



Percutaneous Endovascular Aortic Aneurysm Repair with INCRAFT Endograft Guided by CO₂ Digital Subtraction Angiography in Patients with Renal Insufficiency

Cesar Cuen-Ojeda, Javier E. Anaya-Ayala, Rene Lizola, Julio A. Navarro-Iniguez, Lizeth Luna, Manuel Guerrero-Hernandez, and Carlos A. Hinojosa

Department of Vascular and Endovascular Surgery, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, Mexico City, México

Iodinated contrast is the most common contrast agent used during endovascular abdominal aneurysm repair (EVAR). However, its use may worsen kidney function in patients with renal insufficiency. Previous studies have demonstrated the safety and effectiveness of carbon dioxide (CO₂)-EVAR. Here, we report cases of three male patients with mild renal insufficiency (mean age: 79 years) that successfully underwent CO₂-EVAR using INCRAFT ultra-low profile endografts. CO₂ angiography provided the necessary vascular roadmap for safe and effective percutaneous EVAR, eliminating the need for iodinated contrast media and preventing contrast-induced nephropathy.

Key Words: Abdominal aortic aneurysm, Endovascular procedures, Carbon dioxide, Contrast media, Nephropathy

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Corresponding author: Carlos A. Hinojosa

Department of Vascular and Endovascular Surgery, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, Vasco de Quiroga 15, 14080 Mexico City, México

Tel: 52-55-54-87-09-00

E-mail: carlos.a.hinojosa@gmail.com

<https://orcid.org/0000-0002-9664-8703>

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INTRODUCTION

Endovascular aneurysm repair (EVAR) has lower short-term morbidity and mortality rates than open surgery [1]. Although iodinated contrast medium (ICM) is the most commonly used contrast agent in EVAR, its use is not recommended in patients with renal dysfunction and ICM hypersensitivity because ICM-induced acute kidney injury after EVAR has been associated with increased mortality and morbidity [2,3]. Some medical strategies for avoiding contrast-induced nephropathy (CIN) have been used with controversial results in literature [4,5]. In recent years, the use of CO₂ as a contrast agent has been proposed as an alternative strategy to prevent CIN in this group of patients. Several studies have demonstrated the safety and effectiveness of using CO₂ as a contrast agent during EVAR. How-

ever, the outcomes of percutaneous EVAR (PEVAR) using the INCRAFT™ (Cordis, Bridgewater, NJ, USA) aortic device have not yet been reported. The INCRAFT™ abdominal aortic aneurysm (AAA) Stent-Graft System is an United States Food and Drug Administration (FDA) approved stent-graft and ultra-low profile endoprosthesis for EVAR [6-8]. We successfully used CO₂ digital subtraction angiography (DSA) for PEVAR with INCRAFT™ in three patients with renal insufficiency. This study was approved by the Institutional Review Board with the reference number: SIN-828-13/13-1 of the National Institute of Medical Sciences and Nutrition Salvador Zubirán (INCMNSZ). Informed consent for publication was obtained from the patients or family members.

CASE

1) Techniques for CO₂ DSA and PEVAR

All patients were placed in the supine position. A right femoral percutaneous access point was made using a 13 Fr sheath. To insufflate CO₂, a UHI-4 high flow insufflation unit (Olympus, Tokyo, Japan) was utilized. After placing a 5 Fr pigtail catheter at the L1 level and withholding ventilation, a 60 mL syringe was used to hand-inject 40 mL of CO₂ over 2.5 seconds. A proper aortogram was obtained to

visualize the patient's aortic anatomy. Before deployment of the main body, a new angiogram was obtained by positioning the pigtail catheter above the renal arteries. A 10 to 15 degree left anterior oblique projection was obtained to localize the origin of the renal arteries. Contralateral anterior oblique projection was used to characterize the bifurcation of the common iliac artery into the internal and external branches.

We performed PEVAR successfully on three patients using CO₂ DSA (Fig. 1-3). Because the patients had kidney disorders, CO₂-EVAR was chosen as a contrast agent to preserve their renal function.



Fig. 1. CO₂ digital subtraction angiogram after injecting 40 mL CO₂ (20 mL/sec). Angiogram shows an abdominal aortic aneurysm and the bilateral iliac arteries. Because the pigtail catheter is positioned below the renal arteries, the renal arteries are not visualized.



Fig. 2. CO₂ angiogram showing clear opacification of both renal arteries and aortic bifurcation. The angiogram provided good guidance during endograft deployment.

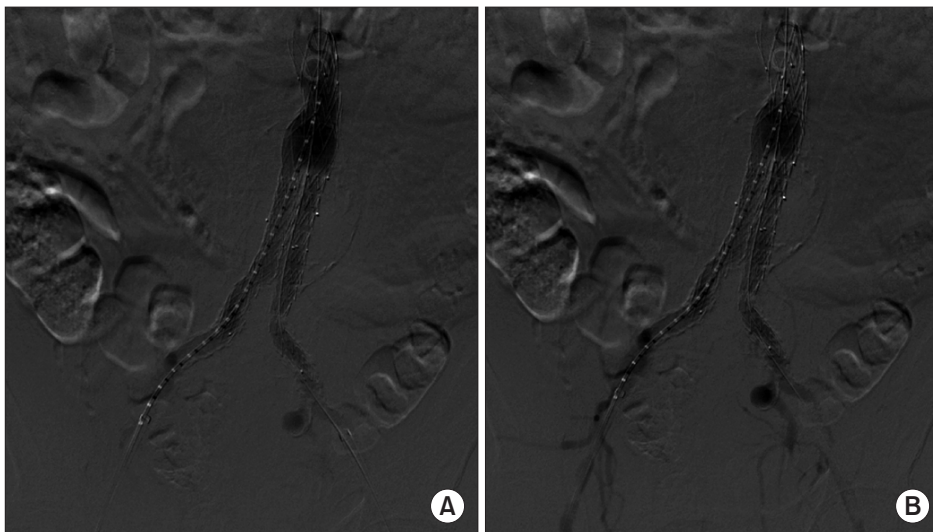


Fig. 3. (A) CO₂ completion angiogram after endovascular aneurysm repair with a pigtail catheter in the perirenal aorta. (B) The late arterial phase of the angiogram shows the patient's bilateral internal and external iliac arteries.

2) Case 1

A 73-year-old man with a history of coronary artery disease (CAD) and hypertension presented with an asymptomatic AAA. Computed tomography angiography (CTA) showed an infrarenal AAA measuring 55×111 mm with a 20-mm neck length. The preoperative serum creatinine (sCr) level was 1.5 mg/dL. An INCRAFT endograft was implanted through a 13 Fr sheath. The patient was discharged 2 days after PEVAR without complications. One week after the procedure, his sCr was 0.99 mg/dL. Follow-up CTA after 1 month revealed neither endoleaks nor any graft migration. Five months after the procedure, he remained asymptomatic.

3) Case 2

An 84-year-old man who lived in Mexico City presented with abdominal pain. He had chronic kidney disease, dyslipidemia, and type 2 diabetes. CTA revealed an AAA of 67.3×91.8 mm without iliac tortuosity and with a 22-mm neck length. Preoperative sCr was 1.72 mg/dL; therefore, we decided to use CO₂ as a contrast agent instead of ICM. EVAR was performed without complications. Seven days after the procedure, his sCr was 1.5 mg/dL. A 1-month follow-up CTA and duplex ultrasonography showed no endoleaks.

4) Case 3

An 82-year-old man with a history of CAD and atrial fibrillation visited the vascular surgery clinic due to an incidentally found AAA of 44.8×94.3 mm with straightforward neck characteristics. His preoperative sCr was 0.87 mg/dL. CO₂-EVAR was performed to prevent CIN. After 48 hours, his sCr remained constant at 0.89 mg/dL, and after 10 weeks, it decreased to 0.62 mg/dL. A follow-up CTA after 6 months of follow-up showed neither endoleaks nor device migration.

The patients' perioperative sCr changes are summarized in Table 1. The average pre-operative sCr was 1.36 mg/dL, and sCr at 72 hours post-surgery was 1.08 mg/dL, indicating that using CO₂ as a contrast agent helped prevent kidney injury after EVAR in our case series.

DISCUSSION

Renal failure remains an important postoperative complication after EVAR. Among the factors associated with postoperative kidney dysfunction, ICM may be the only factor that can be completely avoided to prevent acute kidney injury in patients at a risk of renal failure [9].

Takeuchi et al. [1] compared 351 patients who underwent ICM-EVAR versus 30 patients who underwent CO₂-EVAR and reported that CO₂-EVAR was a feasible and effective procedure that decreased the probability of renal dysfunction. Criado et al. [9] retrospectively compared 114 patients who underwent CO₂-EVAR versus 22 patients who underwent ICM-EVAR procedures and found that the CO₂ group had a shorter mean operation time (177 vs. 194 minutes, P=0.01). Patients with reduced glomerular filtration rate (GFR) undergoing ICM-EVAR had a 12.7% greater decrease in GFR after surgery compared with the corresponding CO₂ EVAR group (P=0.004). However, INCRAFT endografts were not used in these studies [1,9].

CO₂ gas displaces blood within the blood vessels, thus serving as a negative contrast agent. In order to prevent CIN, CO₂ is considered a good alternative to ICM in patients with acute and chronic kidney diseases [1-3]. CO₂ is cheaper than ICM and causes no known systemic complications. It is also non-allergenic and is widely available in most hospitals. When used with caution, CO₂ is an undoubtedly safe negative contrast agent that helps in localization of the aortic and iliac branches, allowing precise graft deployment during EVAR [9,10]. Chaudhuri and Dey described ICM-free EVAR using CO₂ angiography and concluded that CO₂-EVAR can be performed safely in cases of renal transplant, contrast allergy, and renal dysfunction [11]. Considering the high volume of ICM-EVAR procedures performed annually, the use of CO₂-EVAR remains poorly described in the literature [9,12]. Even though it is demonstrated that CO₂-EVAR is not inferior to ICM-EVAR, its short-term, mid-term, and long-term outcomes have not been reported to date. To our knowledge, this is the first report describing INCRAFT endograft placement using CO₂ as a contrast agent [6].

In our institution, we offer CO₂ angiography-guided EVAR to patients with chronic kidney disease to protect their kidney function. When we decided to perform a CO₂-EVAR, we ordered a non-iodinated computed tomography

Table 1. Serum creatinine levels of the patients before and after endovascular aneurysm repair procedure

Patient no.	Age (y)	Preoperative (mg/dL)	Postoperative, 24-72 h (mg/dL)	Postoperative >72 h (mg/dL)
1	73	1.5	1.08	0.99
2	84	1.72	1.48	1.5
3	82	0.87	0.69	0.62

scan for procedure planning, thus avoiding any worsening of the patients' kidney disease. In this study, all EVAR procedures were performed using C-arm fluoroscopic imaging in the operating room. The handheld syringe method was used to deliver CO₂ for DSA. CO₂-DSA was performed with manual injections of CO₂ at a rate of 10 to 20 mL/sec for a total volume of 40 mL. At the end of the procedure, a completion angiography was performed by injecting 40 mL CO₂ at the renal artery origin and at the common iliac bifurcation. Undoubtedly, the CO₂-DSA technique employed here can be used to perform EVAR with other currently available endografts.

We opted to use INCRAFT stent grafts because they have low profiles, allowing easy navigability in the small and convoluted iliac arteries. It has been available in Mexico since 2015 and was recently approved by the FDA in the USA. Gill et al. [6] reported the first North American experience with the INCRAFT device, concluding that it is safe, effective, and associated with a low complication rate. Some advantages of the INCRAFT aortic device include its customizable tri-modular design with an ultra-low profile delivery system (13-Fr inner and 14-Fr outer diameter) and its ability to treat aortic necks of 17 to 31 mm in diameters and iliac necks of 7 to 22 mm in diameters. Bilateral in situ adjustments of limb prostheses during the procedure are easy (3 cm on the ipsilateral and 2 cm on the contralateral side) [6].

We presented three cases of successful EVAR with INCRAFT aortic endografts using CO₂ angiography. Short-term follow-ups showed no endoleaks, no migrations, and no secondary interventions. As expected, we did not note increased sCr or decreased GFR in our patients during the 6-month follow-up appointments.

In conclusion, CO₂-EVAR with the INCRAFT endograft

is a technically safe and effective procedure that decreased the risk of renal failure in patients with marginal kidney function. A prospective long-term trial of EVAR comparing CO₂ and ICM in patients with renal dysfunction is warranted.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

ORCID

Cesar Cuen-Ojeda
<https://orcid.org/0000-0002-8000-4866>
 Javier E. Anaya-Ayala
<https://orcid.org/0000-0003-0936-3310>
 Rene Lizola
<https://orcid.org/0000-0001-8344-7454>
 Julio A. Navarro-Iniguez
<https://orcid.org/0000-0002-2671-5114>
 Lizeth Luna
<https://orcid.org/0000-0002-1195-7188>
 Manuel Guerrero-Hernandez
<https://orcid.org/0000-0002-2763-6880>
 Carlos A. Hinojosa
<https://orcid.org/0000-0002-9664-8703>

AUTHOR CONTRIBUTIONS

Concept and design: CCO, CAH. Analysis and interpretation: CCO, JEAA, RL, JANI, LL, MGH, CAH. Data collection: CCO, JEAA, RL, JANI, LL, MGH, CAH. Writing the article: CCO, JEAA. Final approval: CCO, JEAA, RL, JANI, LL, MGH, CAH. Obtained funding: none. Overall responsibility: CAH.

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