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An Evaluation of the Use of Carbon Dioxide Angiography in Endovascular Aortic Aneurysm Repair

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Abstract

Introduction: Renal dysfunction after endovascular aortic aneurysm repair is an increasingly recognised problem. Carbon dioxide (CO_2) angiography has been used to limit the risk of contrast nephrotoxicity during endovascular procedures. This prospective study evaluates the performance of CO_2 angiography during EVAR. Methods: Seventeen patients undergoing EVAR over a 12 month period were included. All were males with a median age of 74 (range 62-86) years. The median preoperative creatinine was 105 (range 77-165) μmol/L. CO_2 angiography was used routinely in all patients for graft positioning. Contrast was used for completion angiograms and whenever CO_2 did not satisfactorily demonstrate the anatomy. Results: All patients had successful deployment of stent graft. The median contrast usage was 59 (range 20-250)ml. CO_2 angiography successfully demonstrated the aortic and iliac bifurcation in all 17 cases and the renal artery anatomy in 9. 7 out of 17 patients had both CO_2 and contrast completion angiography. CO_2 correlated with contrast angiography in 6 of the 7 patients. There was no significant difference in pre and post-operative creatinine values ($P > 0.9$; Wilcoxon test). Conclusion: CO_2 angiography is a useful adjunct to contrast during the performance of EVAR and helps reduce contrast load and the risk of contrast nephrotoxicity.

Keywords

aneurysm, aorta, endovascular, angiography

Introduction

Endovascular aortic aneurysm repair (EVAR) is now an established alternative to open repair with significant advantages in the early postoperative period.[1] Endovascular aortic aneurysm repair is, however, associated with a higher complication and re-intervention rate, necessitating close, long-term follow-up.[2]

There is a growing body of evidence to show that EVAR is associated with a gradual, progressive decline in renal function.[3,4] This decline is believed to be multifactorial with atheroembolism, transrenal fixation, and cumulative contrast nephrotoxicity all playing a role. Exposure to iodinated contrast during the procedure and follow-up may be the single most important cause for post EVAR renal dysfunction.

Carbon dioxide (CO_2) has been used as an alternate to conventional contrast agents during EVAR in patient with preexisting renal dysfunction.[5] In an effort to reduce the risk of contrast nephrotoxicity, we have recently been using CO_2 routinely in all patients having an EVAR. This article describes our experience with the routine use of CO_2 angiography during EVAR. The methodology, principles, and pitfalls are discussed.

Methods

We prospectively evaluated 17 patients who underwent EVAR over a 12-month period. All patients had infrarenal aortic aneurysms suitable for EVAR. All were males with median age of 74 (range 62-86) years. The median preoperative creatinine was 105 (range 77-165) μmol/L. Five patients had preoperative renal dysfunction with estimated glomerular fllteration rates (eGFR) below 60 mL/min per 1.73 m^2, 4 of whom were stable in the 45 to 59 mL/min per 1.73 m^2 category.[6]

Contrast computed tomography (CT) was used for preoperative planning in all patients except for 1 patient with significant preoperative renal dysfunction who had a noncontrast CT and CO_2 calibration aortography. In all, 4 patients had preoperative calibration angiography for planning and 2 had unilateral internal iliac embolization; 1 patient had a staged bilateral internal iliac embolization.

All procedures were done in an operating suite with a mobile C-arm, under general anesthesia with bilateral femoral cutdown and using the COOK Zenith device (Cook, Brisbane, Australia).

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Figure 1. Carbon dioxide angiogram before final deployment of stent.

Carbon dioxide angiography was done using a standard protocol consisting of a medical grade CO_2 gas cylinder and a CO_2 AngioSet (OptiMED, Denmark). Standard precautions to prevent air contamination and explosive delivery were taken with regular purging. After femoral artery access was obtained, CO_2 angiography was used to mark the position of the renals and the iliac bifurcation. The main body of the graft was then deployed below the level of the lowest renal and the contralateral limb cannulated. Carbon dioxide was used to confirm contralateral limb cannulation. A final check of the graft position in relation to the renal arteries was done with CO_2 angiography, before deploying the suprarenal bare stents (Figure 1). Carbon dioxide angiography was used to mark the position of the iliac bifurcation prior to deploying the graft limbs. Contrast was used for completion angiograms and whenever CO_2 did not satisfactorily demonstrate the anatomy despite changing catheter and patient position.

All patients were followed-up with either contrast CT or duplex imaging 6 weeks after the procedure and then subsequently per the protocol.

Results

All patients had successful deployment of stent grafts. The median contrast usage was 59 (range 20-250) mL. The median contrast usage in the 5 patients with preexisting renal dysfunction was 48.5 (range 20-64) mL. Carbon dioxide angiography successfully demonstrated the aortic and iliac bifurcation in all 17 cases and the renal artery anatomy in 9 cases. Confirmation of contralateral cannulation, invariably required injection of contrast as CO_2 in our experience, failed to outline the inside of the partially deployed graft (Table 1 and 2).

There were 6 type-2 endoleaks and 1 type-1 endoleak among the 17 patients. Of the 17 patients, 7 had both CO_2 and contrast completion angiography. The CO_2 completion angiogram correlated well with the contrast angiogram in 6 of the 7 patients in whom both were done. In 1 other patient, there was suspicion of a type-2 endoleak on CO_2 angiography, which was unclear due to overlying bowel gas but was clearly seen with contrast.

There was no significant difference between pre- and postoperative creatinine values ($P > .9$; Wilcoxon test). Of the 17 patients, 16 had stable renal functions after the procedure. One patient who had a total contrast load of 250 mL had a deterioration of renal function, which did not require hemodialysis. This patient had a type-1 endoleak on completion and required a proximal aortic extension to treat this. Incidentally, this patient also had had staged internal iliac embolization in the weeks preceding the procedure. He remains asymptomatic from his renal dysfunction.

All 17 patients have had follow-up studies with duplex ultrasound and 11 had additional contrast CT scan. There were no new endoleaks and adequate graft position was confirmed in all. Three patients have persistent type-2 endoleaks with a stable sac.

Discussion

Carbon dioxide was first used as a vascular contrast agent in hepatic venography. Carbon dioxide for peripheral arteriography was first described in 1982.[7] Further work in this area has proven CO_2 to be a safe contrast agent that is nonallergenic and with no renal or hepatic toxicity, making it especially valuable in patients with intolerance to iodinated contrast and in those with renal insufficiency.[8]

While iodinated contrast agents are radio-opaque liquids, CO_2 is a radiolucent, highly compressible gas. Iodinated contrast agents mix with the blood within the vascular tree to produce an image; CO_2 displaces the blood within the vascular tree to produce a difference in density between the vessel and the surrounding soft tissue. The quality of imaging with iodinated contrast agents depends on the concentration of contrast and the speed of injection, while with CO_2 the quality of the image depends on the amount of blood displacement within the vessel of interest. Being a buoyant gas lighter than blood, CO_2 tends to "float" into the nondependent blood vessels resulting in better imaging of, for example, the more anteriorly placed branches of the aorta in the supine patient.

Theoretically, injection of a gas into a blood vessel can lead to a fatal "vapor lock" of the pulmonary artery as it happens in air embolism. However, animal experiments have shown that extremely large volumes of CO_2 are required to be injected before this occurs. This is believed to be due to the much higher solubility of CO_2 when compared to air or oxygen. The volumes normally used for medical imaging are rapidly eliminated without any physiological effects. The use of CO_2 above the diaphragm is, however, not recommended because of disruption of the blood brain barrier.[9] Large bubbles of trapped CO_2 within arterial branches can lead to transient disruption in blood flow. Proper CO_2 delivery technique to allow a smooth, nondisruptive, nonexplosive delivery is essential to prevent this.

In our experience, there were no adverse effects from using CO_2 routinely in our endovascular abdominal aortic aneurysm

Table 1. Patient Characteristics

Male:Female	Median Creatinine Preop (μmol/L)	Total Median Contrast (mL)	Median Creatinine Postop (μmol/L)	eGFR deterioration
17:0	105	59	103	1/17 (5.8%)

Table 2. Technical Success of CO_2 Angiography

Total CO_2 angiography, n = 17	Renals	Aortic Bifurcation	Ipsilateral Iliac	Contralateral Iliac
Successful demonstration	9 (53%)	17 (100%)	17 (100%)	17 (100%)

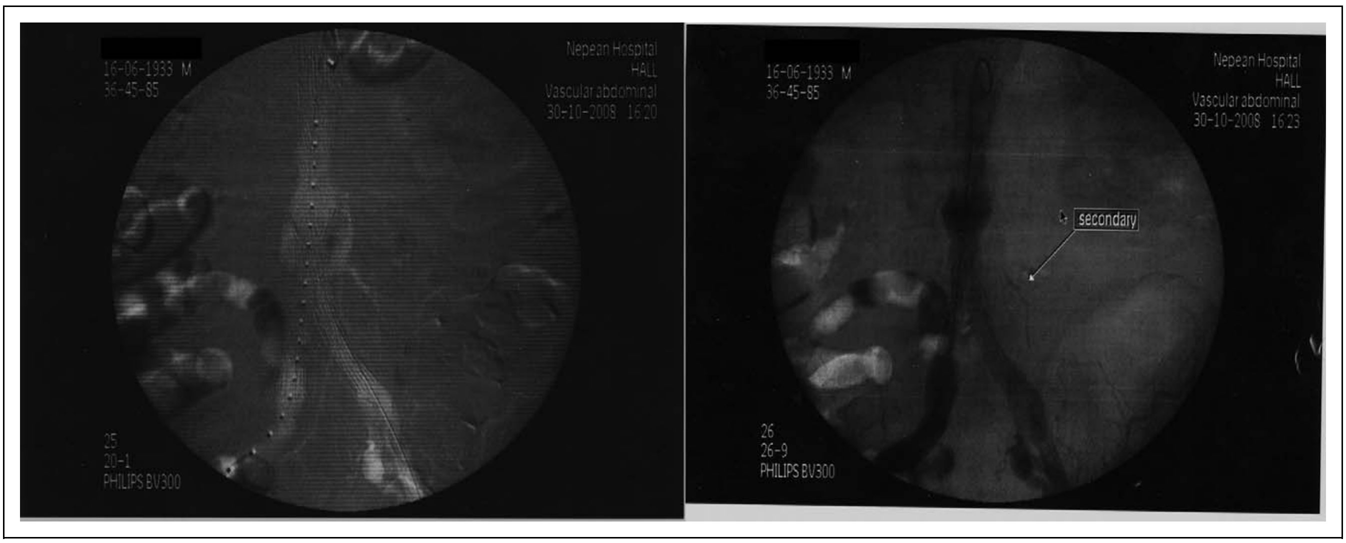

Figure 2. Type 2 endoleak with CO_2 angiogram showing early filling of sac compared to conventional contrast.

(AAA) repairs. Other series on EVAR with CO_2 as the primary intravascular contrast agent also have not shown any adverse outcomes ascribable to the use of CO_2.[10,11] The commonest problem we encountered in our series was with unsatisfactory demonstration of the renal arteries. While multiple attempts and patient position change may result in successful demonstration of the renal artery anatomy, we chose not to expose the patient and operating staff to extra radiation with more than 3 attempts.

Not having experience with the use of CO_2 completion angiography after EVAR, we routinely performed a conventional contrast run to identify endoleaks. In the 7 patients who had both CO_2 and contrast completion angiography, we noted that CO_2 was extremely sensitive in showing endoleaks (Figure 2). Endoleaks with CO_2 also filled the sac earlier than endoleaks with conventional contrast agents, probably due to its lower viscosity. Other authors have also reported on the high sensitivity of CO_2 angiography in picking endoleaks.[8]

As we routinely used contrast for the completion angiogram, the median contrast load in this series is higher than what has been reported in other series using CO_2 for EVAR.[11] However, in the series published by Chao and colleagues, the mean contrast use in patients in whom iodinated contrast was used exclusively was 148 mL,[11] which is well above the 59 mL achieved in our series using CO_2 as an adjunct. In the 5 patients with preexisting renal dysfunction, being more mindful of the amount of contrast used, the median contrast use was an even lower 46.5 mL. From the experience gained from this series, we believe that further reduction in the amount of contrast can be achieved. The routine use of CO_2 angiography during EVAR also helps in operating staff get familiar with its performance and comfortable with the images produced.

Progressive renal dysfunction after EVAR is an increasingly recognized clinical problem. This is most likely due to the cumulative effect of contrast exposure during the EVAR and from follow-up CT angiography. The US Zenith multicenter trial investigators have recently recommended an amended postoperative surveillance regime to minimize contrast exposure.[12] There is evidence to suggest that duplex ultrasonography may be sufficient in the routine follow-up after EVAR.[13] A concerted effort in minimizing contrast load with CO_2 angiography during the performance of EVAR and duplex ultrasonography for follow-up may well be the way to reduce renal dysfunction following an EVAR.

In conclusion, CO_2 angiography is a cheap and effective adjunct to contrast in the performance of EVAR. Carbon dioxide angiography correlates well with contrast in the detection of endoleaks and its routine use helps reduce contrast load and the risk of contrast-mediated nephrotoxicity. The routine use of CO_2 angiography during EVAR helps the endovascular surgeon gain familiarity with the nuances involved in its performance.

Declaration of Conflicting Interests

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