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RESEARCH LETTER

Complications of Carbon Dioxide Angiography in Endovascular Aortic Repair: A Review of Current Literature

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To the reduce the use of iodinated contrast medium (ICM), carbon dioxide (CO_2) has emerged as an alternative for digital subtraction angiography in endovascular procedures particularly in patients with chronic kidney disease or known allergy to ICM. Carbon dioxide digital subtraction angiography (CO_2-DSA) reduces the risk of post-contrast acute kidney injury (PC-AKI), a well recognised concern in ICM based radiological procedures, that although irrelevant for the majority of patients, may be significant for patients with pre-existing factors favouring PC-AKI.[1] In the context of endovascular aneurysm repair (EVAR) for infrarenal abdominal aortic aneurysm (AAA), CO_2-DSA has emerged as a valuable adjunct and can be used as an exclusive contrast agent or in combination with ICM, providing high quality imaging and optimal visualisation, while reducing ICM related risks.[2] However, the latest European Society for Vascular Surgery (ESVS) 2024 clinical practice guidelines on the management of abdominal aorto-iliac artery aneurysms[3] did not include recommendations on the use of CO_2-DSA as a contrast medium for prevention of PC-AKI. Furthermore, while its feasibility has been demonstrated in numerous reports, data on its safety remain scarce.

To address this knowledge gap, a review of the literature was conducted to evaluate intra- and post-operative complications associated with CO_2-DSA in EVAR.

The review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines and included searches of PubMed, Scopus, and the Cochrane Library up to December 2024. All studies reporting on the use of CO_2 as a contrast medium in EVAR procedures were selected. Complications were classified as intra-operative, peri-procedural ($<$ 24 hours), and post-operative (within 30 days).

From 312 studies initially screened, 16 met the inclusion criteria for this review, reporting the use of CO_2 during EVAR for infrarenal AAAs. These studies, published between 2007 and 2024, collectively included 901 patients, with 622 interventions (69.0%) performed as zero contrast procedures without any ICM used. The remaining 279 procedures (31.0%) were performed with a combination of both CO_2 and ICM on a case by case or operator's preference basis. An automated CO_2 injector (Angiodroid, San Lazzaro di Savena, Bologna, Italy) was employed in nine of the 16 studies, and all studies published after 2018 used this system avoiding manual injections. No 30 day death directly attributable to CO_2 was reported across the entire cohort. Among the included studies, only six of the 16 studies (investigating 492 patients) reported detailed analysis of CO_2 related complications.[1,2,4—7]

Table 1 summarises the finding of the studies investigating CO_2 related complications, with three studies[1,6,7] reporting 100% zero contrast procedures. Intra-operative complications occurred in 21 patients (4.9%), all undergoing the procedure under locoregional anaesthesia. These were self limited and included transient abdominal pain, nausea, vomiting, and hypotension. Peri-procedural complications included three cases of abdominal pain, three of vomiting, and two of diarrhoea. All of the reported complications resolved spontaneously within the first 24 hours, and no post-operative complications or re-interventions were described, together with an absence of major adverse events (e.g., stroke, embolism, and end organ ischaemia or malperfusion) related to CO_2 injections. Two of the included studies reported no intra-operative or peri-operative complications.[5,6]

ICM is associated with well documented risks after EVAR. PC-AKI remains a significant iatrogenic cause of AKI, with a reported incidence affecting 4 — 18% of patients depending on the volume of ICM.[4] Evidence suggests that most cases of AKI might not be contrast dependent but directly related to variation in renal function (especially for patients with advanced pre-operative renal disease) and individuals with baseline risk of PC-AKI.[5] These risks have led to a growing interest in protective pre- and or post-operative measures as well as investigating the intra-operative role of CO_2-DSA.

The findings of this narrative review suggest that CO_2 related complications are rare, and when they do occur they are minor and resolve within the first 24 hours, not affecting post-operative care and without prolonging hospital length of stay.

Notably, all symptomatic patients were under locoregional anaesthesia, which might represent a confounding factor and itself be responsible for neurovegetative symptoms.

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Table 1. Carbon dioxide (CO_2) related complications in endovascular aneurysm repair procedures from included studies.*

Author	Year	Patients – *n*	CO_2 injection system	Zero contrast – *n* (%)	Complications – *n* (%)			
					Intra-operative	Peri-procedural, <24 h	Resolved <24 h†	Post-operative, <30 d
Mascoli *et al.*[1]	2018	31	Automatic (Angiodroid)	31 (100)	5 (16%): 3 hypotension, 2 nausea and vomiting	0	5 (100)	0
Vacirca *et al.*[4]	2023	65	Automatic (Angiodroid)	16 (25)	5 (8%): abdominal pain, vomiting, nausea	8 (12)	13 (100)	0
Unal *et al.*[5]	2023	34	Automatic (Angiodroid)	29 (85)	0	0	0	0
Esposito *et al.*[6]	2023	17	Automatic (Angiodroid)	17 (100)	0	0	0	0
Quaglino *et al.*[7]	2024	52	Automatic (Angiodroid)	52 (100)	8 (15%): mild abdominal pain/nausea	0	8 (100)	0
Chisci *et al.*[2]	2025	293	Automatic (Angiodroid)	240 (81.9)	3 (1.0%): abdominal pain, nausea, vomiting	0	3 (100)	0
Total	–	429	–	–	21 (4.9%)	8 (1.9)	29 (100)	0

* Additional information on the other studies included in the review are available on request from the corresponding author.
† The overall number of patients experiencing CO_2 complications was 29. The rate of resolved intra-operative and peri-procedural complications was calculated using the overall number as denominator.

Furthermore, only the most recent studies and those employing automatic injection systems analysed CO_2 related complications, thus representing a potential selection bias. Hence, automated injection systems have become more prevalent in the past few years, with the advantage of having computerised control that allows precise management of injection volumes and pressures, thereby reducing the risk of air contamination compared with manual injection systems (syringe based delivery). Automated delivery ensures better control over injection parameters, reducing gas overdistension and bowel irritation.

The absence of any major adverse events across 492 patients reported in the six studies analysing this specific issue supports the safety profile of CO_2-DSA in EVAR, particularly when contemporary automated systems are employed. Although CO_2 has occasionally been implicated in severe complications such as mesenteric ischaemia, these are limited to isolated reports in iliac or visceral interventions with manual injection and were not observed in the EVAR specific population analysed in this review.

In conclusion, this review suggests that CO_2-DSA during EVAR is safe, well tolerated, and associated with a low rate of minor, self resolving complications. These events occur predominantly under locoregional anaesthesia. No major adverse events were identified. When delivered using modern automated injectors, CO_2-DSA appears to be a highly reliable adjunctive or alternative imaging modality, to be further explored in larger prospective studies and reflected in updated clinical guidelines.

CONFLICTS OF INTEREST AND FUNDING

M.G. and E.G. are consultants for Cook Medical for fenestrated and branched endovascular aneurysm repair. The other authors declare that they have no competing interests. No funding was received for this study.

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