CASE REPORT

Role of carbon dioxide angiogram in endovascular abdominal aortic aneurysm repair (EVAR): A case series

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SUMMARY

Iodinated contrast media has been widely used as the main contrast agent since the early 1920's. However, recently carbon dioxide (CO_2) has emerged as an alternative media to iodine due to its special characteristics of non-nephrotoxic and non-allergenic properties. This study reports one of the earliest Malaysian experiences using CO_2 angiography as the primary intraoperative imaging modality during Endovascular Abdominal Aortic Aneurysm Repair (EVAR). This retrospective case series was conducted at Institut Jantung Negara (IJN) as the national tertiary cardiothoracic and vascular center. We analyzed six patients who underwent EVAR using CO_2 as the primary contrast agent between February and May 2021. Data collected included demographics, aneurysm morphology, renal function, operative details, complications, and postoperative outcomes. Six patients underwent EVAR, five elective and one emergency. All patients underwent operations with successful deployment of the device without intraoperative complications, conversion to open surgery or CO_2 related complications . Postoperatively, renal function was stable in five patients with one demonstrating a slight decline in renal function (eGFR 40 to 35) but not requiring dialysis. Completion angiogram using minimal iodine contrast used to confirm stent placement with no endoleaks. Follow up CT scans showed satisfactory graft positioning without evidence of endoleaks. Owing to special characteristics of CO2 it provides good clinical benefit especially in those with underlying CKD and iodine allergy. It is a feasible and safe alternative imaging modality for EVAR. This aims to increase familiarity among surgeons with the use of CO2 angiography in EVAR and other relevant vascular procedures.

INTRODUCTION

Iodinated contrast media (ICM) has been the basic foundation in vascular imaging as early as the 1920's, widely accepted for the last 100 years. Nevertheless, in recent years, Carbon Dioxide (CO_2) appeared as a new alternative due to its natural characteristics of non-toxicity, low cost, rapid tissue clearance, and wide availability.[1]

CO_2 angiography is distinctly beneficial for patients with iodine contrast allergies or those at high risk of iodinated contrast-induced nephropathy (CIN).[1]

In patients with abdominal aortic aneurysm (AAA) undergoing endovascular repair with chronic kidney disease or in acute renal failure, CO_2 angiography offers an opportunity to alleviate renal injury and potential requirement for dialysis[2] as these patient groups undergoing EVAR with renal failure experience significantly increased postoperative mortality and morbidity.[3]

This case series represents the first Malaysian experience in managing EVAR using CO_2 angiography as the primary intraoperative imaging modality, undertaken during the initial implementation phase at our centre. These could serve as the foundation of subsequent larger studies. The patient's background, pre-existing conditions, interventions and outcomes are discussed below.

METHODOLOGY

This is a retrospective case series conducted at Institut Jantung Negara (IJN) Kuala Lumpur, a national tertiary centre for cardiothoracic and vascular surgery.

The series includes all consecutive patients undergoing EVAR for AAA using CO_2 as a primary contrast agent between February 2021 till May 2021. No patients were excluded. Data were obtained from electronic medical records and operative notes. These include demographic background, morphology of the disease, preoperative and postoperative renal function, operative time, intraoperative complications, postoperative outcome and length of stay are presented in Table I.

PROCEDURAL PROTOCOL

In this case series, all patients underwent EVAR under general anaesthesia by an experienced consultant vascular surgeon, irrespective of their renal function status. Preoperatively, computed tomography was performed to confirm the diagnosis of AAA and precisely measure the aneurysm size and determine the suitability of either EVAR or open surgical repair. During admission, routine blood investigations were taken, including a preoperative renal profile, and were evaluated by the anaesthetist before surgery.

In our centre, the standard protocol for EVAR using CO_2 angiography begins with bilateral femoral arteries access using an initial 6Fr sheath. Following arterial puncture, three ProstyleTM 6Fr closure devices (Abbott Vascular) are

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Table I: Patient characteristics, procedural details, and postoperative outcomes

Case No, Gender/ Age	Comorbidities	Diagnosis	Procedure (Urgency)	Duration of Operation (Hours)	Post Op RP	Post Op RP	CO_2 related morbidity	Length Of Stay Post Operation (days)
1. Male/72	Ex-smoker/	Infrarenal AAA HTN/ HPLD	EVAR + CO2 Angiogram (Elective)	2.9	Urea 7.9/ Creatinine 151, eGFR >60	Urea 7.6/ Creatinine 142, eGFR >60	No	3
2. Male/59	Ex-smoker/ HTN/ HPLD	Infrarenal AAA + Occluded left CIA	EVAR + CO2 Angiogram + Femoral-Femoral	2.58	Urea 3.9/ Creatinine 117, eGFR 55	Urea 5.0/ Creatinine 117, eGFR 55	No	2
3. Male/63	Hypertension/ HPLD/ CKD	Infrarenal AAA	EVAR + CO2 CO2 Angiogram (Elective)	2.17	Urea 7.4/ Creatinine 155, eGFR 39	Urea 3.7, Creatinine 120, eGFR 53	No	7
4. Male/61	Smoker/HPLD	Infrarenal Saccular AAA	EVAR + CO2 Angiogram (Emergency)	2.8	Urea 4.2, Creatinine 77, eGFR >60	Urea 5.2, Creatinine 79, eGFR >60	No	3
5. Male/70	HTN/CKD	Infrarenal AAA	EVAR + CO2 Angiogram (Elective)	2.37	Urea 8.7, Creatinine 147, eGFR 40	Urea 8.8, Creatinine 166, eGFR 35	No	4
6. Female/64	HTN/HPLD	Infrarenal AAA with angulated neck	EVAR + CO2 Angiogram + Femoral-Femoral Bypass (Elective)	3.85	Urea 5.4, Creatinine 79, eGFR >60	Urea 5.3, Creatinine 61 eGFR	No	4

CKD: Chronic Kidney Disease; HPLD: Hyperlipidemia; HTN: Hypertension; EVAR: Endovascular Aneurysm Repair; CO2: Carbon dioxide; AAA: Abdominal Aortic Aneurysm

deployed on each side for pre-closure purposes. After deployment of Prostyle device, sequential iliac pre-dilatations are performed and gradually increasing the sheath size to accommodate larger delivery system required for the specific EVAR device.

Following vascular access, the CO_2 was delivered via a special Angiodroid machine (Angiodroid SRL, San Lazzaro di Savena, Italy). The sheaths are connected to CO_2 tubing via a three-way stopcock to the Angiodroid, ensuring concurrent delivery of CO_2 to both sides (Figure 1). This method allows overall visualisation of the arterial system, ensuring good-quality imaging and precisely assisting during the procedure. Injection parameters were :

- Volume approximately 80±20mL
- Maximum pressure of 700±50 mmHg.
- Injection timing : automated as per Angiodroid settings.

This Angiodroid machine helps to accurately administer CO_2 according to the volume, pressure, and timing of injection, as well as minimize radiation exposure.[1] Patient positioning was adjusted at slight lateral tilting or Trendelenburg position if necessary to optimise vessel visualisation.

RESULTS

Six patients underwent EVAR with CO_2 during the study period. Five underwent elective procedures and one was performed under the emergency list. The aneurysm mainly arose from infrarenal and one of them had a complex angulated neck. All surgeries went uneventfully, and grafts were deployed successfully without evidence of endoleak, and none required conversion to open surgical repair. At the end of the operation, completion runs were made by using iodinated-contrast media as an adjunct to confirm the stent placement and check for extravasation of contrast (Figure 2). The operation durations range from 2.17 to 3.85 hours in total. Postoperatively renal profiles were measured again immediately after 1-2 days. Out of six patients only one demonstrated a slight decline in renal function (eGFR 40 to 35) but not requiring dialysis. However, these observations require proper case-control or analytical study to determine the effect of CO_2 towards renal profile in detail. No CO_2-related complications arose during Intensive Care Unit (ICU) or ward stay, and their total length of stay postoperative period ranged from 2-7 days. Follow-up care CT scans were repeated and confirmed device placement and no evidence of endoleak in all cases (Figure 3).

DISCUSSION

AAA is characterized by an enlargement of abdominal aorta diameter by 3.0cm or more. The localized dilation of the aorta begins below the diaphragm and is classified based on their specific locations: supra-renal, pararenal or infrarenal arteries.[4] This must not be left untreated especially in large AAAs as rupture carries a mortality rate up to 80%.[4]

The increasing practice of EVAR in modern management of AAA, by introduction of endovascular stent into the vascular lumen to exclude aneurysm brings significant reduction in perioperative mortality when compared to open surgical repair by three-fold.[5] Advantages include smaller incisions, reduced risk of rupture and bleeding, and decreased renal hypoperfusion and surgical trauma.[3] This procedure is a minimally invasive surgery where a small incision is made percutaneously to introduce artificial stent and deployed within the aorta, reducing the risks of rupture and bleeding and thus favoured over open repair. At present, in those with pre-existing renal injury, surgeons preferred open repair compared to EVAR due to concerns use of iodinated-contrast media may result in dialysis postoperatively. Nonetheless,

Fig. 1: Both femoral arteries cannulated with 6Fr sheaths, with CO_2 delivery tubing connected via a three-way stopcock

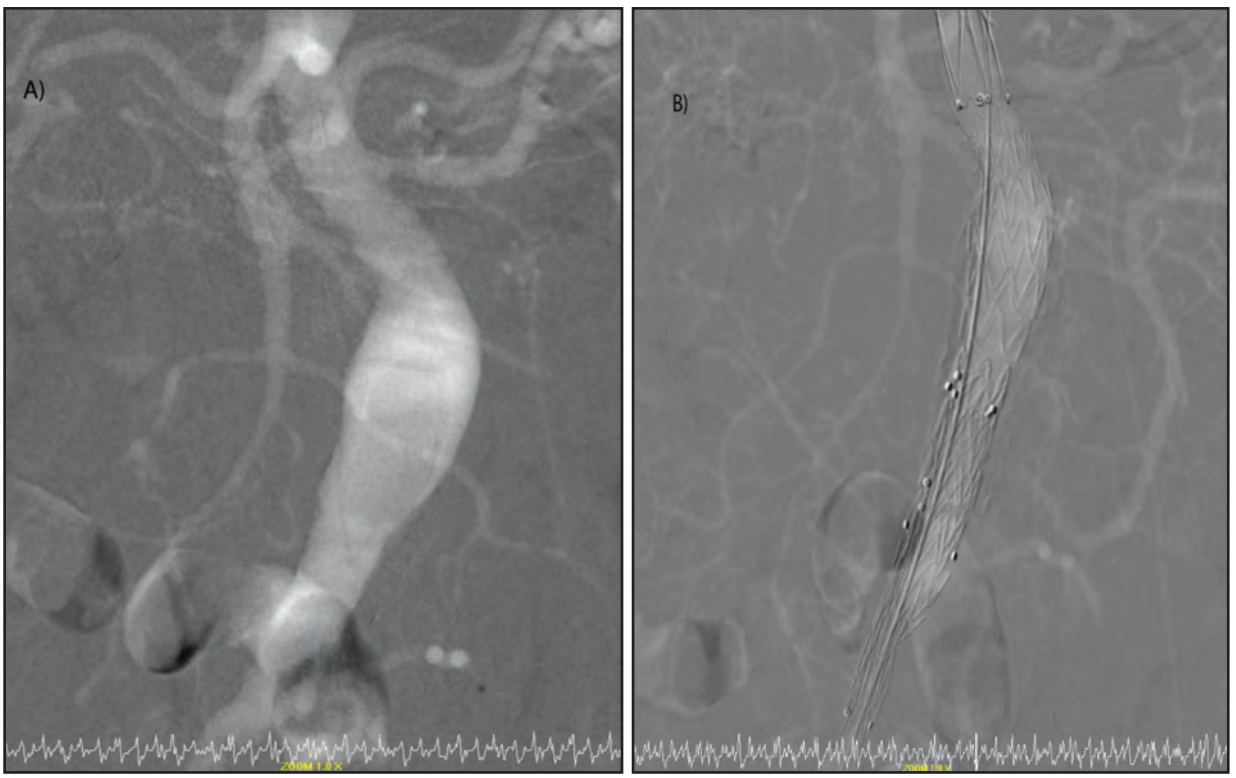

Fig. 2: A) Carbon dioxide (CO_2) digital subtraction angiography (DSA) showing an infrarenal abdominal aortic aneurysm (white arrow) prior to stent placement. B) Post stent deployment, CO_2 contrast completion run shows filling of abdominal aorta without evidence of endoleak.

severe pre-existing renal dysfunction in both open repair and EVAR is associated with poor outcomes regarding mortality and cardiovascular events.[6]

CO_2 angiography has recently gained attention as an alternative due to its safety, being a naturally existing inert substance, and its non-nephrotoxic and non-allergenic properties, especially in patients at risk of CIN. It has been

Fig. 3: Showed CT Aortogram of one of the patient with infrarenal AAA, post-EVAR.
No evidence to suggest Endoleak.

proven to be safe for vascular imaging in those with renal impairment requiring precise imaging and therapy.[7] The CO_2 can be used alone or in combination with ICM so that the regular dose of iodine is minimized, especially in procedures requiring large amounts of contrast volumes. It acts as a negative contrast agent due to its low-density properties as well as its ability to absorb X-rays to a minimal degree compared to surrounding blood vessels. The notable buoyancy of CO_2 allows it to float in the blood and visualize visceral arteries.[1,8] It accumulates in the anterior part of the vessels (useful in visualizing the superior mesenteric and celiac arteries) but does so poorly in posteriorly located vessels, as the CO_2 in the anterior portion does not displace blood at the lower part. It also provides better visualization in small vessels (less than 10 mm in diameter), promising good imaging quality, but it is less effective in larger vessels due to incomplete displacement of blood in the lower (posterior) part of the vessel, which can lead to poor visualization.[1,9] CO_2 is highly soluble - about 28 times more than oxygen and 54 times more than nitrogen allows its safe administration into arteries below the diaphragm and veins in the absence of gas embolism. It can be temporarily trapped in the right atrium and typically dissolves within 45 seconds if minimal, but takes longer to dissolve in larger volumes.[8]

From a practical standpoint, the CO_2 peculiar physical aspects such as ultra-low viscosity and immiscibility with blood allow for augmented imaging precision in certain applications. Furthermore, CO_2 toxicity is of minimal concern as it can be administered repetitively, indirectly enhancing accuracy during imaging and device deployment. They are widely available and less expensive, making them economically efficient compared to ICM.[1]

The CO_2 has several limitations and occasionally presents with rare, but severe side effects such as vapor air lock and air embolism. It is also less suitable to be used in procedures above the diaphragmatic region due to the risk of neurotoxicity. Patients may experience milder symptoms such as nausea, vomiting, abdominal discomfort and leg cramps (especially when CO_2 contrast is injected in peripheral vascular procedures). One of the important downsides of CO_2 angiography is that it may produce lower imaging quality in certain conditions. Due to its buoyancy properties, it does not adequately fill the posterior aspect of the blood vessels, as well as larger vascular diameters, and hence results in incomplete visualisation.

Our case series demonstrates that using CO_2 angiography as the main intraoperative agent allowed successful EVAR device deployment in all six cases without intraoperative complications, conversion to open surgery or significant postoperative renal dysfunction. Only one patient experienced a mild decline in eGFR not requiring dialysis. Adjunctive ICM use was minimal during completion runs, supporting the role of CO_2 in minimising iodine exposure. This is small, retrospective, single-centre series limits the generalisability of the results. No control group was included, hence no direct statistical comparison to standard ICM-based EVAR made.

Our primary goal objective is not to draw any statistical comparisons, instead we aim to show feasibility, technical aspects and outcomes to guide future clinical practice. As the leading vascular centre in Malaysia, we seized the opportunity to become the pioneer user of CO_2 angiography as the primary contrast agent in EVAR surgery. Previous studies often restricted CO_2 use specifically to cases associated with CIN and its contraindications, but our approach in these studies focuses on its application to a broader patient spectrum. This provides flexibility and productivity without being limited by usual criteria.

CONCLUSION

Due to the exceptional and unique properties of CO_2, it offers numerous advantages, as mentioned earlier. The use of CO_2 as an alternative contrast medium should be considered in modern EVAR, while ICM can still be used in minimal volumes as an adjunct. We aim to increase familiarity among surgeons with CO_2 angiography, not only in EVAR but also in various other relevant procedures, particularly for interventions below the diaphragm. Not only does it reduce the incidence of CIN, but it is also cost-effective and reduces resource utilization.

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