultaneous contrast enhancement of the aorta and contralateral iliac and femoral arteries. This fact makes it possible to perform angiographic studies on an outpatient basis using a puncture method through a thin pediatric needle.

The volume and rate of carbon dioxide injection to obtain a high-quality angiogram were established empirically, starting with a few cubic centimeters of CO2. For example, to obtain a high-quality angiogram of the aortoiliac segment with a catheter installed above the renal arteries, it is necessary to administer 50–60 ml of CO2 at a rate of 30–40 ml/s. For adequate imaging of the iliofemoral segment with a catheter installed at the level of the aortic bifurcation, the injection of 35–40 ml of CO2 at a rate of 30–40 ml/s is required. For high-quality visualization of the femoral arteries, selective injection requires a smaller volume of carbon dioxide (20–25 ml). When introduced into the superficial femoral artery, CO2 spread above the injection site and filled the deep femoral artery with visualization of the smallest collaterals.

With selective administration, good visualization of the renal artery was achieved by using CO2 in a volume of 10 ml (Figure 3). All patients noted the appearance of a sensation of warmth along the distribution of carbon dioxide, and 9 (23%) of 39 patients indicated short-term paresthesia in the lower extremities.

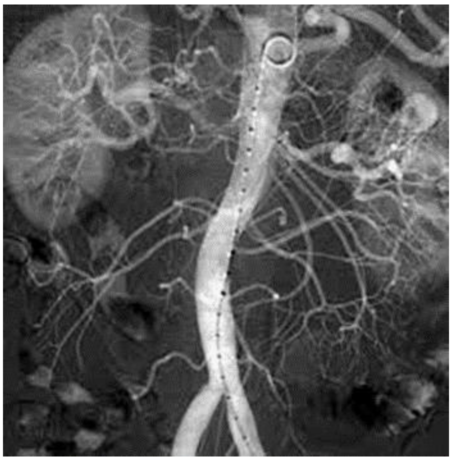

Figure 2 Carboxy Angiography of the abdominal aorta

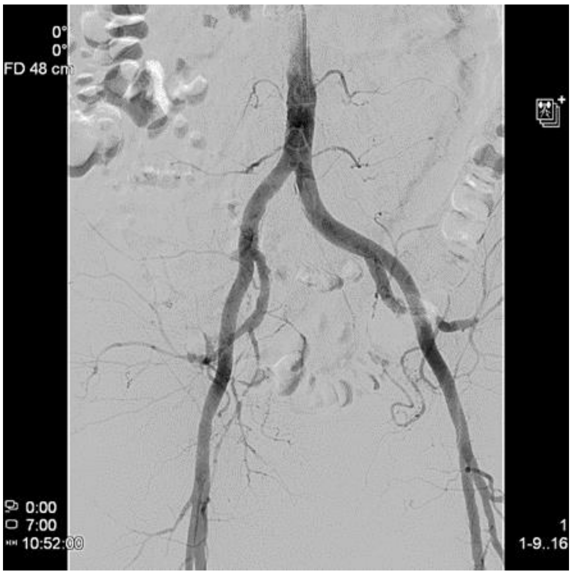

Figure 3 Carboxyangiography of the abdominal aorta, iliac and femoral arteries

Due to the high buoyancy and much lower viscosity of CO2 compared to conventional iodine-containing CVs, it is possible to contrast the smallest collaterals in both the arterial and venous systems. It should be noted that high-quality visualization of the arteries of the leg was achieved by elevating the lower limb; the elevation angle was 25–30°. Due to the above-mentioned unique properties of carbon dioxide, despite the presence of obstacles to distribution in the form of occlusions and numerous stenoses, high-quality contrast of the arteries of the leg was obtained.

Carbon dioxide was also used as a contrast agent in patients with thrombosis of the left iliac arteries after contrasting with iodine-containing CV (Omnipaque 350). The use of traditional liquid CV did not allow visualization of the distal bed due to thrombosis of the iliac arteries. With subsequent carbon dioxide contrast, the distal bed is adequately visualized. Lower viscosity and high buoyancy compared to iodine-containing HF allowed carbon dioxide to diffuse through the smallest collaterals distal to the thrombosis zone. Carbon dioxide has been used in radiology since the early 1950s to detect pericardial effusion. Some authors [3, 4] administered CO2 through the cubital vein to more than 1600 patients without any complications. In the 1960s, Payziev [4] used CO2 to visualize the inferior vena cava and hepatic veins. Since the 1970s, more than 3000 carboxyangiographies have been performed at the University of Florida (USA), and the use of CO2 has become routine with the introduction of DSA in the 1980s. In our country in the 1960s, Hipnoa et al. [5, 6, 7] used carbon dioxide as a CV during angiocardiography to detect a ventricular septal defect according to the left-to-right shunt type.

In the presence of this defect, gas penetration was recorded during radiography, but it was impossible to obtain a high-quality image without using the electron subtraction angiography mode. This is explained by the fact that CO2, when administered, is defragmented into tiny gas bubbles, which are visible fluoroscopically, but to obtain a high-quality composite image, it is necessary to sum up each image, which is achieved only in the digital subtraction angiography mode. The physical properties of carbon dioxide fundamentally differ from the properties of standard iodine-containing liquid HFs. This must be taken into account for the safe and effective use of CO2 in clinical practice.

4. Conclusions

When performing aortoarteriography, carbon dioxide can be considered as a real alternative to iodinated contrast agents. In terms of contrast quality, it is close to these substances, but does not cause allergic reactions, which allows the use of CO2 in patients with hypersensitivity to iodine-containing CBs. The use of carbon dioxide in patients at risk of developing contrast-induced renal failure is absolutely safe. It is known that angiographic studies using traditional iodine-containing CVs are not very informative in acute arterial insufficiency due to the lack of collateral flows.

The use of CO2 for arteriography in such patients, especially in patients with thrombosis of the arteries of the lower extremities to verify the distal peripheral bed, may be quite promising. Thus, the indications for carboxyangiorrhaphy can be considered: the risk of contrast-induced renal failure; allergic reactions to iodine-containing contrast agents; visualization of the distal peripheral bed in patients with acute thrombosis or embolism of the arteries of the lower extremities, as well as with elevated levels of urea and creatinine in this group of patients. Further accumulation of material is necessary to obtain a more complete understanding of the clinical significance of carboxyangiography.

Compliance with ethical standards

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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