Optimal device for carbon dioxyde deairing:

Further down the road!

By Marie-Soleil Brosseau, BHSc, CPC

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- Devices in this study will be supply free of cost by Ebbtides medical inc.

What is behide us?

INJECTIONS OF AIR AND OF CARBON DIOXIDE INTO A PULMONARY VEIN*

R. M. Moore, M.D. and C. W. Braselton, Jr.,† M.D.
Galveston, Tex.
From the Laboratory of Experimental Surgery, University of Texas School of Medicine, Galveston, Tex.

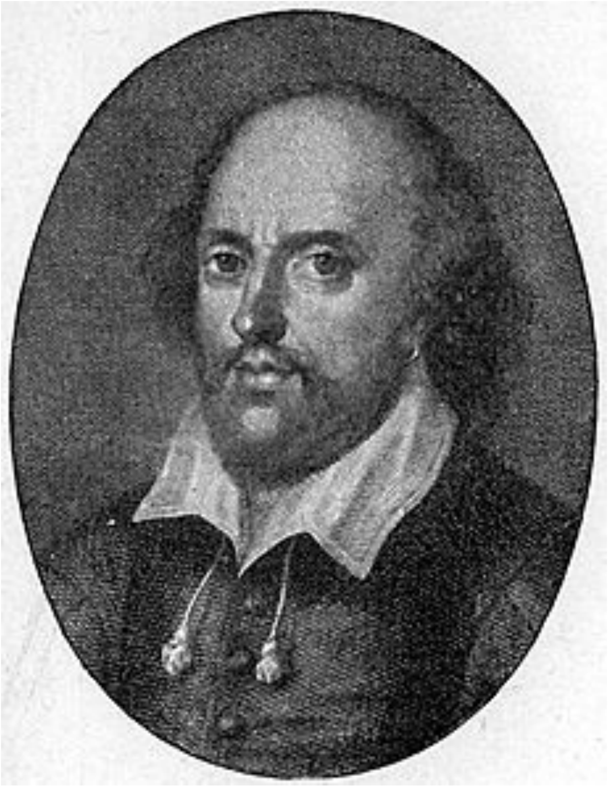
- Carbon dioxyde's solubility in blood: 0,48 mL/mL
- Oxygene's solubility in blood: 0.023 mL/ mL

Conclusion:

Upon injecting pure carbon dioxide into a pulmonary vein, the gas would not produce a stable coronary embolus has oxygen would do.

ICM-01-01-2012-08

CO2 or no CO2: That is the question!



ICM-01-01-2012-08

CO2 – Post-op intracardiac air

Perfusion 2003; **18:** 291 – 294

Carbon dioxide field flooding versus mechanical de-airing during open-heart surgery: a prospective randomized controlled trial

Mario V Kalpokas[1], Ian K Nixon[2], Roman Kluger[1], David S Beilby[1] and Brendan S Silbert[1]

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[2]*Department of Cardiothoracic Surgery, St. Vincent's Hospital, Melbourne, Australia*

Removal of intracardiac air during valvular surgery should be accomplished in the most effective manner. We conducted a prospective randomized controlled trial to compare mechanical de-airing and carbon dioxide (CO_2) field flooding in 18 patients undergoing elective valvular surgery. Transoesophageal echocardiography was used to record intracardiac bubbles, and this was assessed postoperatively by two independent echocardiographers blinded to treatment group. Both assessors graded the bubble count higher in the mechanical de-airing group compared with the CO_2 flooding group, and there was good agreement between assessors. CO_2 field flooding is more effective than mechanical de-airing in removing intracardiac bubbles following valvular surgery. *Perfusion* (2003) **18,** 291 – 294.

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CO2 – Post-op intracardiac air

Table 3 Scoring of air bubbles

Method of de-airing *Group A: mechanical* *Group B: carbon dioxide*	*Assessor 1* **p = 0.01*	*Assessor 2* **p = 0.03*	*Mean score* **p = 0.01*
Mechanical	3	3	3
Mechanical	2	3	2.5
Mechanical	3	3	3
Mechanical	3	3	3
Mechanical	0	0	0
Mechanical	1	3	2
Mechanical	1	2	1.5
Mechanical	1	2	1.5
Median (range)	1.5 (0–3)	3 (0–3)	2.25 (0–3)
CO_2	1	2	1.5
CO_2	1	2	1.5
CO_2	0	1	0.5
CO_2	0	0	0
CO_2	1	2	1.5
CO_2	1	1	1
CO_2	1	1	1
CO_2	0	0	0
CO_2	1	2	1.5
CO_2	0	0	0
Median (range)	1 (0–1)	1 (0–2)	1 (0–1.5)

* *p* values are for comparison between mechanical and CO_2 flooding groups (Mann–Whitney U-test).

Conclusion: CO2 field flooding is more effective than mechanical de-airing in removing intracardiac bubbles following valvular surgery.

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CO2 – Post-op intracardiac air

Effect of CO_2 Insufflation on the Number and Behavior of Air Microemboli in Open-Heart Surgery
A Randomized Clinical Trial

P. Svenarud, MD; M. Persson, PhD; J. van der Linden, MD, PhD

Background—The risks that the presence of air microemboli implies in open-heart surgery have recently been emphasized by reports that their number is correlated with the degree of postoperative neuropsychological disorder. Therefore, we studied the effect of CO_2 insufflation into the cardiothoracic wound on the incidence and behavior of microemboli in the heart and ascending aorta.

Methods and Results—Twenty patients undergoing single-valve surgery were randomly divided into 2 groups. Ten patients were insufflated with CO_2 via a gas diffuser, and 10 were not. Microemboli were ascertained by intraoperative transesophageal echocardiography (TEE) and recorded on videotape from the moment that the aortic cross-clamp was released until 20 minutes after end of cardiopulmonary bypass (CPB). The surgeon performed standard de-airing maneuvers without being aware of TEE findings. Postoperatively, a blinded assessor determined the maximal number of gas emboli during each consecutive minute in the left atrium, left ventricle, and ascending aorta. The 2 groups did not differ in the usual clinical parameters. The median number of microemboli registered during the whole study period was 161 in the CO_2 group versus 723 in the control group ($P<0.001$). Corresponding numbers for the left atrium were 69 versus 340 ($P<0.001$), left ventricle 68 versus 254 ($P<0.001$), and ascending aorta 56 versus 185 ($P<0.001$). In the CO_2 group, the median number of detectable microemboli after CPB fell to zero 7 minutes after CPB versus 19 minutes in the control group ($P<0.001$).

Conclusions—Insufflation of CO_2 into the thoracic wound markedly decreases the incidence of microemboli. (*Circulation*. 2004;109:1127-1132.)

Key Words: microemboli ■ surgery ■ carbon dioxide ■ echocardiography

CO2 – Post-op intracardiac air

TABLE 2. No. of Microemboli According to Transesophageal Echocardiographic Evaluation of the Left Atrium and Ventricle and the Proximal Part of the Ascending Aorta

	No. of Microemboli		
Study Period/Area of Interest	Group Control (n=10)	Group CO_2 (n=10)	*P*
From release of cross-clamp until 20 minutes after end of CPB			
LA	340 (300/393)	69 (39/129)	<0.001
LV	254 (173/334)	68 (59/112)	<0.001
Ao	184 (155/244)	56 (19/78)	<0.001
LA+LV+Ao	723 (634/895)	161 (149/310)	<0.001
First 15 minutes after release of cross-clamp			
LA	224 (108/336)	36 (16/69)	<0.01
LV	131 (77/170)	43 (24/61)	<0.001
Ao	81 (71/111)	25 (11/33)	<0.001
LA+LV+Ao	414 (316/597)	101 (67/143)	<0.001
Last 10 minutes of CPB			
LA	72 (27/193)	17 (9/41)	<0.01
LV	50 (36/82)	21 (9/30)	<0.001
Ao	47 (30/87)	16 (5/26)	<0.01
LA+LV+Ao	179 (92/327)	66 (22/88)	<0.001
First 20 minutes after end of CPB			
LA	94 (40/141)	8 (4/32)	<0.01
LV	73 (14/175)	12 (2/33)	0.01
Ao	56 (16/105)	13 (1/19)	<0.01
LA+LV+Ao	221 (67/418)	32 (8/77)	<0.01

Values are given as median (25th/75th percentile). LA indicates left atrium; LV, left ventricle; and Ao, aorta.

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CO2 – Post-op intracardiac air

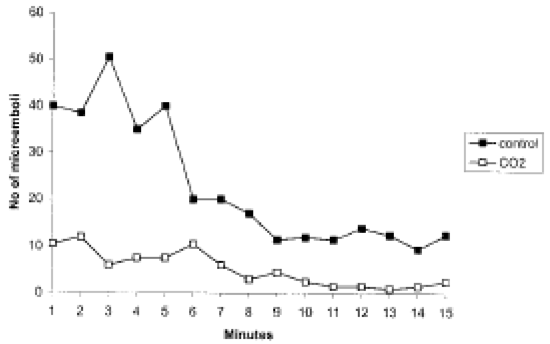

Figure 1. Median number of microemboli minute by minute during first 15 minutes after release of aortic cross-clamp in 3 areas of interest (left ventricle, left atrium, and proximal part of ascending aorta taken together shown by TEE).

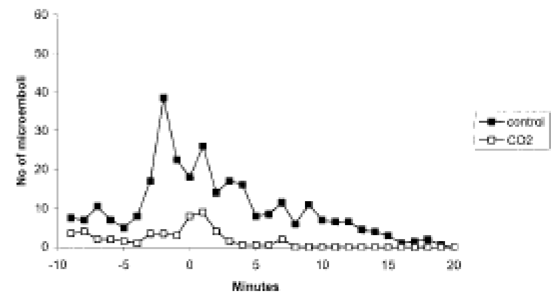

Figure 2. Median number of microemboli minute by minute from 10 minutes before to 20 minutes after discontinuation of CPB in 3 areas of interest (left ventricle, left atrium, and proximal part of ascending aorta taken together shown by TEE).

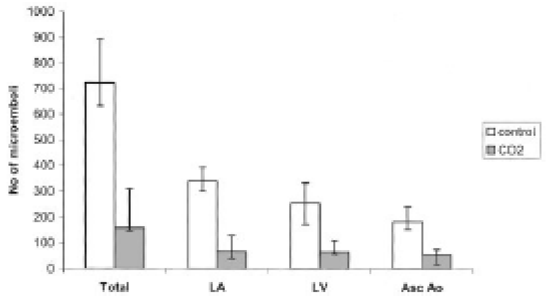

Figure 3. Total numbers of microemboli present in different areas of interest (left ventricle, left atrium, and proximal part of ascending aorta, and in all 3 areas taken together during whole study shown by TEE).

Conclusion: Insufflation of CO_2 into the thoracic wound markedly decreases the incidence of microemboli.

CO2 – Neurocognitive outcome

Carbon Dioxide Field Flooding Reduces Neurologic Impairment After Open Heart Surgery

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Background. Air emboli released from incompletely deaired cardiac chambers may cause neurocognitive decline after open heart surgery. Carbon dioxide (CO_2) field flooding is reported to reduce residual intracavital air during cardiac surgery. A protective effect of carbon dioxide insufflation on postoperative brain function remains unproven in clinical trials.

Methods. Eighty patients undergoing heart valve operations by median sternotomy were randomly assigned to either CO_2 insufflation (group I, n = 39) or unprotected controls (group II, n = 41). Preoperative evaluation included neurocognitive test batteries consisting of six different tests, and objective measurements of brain function by means of P300 wave auditory-evoked potentials (peak latencies, ms). Neurocognitive testing and P300 measurements were repeated on postoperative day 5. Neurocognitive deficit (ND) was defined as a 20% decrement in two or more tests.

Results. Preoperatively, P300 peak latencies did not differ between groups (374 ± 75 vs 366 ± 72 ms, not significant [n.s.]). Five days after surgery, P300 peak latencies were significantly shorter with CO_2 protection as compared with the unprotected control group (group I: 390 ± 68 ms, group II: 429 ± 75 ms, $p = 0.02$). Clinical outcome was comparable as for mortality (group I: 1 patient; group II: 2 patients) and cerebrovascular events or confusional syndromes (group I: 5 patients; group II: 4 patients) or other clinical variables as intubation time or hospital stay. Neurocognitive test batteries did not reveal differences between groups.

Conclusions. Shorter P300 peak latencies after surgery indicate less brain damage in patients who underwent heart valve operations with CO_2 flooding of the thoracic cavity. Even if these findings were not supported by clinical results or neurocognitive test batteries in our cohort, carbon dioxide field flooding has proven efficiency and should be advocated for all patients undergoing open heart surgery.

(Ann Thorac Surg 2008;85:543–7)

CO2 – Neurocognitive outcome

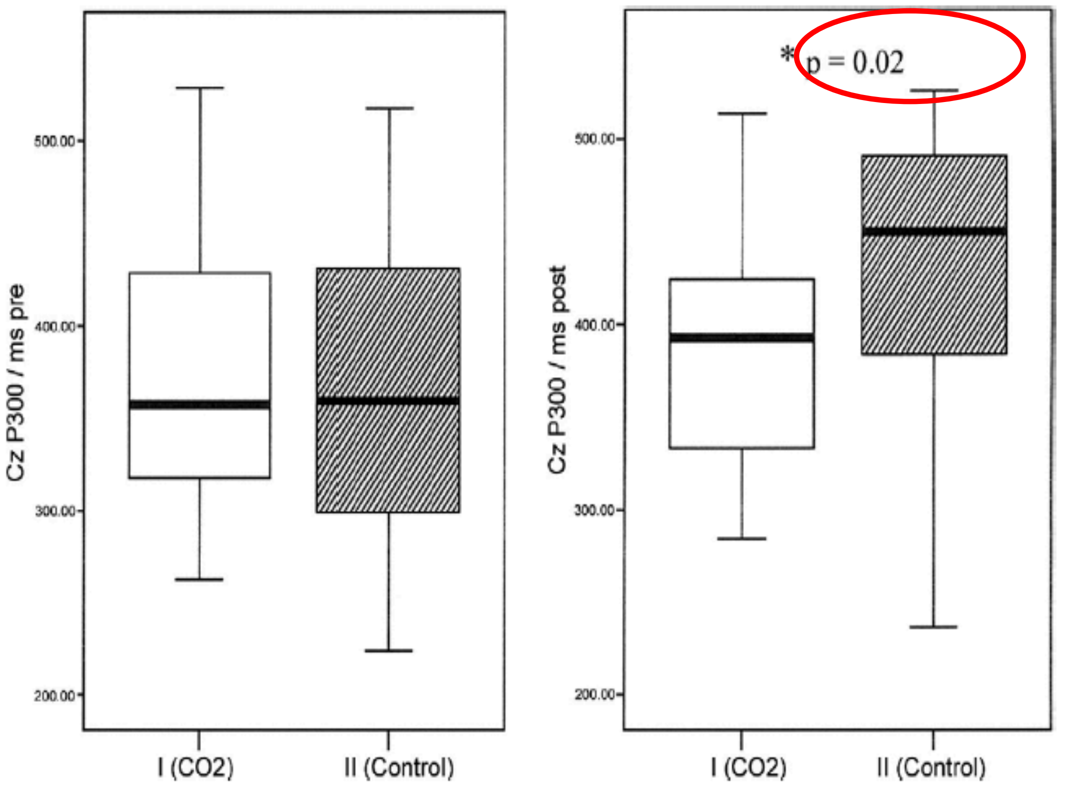

Fig 1. P300 peak latencies, before (left) and five days after surgery (right). Median, 25th/75th percentile and range are depicted. (Group I [CO2]; group II [control]; Cz = vertex; pre = preoperative; post = postoperative.)

ICM-01-01-2012-08

CO2 – Neurocognitive outcome

Table 3. Clinical Outcome

Characteristics	Group I, CO_2 (n = 39)	Group II, Control (n = 41)	*p*
Mortality	1 (low output)	2 (low output, respiratory failure)	0.56
Stroke, TIA or PRIND	0	2	0.18
Confusional syndrome	5	2	0.26
Hospital stay (days)	9.4 ± 2.5	9.4 ± 3.3	0.70
Intubation (hours)	17.2 ± 24.5	19.0 ± 30.7	0.89

PRIND = prolonged reversible ischemic neurological deficit; TIA = transient ischemic attack.

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CO2 – Neurocognitive outcome

Table 5. Neurocognitive Tests

Test	Group I (n = 36) Mean ± SD	p	Group II (n = 38) Mean ± SD	p
Block design (points)				
pre	11.4 ± 8.0	0.09	13.5 ± 9.8	0.23
post	10.5 ± 9.1		12.2 ± 8.9	
Digit span (points)				
pre	10.7 ± 3.0	0.20	10.9 ± 2.8	0.89
post	10.2 ± 3.4		10.7 ± 4.3	
Trail making (sec)				
pre	136.2 ± 60.3	0.004[a]	143.4 ± 62.7	0.02[a]
post	156.8 ± 79.5		156.3 ± 74.8	
Trail making (points)				
pre	87.9 ± 10.4	0.05	84.5 ± 8.8	0.02[a]
post	86.4 ± 14.0		80.8 ± 16.7	
d2 - Test (points)				
pre	134.2 ± 41.4	0.01[a]	129.2 ± 43.9	0.02[a]
post	120.9 ± 50.4		115.2 ± 49.2	
d2 (wrong)				
pre	23.8 ± 15.9	0.82	30.1 ± 42.6	0.57
post	26.8 ± 27.3		24.7 ± 24.3	
Benton (right)				
pre	4.4 ± 2.4	0.08	4.5 ± 2.1	0.03[a]
post	3.9 ± 2.3		3.8 ± 2.3	
Benton (wrong)				
pre	8.8 ± 4.6	0.08	9.4 ± 4.1	0.38
post	10.3 ± 5.4		9.7 ± 4.7	
Beck scale f. depression				
pre	8.5 ± 5.8	0.62	8.1 ± 7.2	0.14
post	8.1 ± 7.1		7.2 ± 6.8	

[a] Significant decline in pre- to postoperative performance.

Post = postoperative; pre = preoperative.

Conclusion: Shorter peak in CO2 group D5 post op indicating less brain dammage.
No difference in clinical results or congnitive test batteries
Advocate that C02 is efficient

ICM-01-01-2012-08

CO2 – Neurocognitive outcome

Asian Cardiovascular & Thoracic Annals
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Carbon dioxide insufflation and neurocognitive outcome of open heart surgery

Gautam Ganguly[1], Vikas Dixit[1], Seema Patrikar[2], Ravishankar Venkatraman[1], Satya Prakash Gorthi[3] and Nikhil Tiwari[1]

Abstract

Aim: Neurocognitive dysfunction continues to be the bane of open heart surgery despite vast improvements in surgical, anesthetic, and postoperative management. This observational cohort study was carried out to evaluate the efficacy of intraoperative CO_2 insufflation by the field flooding technique in reducing postoperative neurocognitive dysfunction.
Methods: Three hundred randomly selected patients undergoing open heart surgery were observed: 150 (group A) were exposed to CO_2 insufflation, and the other 150 (group B) were not exposed to CO_2. Anesthetic, cardiopulmonary bypass, and myocardial protection techniques were standardized and similar in both groups. Neurocognitive function tests were performed preoperatively, 1 week postoperatively, and after 1 month.
Results: The analysis revealed that neurocognitive dysfunction occurred in 8 of 150 patients in group A (incidence $p_1 = 0.053$) and 27 of 150 in group B (incidence $p_2 = 0.18$). The relative risk of neurocognitive dysfunction was 0.30 ($p = 0.001$, 95% confidence interval 0.14–0.63), implying that CO_2 insufflation is protective against neurocognitive dysfunction. The risk difference was 0.13 (p_2–p_1); this implies that 13% of patients can be prevented from developing neurocognitive dysfunction if exposed to CO_2.
Conclusion: This study confirms the known advantage of the relatively underutilized practice of CO_2 insufflation. We recommend that CO_2 insufflation be performed in all open heart surgery cases to bring down the incidence of neurocognitive dysfunction. This technique is simple to use without any major paraphernalia or additional cost.

CO2 – Neurocognitive outcome

Table 3. Neurocognitive dysfunction.

Variable	D+ (NCD)	D− (no NCD)	Relative risk*	95%CI
E+ (CO_2 insufflation)	8	142	$p_1/p_2 = 0.30$	0.14–0.63
E− (no CO_2 insufflation)	27	123		

*Risk difference $= p_2 - p_1 = 0.13$. D: outcome variable; E: exposure variable.

CO2 – Deflects airborne particles

Carbon dioxide insufflation deflects airborne particles from an open surgical wound model

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[b] Department of Engineering Science, University of Auckland, Auckland, New Zealand
[c] Department of Colorectal Surgery, Peter MacCallum Cancer Centre, Melbourne, Australia
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A R T I C L E I N F O

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Flow visualization
Medical device
Surgical site infection

CrossMark

S U M M A R Y

Background: Surgical site infections remain a significant burden on healthcare systems and may benefit from new countermeasures.
Aim: To assess the merits of open surgical wound CO_2 insufflation via a gas diffuser to reduce airborne contamination, and to determine the distribution of CO_2 in and over a wound.
Methods: An experimental approach with engineers and clinical researchers was employed to measure the gas flow pattern and motion of airborne particles in a model of an open surgical wound in a simulated theatre setting. Laser-illuminated flow visualizations were performed and the degree of protection was quantified by collecting and characterizing particles deposited in and outside the wound cavity.
Findings: The average number of particles entering the wound with a diameter of <5 µm was reduced 1000-fold with 10 L/min CO_2 insufflation. Larger and heavier particles had a greater penetration potential and were reduced by a factor of 20. The degree of protection was found to be unaffected by exaggerated movements of hands in and out of the wound cavity. The steady-state CO_2 concentration within the majority of the wound cavity was $>95\%$ and diminished rapidly above the wound to an atmospheric level ($\sim 0\%$) at a height of 25 mm.
Conclusion: Airborne particles were deflected from entering the wound by the CO_2 in the cavity akin to a protective barrier. Insufflation of CO_2 may be an effective means of reducing intraoperative infection rates in open surgeries.

Journal of Hospital Infection 95 (2017) 112–117

CO2 – Deflects airborne particles

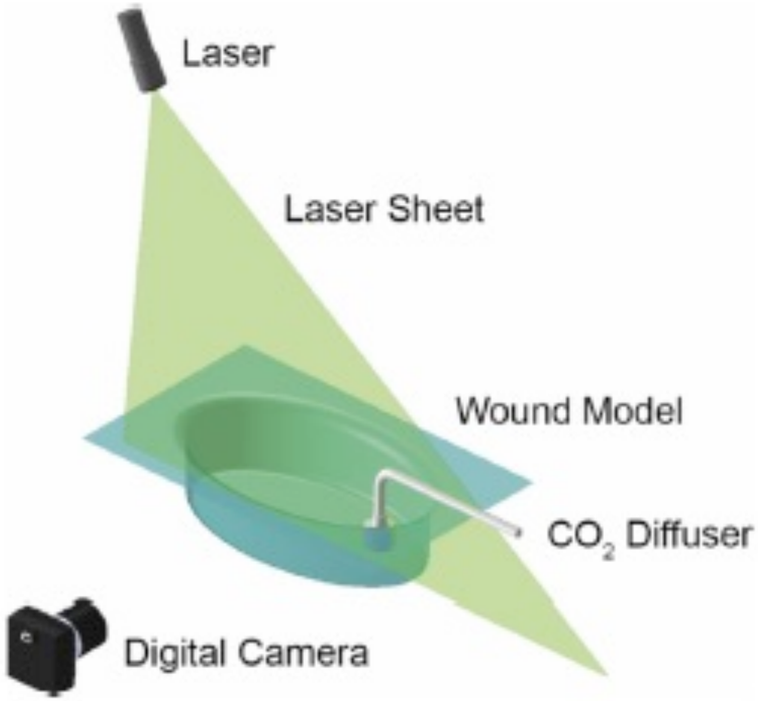

Figure 1. Schematic of modelled wound geometry.

Journal of Hospital Infection 95 (2017) 112–117

CO2 – Deflects airborne particles

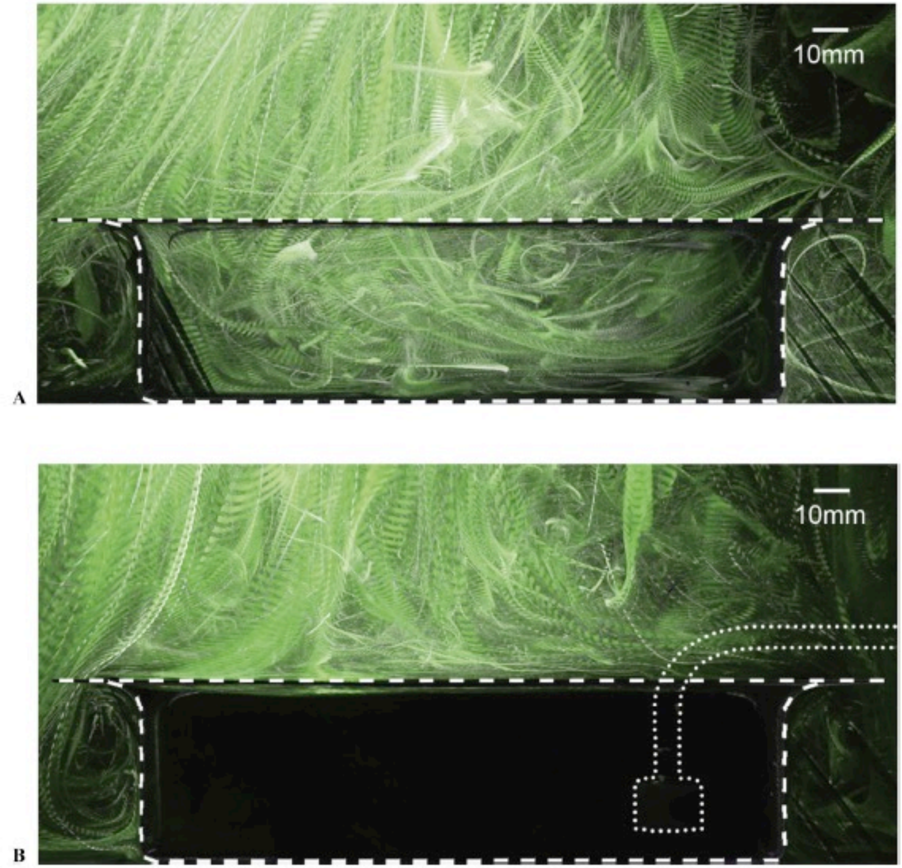

Figure 2. Flow and particle distribution in an open surgical wound model (a) without (control), and (b) with insufflation of CO_2 in a simulated theatre environment with 0.2 m/s downward flow ventilation.

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CO2 – Deflects airborne particles

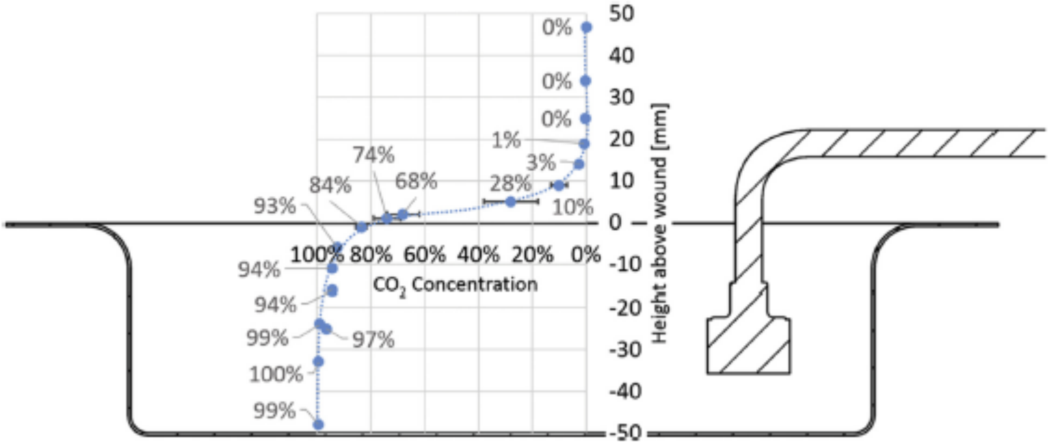

Figure 3. Carbon dioxide concentrations measured vertically above the centre of the wound cavity.

Table I
Mean ($N = 3$) protection factors for different wound depths and conditions investigated (standard deviations are shown in parentheses)

Depth	No insufflation (control)		CO_2 insufflation		CO_2 insufflation with hand movement	
	<5 μm	>5 μm	<5 μm	>5 μm	<5 μm	>5 μm
Wound edge	–	–	>3.4 (0.4)	>1.4 (0.1)	3.5 (0.4)	1.3 (0.0)
0 mm centre (top)	–	–	2.9 (1.0)	1.1 (0.6)	–	–
−10 mm centre	–	–	3.4 (1.7)	>1.2 (0.2)	–	–
−30 mm centre	–	–	2.4 (0.3)	1.6 (0.0)	–	–
−50 mm centre (floor)	−0.2 (0.1)	−0.1 (0.0)	2.9 (0.3)	1.3 (0.2)	3.9 (1.0)	>1.4 (0.2)

Conclusion:

-- Insufflation of CO2 may be an effective means of reducing intraoperative infection rates in open surgeries.

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CO2 – Decrease risk of infection

Intraoperative CO_2 insufflation can decrease the risk of surgical site infection ☆

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Received 12 December 2007; accepted 12 December 2007

Summary Surgical wound infections may ruin otherwise successful operations, and are associated with extended hospital stay, extra costs, and high mortality rates. In open surgery the wound's exposure to ambient air increases the risk of wound infection via several independent factors. The open surgical wound is subjected to airborne bacterial contamination, desiccation, and heat loss that increase the bacterial load, cause superficial necrosis, and impair tissue oxygenation and cellular immune functions, respectively. The present hypothesis is that topically applied carbon dioxide in the open surgical wound can be used intraoperatively to avoid these risks, and thus help to prevent postoperative wound infection. We also criticize existing methods and describe the theoretical background and supporting evidence for our suggested method. If the hypothesis would prove to be correct in a clinical trial, the new method may be an effective complement, or even an alternative, to antibiotics in preventing surgical site infection.

Medical Hypotheses (2008) **71**, 8–13

CO_2 – Decrease risk of infection

Table 1 Effects of intraoperative CO_2 insufflation that may help to decrease the risk of wound infection in open surgery

Expected effects of intraoperative insufflation with humidified CO_2
1. Decreased direct airborne contamination
2. Inhibited bacterial growth in the wound, via
a. Suffocation
b. Specific CO_2 effect
3. Decreased superficial tissue necrosis in the wound, via
a. Decreased desiccation
4. Increased wound tissue oxygenation, via
a. Thermal wound insulation/warming, via
– Decreased evaporation
– Greenhouse effect
– Preheated CO_2
b. Vasodilatation, via
– Increased wound and core temperature
– Specific, local CO_2 effect
c. Bohr effect in wound tissue, via
– Increased wound temperature
– Increased local pCO_2
– Decreased local pH
5. Improved cellular immune functions, via
a. Increased wound and core temperature

CO2 – Improve segmental wall motion

JECT. 2006;38:123–127
The Journal of The American Society of Extra-Corporeal Technology

Flooding the Surgical Field With Carbon Dioxide During Open Heart Surgery Improves Segmental Wall Motion

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University of California, San Francisco, California

Abstract: Air embolization to the coronary arteries is a common cause of myocardial ischemia during open heart surgery. Carbon dioxide emboli may be absorbed faster than air emboli. In this randomized, double blind, placebo-controlled trial, we determined that flooding the surgical field with carbon dioxide is associated with improved myocardial function assessed by transesophageal echocardiography. Forty-three valve surgeries were randomized to insufflation of 6 L/min of carbon dioxide or placebo through a Jackson Pratt drain into the pericardium during cardiopulmonary bypass. During rewarming, as pulse pressure rose above 10 mmHg, two observers graded severity of bubbles in the left heart. Two other observers evaluated wall motion in the transgastric midpapillary short axis view of the left ventricle using transesophageal echocardiography. Compared with baseline average scores among all walls (carbon dioxide, 1.42 ± 0.46; placebo, 1.39 ± 0.45), worsening of wall motion was less at 1 minute in the carbon dioxide (1.60 ± 0.62) than in the placebo group (1.95 ± 0.54; $p = 0.0266$). Better wall motion tended to persist in the carbon dioxide group at 10 (1.58 ± 0.59 vs. 1.77 ± 0.6) and 60 minutes (1.61 ± 0.45 vs. 1.66 ± 0.58). Particularly, the inferior wall tended toward transiently better function in the carbon dioxide group (at baseline and 1, 10, and 60 minutes: placebo, 1.62 ± 0.72, 2.68 ± 0.79, 2.48 ± 0.95, 2.10 ± 0.9 vs. 1.88 ± 0.97, 2.33 ± 1.1, 2.18 ± 0.96, 2.20 ± 0.94). Preoperative characteristics, length of bypass, anesthesia time, hospitalization, and intensive care unit stay were not different. We recommend administration of carbon dioxide because it may improve myocardial function. We describe how to avoid adverse effects of giving carbon dioxide by filtering the supply, continuously managing its level during bypass, increasing sweep speeds, continuously analyzing the in-line blood gas, and avoiding suctioning gases in the field into the cardiotomy reservoir. **Keywords:** cardiac surgery, transesophageal echocardiography, wall motion abnormalities, carbon dioxide. *JECT. 2006;38:123–127*

ICM-01-01-2012-08

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CO2 – Improve segmental wall motion

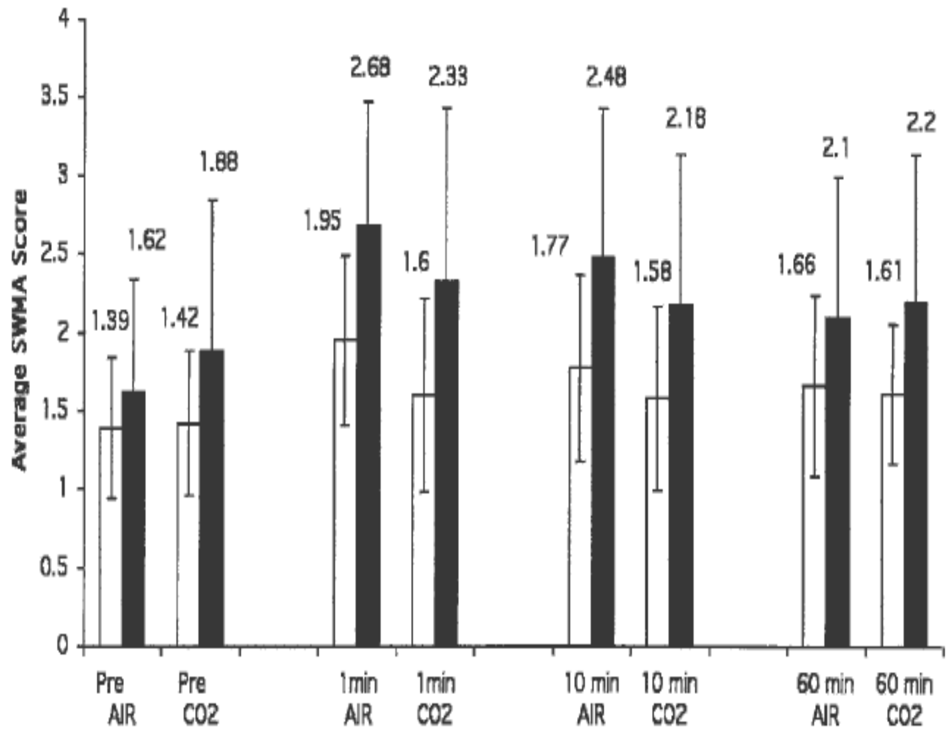

Figure 1. Mean SWMA scores are listed above each error bar. Open blocks represent average SWMA score. Solid blocks represent inferior wall score. All error bars represent ± SD; SD is 0.45, 0.46, 0.54, 0.62, 0.6, 0.59, 0.58, and 0.45, respectively, for each average SWMA bar, moving left to right. SD is 0.72, 0.97, 0.79, 1.1, 0.95, 0.96, 0.9, and 0.94, respectively, for each bar, moving left to right for each inferior wall bar.

CO2 – Management of blood gases

Conventional Carbon Dioxide Application Does Not Reduce Cerebral or Myocardial Damage in Open Heart Surgery

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Background. Open heart surgery is associated with a significant risk of cerebral and myocardial dysfunction, which is attributed in part to air embolism from incompletely deaired cardiac chambers. To evaluate the impact of carbon dioxide (CO_2) insufflation to the thoracic cavity, a prospective randomized study was designed.

Methods. A total of 62 elective patients were randomly assigned to CO_2 insufflation (group I, n = 31) or control (group II, n = 31). According to the Parsonnet risk score, 16 patients in group I (52%) and 10 patients in group II (32%) were categorized as being at either high risk or extremely high risk.

Results. In group II, perioperative mortality was 16.1% (5 patients); in group I, 1 patient died (ns). Creatine kinase MB isoenzyme, as a marker of myocardial damage, was more elevated in group I after surgery (38.0 ± 4.1 vs 28.0 ± 2.1, $p = 0.02$). Neurocognitive test scores did not reveal significant postoperative differences between groups.

Conclusions. Although mortality was lower with CO_2 insufflation, no benefit could be demonstrated for markers of cardiac ischemic damage or neurocognitive outcome in this high-risk population. As CO_2 concentrations in the thoracic cavity did not necessarily reach anticipated levels, our method of application is in question.

(Ann Thorac Surg 2001;72:1940–4)

CO2 – Management of blood gases

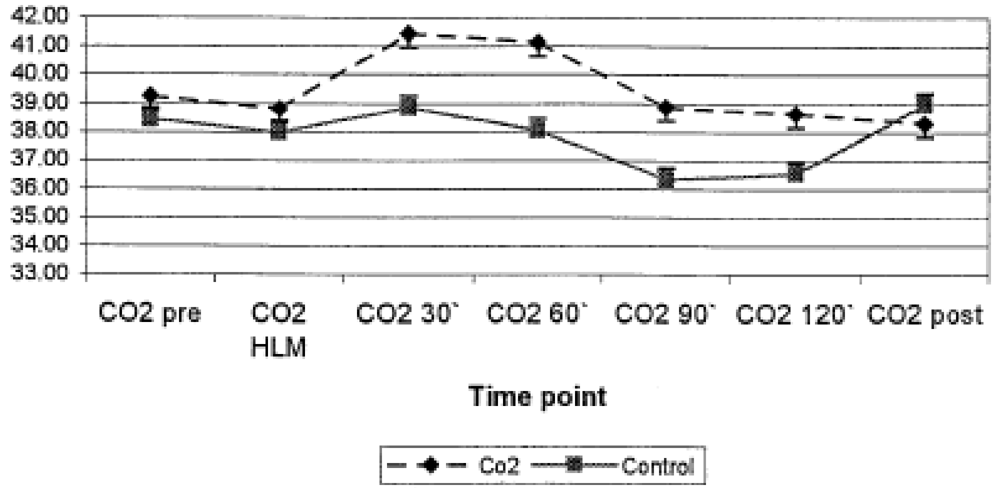

Fig 4. Changes in arterial blood gas. (CO2 pre = *PCO_2 preoperatively;* CO2 HLM = *after start of cardiopulmonary bypass (CPB);* CO2 30′, CO2 60′, CO2 90′, and CO2 120′ = *after 30, 60, 90, and 120 minutes, respectively, of CPB;* CO2 post = *after CPB.) Differences are significant 60 minutes after the start of CPB* ($p < 0.05$).

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CO2 – Management of blood gases

Perfusion 2003; 18: 291 – 294

Carbon dioxide field flooding versus mechanical de-airing during open-heart surgery: a prospective randomized controlled trial

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One concern with CO_2 field flooding is the potential for inducing systemic hypercarbia.[7,11] In this study, we increased the gas flows during CPB by an average of 0.5 L/min (range 0.5 – 1.5 L/min) to compensate for the additional CO_2 load. We used intermittent blood gas analysis to confirm that the $PaCO_2$ was in the normal range in all cases. By making appropriate adjustments to CPB flow in Group B, we were able to prevent any abnormal increases in CO_2. Other methods of managing the increased load of CO_2 include continuous monitoring of CO_2, and purging of a vented cardiotomy reservoir with a separate supply of oxygen or air.[11]

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CO2 – Management of blood gases

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Carbon dioxide insufflation and neurocognitive outcome of open heart surgery

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However, in view of possibility of excess CO_2 causing respiratory acidosis during CPB, we use a flow rate of 5L min^{-1}, and use of a left ventricular vent with multiple side holes appears equally effective.[12] In our study, we did not find CPB management issues of either excess acidosis due to CO_2 insufflation or any deleterious effect on intra- or postoperative acid-base management or inotropic requirement in the postoperative period.

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Optimal device for Co2 deairing

De-airing of a Cardiothoracic Wound Cavity Model With Carbon Dioxide: Theory and Comparison of a Gas Diffuser With Conventional Tubes

Mikael Persson, MSc, and Jan van der Linden, MD, PhD

Objectives: To compare the efficiency of a new gas diffuser with conventional tubes for carbon dioxide (CO_2) de-airing of a cardiothoracic wound cavity model, and to analyze how insufflation flow, outflow velocity, and diffusion affect de-airing.

Design: Technical study *in vitro.*

Setting: A nonventilated room at a University Hospital.

Interventions: De-airing by CO_2 insufflation via 3 methods was studied in a symmetric cardiothoracic wound model.

Measurements and Main Results: The studied insufflation devices were 2 open-ended tubes with an inner diameter of 2.5 mm and ¼-in (6.35 mm), respectively, and a gas diffuser (ie, a 2.5-mm tube with a diffuser at the end). CO_2 flows of 2.5, 5, 7.5, and 10 L/min were used. De-airing was assessed by measurement of remaining air content in a set of systematically distributed measuring points in the model. Three-, 2-, and 1-way analysis of variance all revealed significant interaction of device, flow, and depth on air content ($p < 0.001$). With tubes, the mean air content was 18% to 96% at the studied flows. With the gas diffuser, the mean air content in the cavity was below 0.2% at flows of 5 to 10 L/min. There was an exponential relation between calculated outflow velocity and air content. At a flow of 2.5 L/min, diffusion attenuated de-airing.

Conclusion: These data imply that de-airing of a cardiothoracic wound by CO_2 insufflation depends on flow and outflow velocity. To compensate for diffusion with ambient air, the CO_2 flow should be ≥ 5 L/min, and the outflow velocity should be about 0.1 m/s or less to avoid turbulence in the wound. This is only attainable with a gas diffuser.

KEY WORDS: carbon dioxide, diffuser, insufflation device, air embolism, cardiac surgery

Optimal device for CO2 deairing

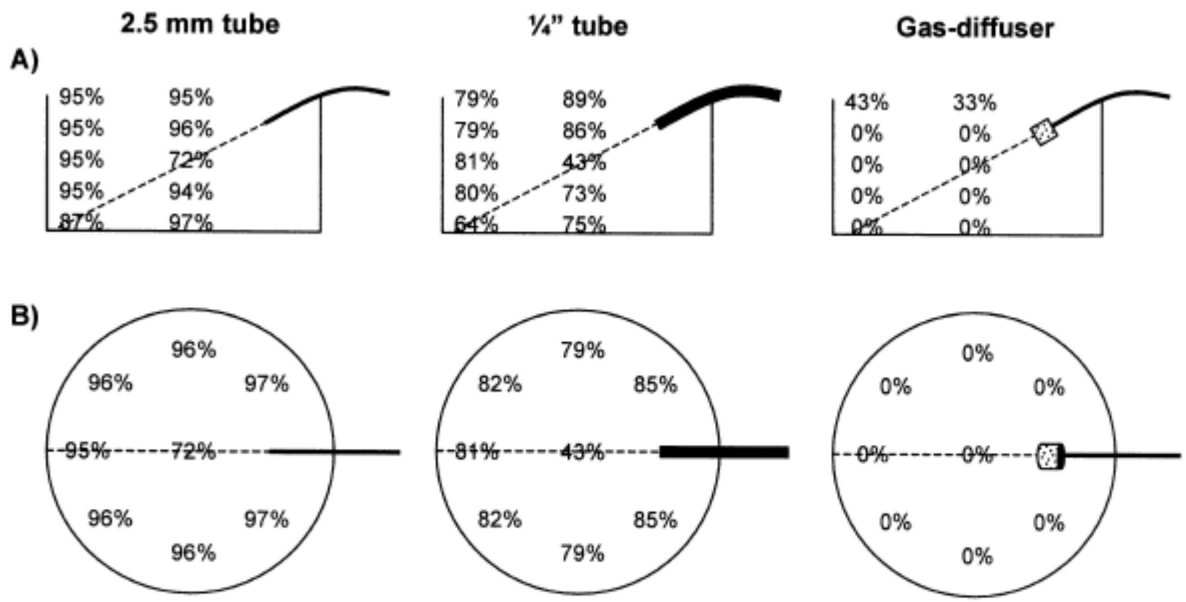

Fig 3. Distribution of mean air contents in % (n = 10) in (A) the vertical plane in the direction of the CO_2 insufflation and (B) in the horizontal plane at half the depth of the model, during CO_2 insufflation with a 2.5-mm tube, a 1/4-in (6.35 mm) tube and a gas diffuser at a CO_2 flow of 7.5 L/min. The dashed line marks the direction of the CO_2 insufflation. The air content in positions No. 6, 7, and 8 in the horizontal plane was not actually measured but was because of symmetry assumed to be equal to positions No. 2, 3, and 4, respectively.

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Optimal device for CO2 dearing

What Is the Optimal Device for Carbon Dioxide Deairing of the Cardiothoracic Wound and How Should It Be Positioned?

Mikael Persson, MSc,*† Peter Svenarud, MD,* and Jan van der Linden, MD, PhD*

Objectives: To compare recently described insufflation devices for efficient carbon dioxide (CO_2) deairing of the cardiothoracic wound and to determine the importance of their position.

Design: Experimental and clinical.

Setting: A cardiothoracic operating room at a university hospital.

Participants: A full-size torso with a cardiothoracic wound and 10 patients undergoing cardiac surgery.

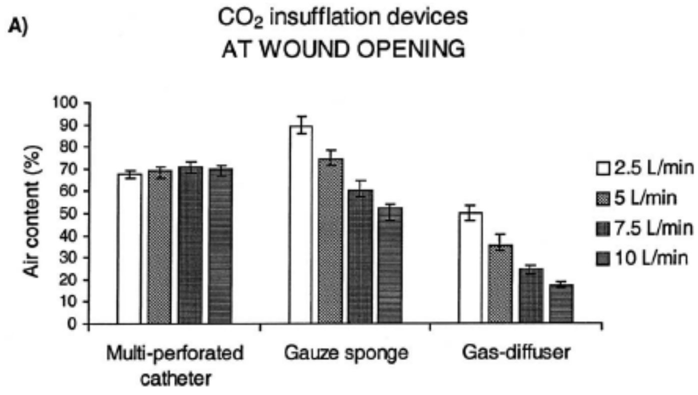
Interventions: Insufflation of CO_2 into the wound cavity at 2.5, 5, 7.5, and 10 L/min with a multiperforated catheter and a 2.5-mm tube with either a gauze sponge or a gas-diffuser of polyurethane foam at its end. The devices were tested when positioned at the level of the wound opening and 5 cm below and after exposure to fluid.

Measurements and Main Results: Deairing was assessed by measuring the remaining air content at the right atrium. With the multiperforated catheter, the gauze sponge, and the gas-diffuser, the lowest median air content in the torso was 8.4%, 2.5%, and 0.3%, respectively ($p < 0.001$), when positioned inside the wound cavity. When exposed to fluid, the gauze sponge and the multiperforated catheter immediately became inefficient (70% and 96% air, respectively), whereas the gas-diffuser remained efficient (0.4% air). During surgery, the gas-diffuser provided a median air content of 1.0% at 5 L/min, and 0.7% at 10 L/min.

Conclusions: For efficient deairing, CO_2 has to be delivered from within the wound cavity. The gas-diffuser was the most efficient device. In contrast to a gas-diffuser, a multiperforated catheter or a gauze sponge is unsuitable for CO_2 deairing because they will stop functioning when they get wet in the wound.

KEY WORDS: cardiac surgery, air embolism, deairing, carbon dioxide, insufflation device

Optimal device for CO2 deairing



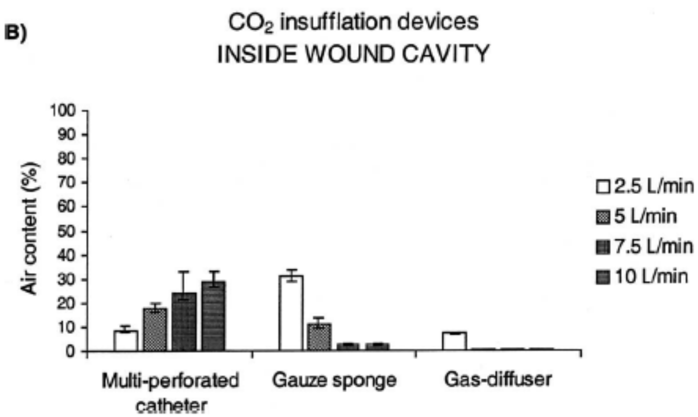


Fig 1. (A and B) Air content (median and range) measured at the topmost part of the right atrium in a cardiothoracic wound model. CO_2 was insufflated into the cavity from (A) the wound opening and (B) from within the wound cavity using a multiperforated catheter, a gauze sponge, and a gas-diffuser. CO_2 was insufflated at flows of 2.5, 5, 7.5, and 10 L/min.

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Optimal device for CO2 deairing

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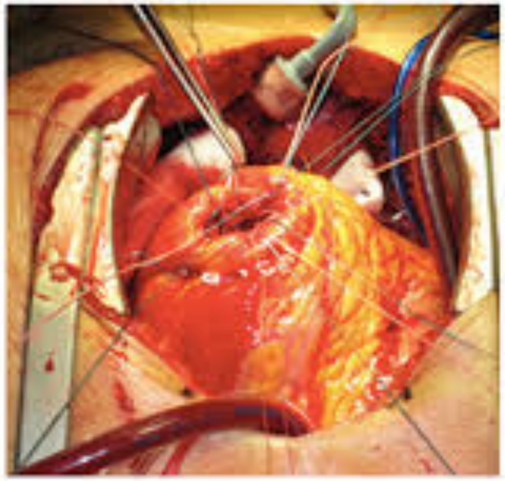
Optimal device for CO2 deairing



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Optimal device for CO2 deairing

Inclusion criteria:
- Patients with valvular surgery with or without revascularization surgery (bypass surgery)

Exclusion criteria:
- Minimally invasive surgery (MIC)
- Other use of CO2 elsewhere than in the thoracic - Emergency surgery
- Re-operation (Redo)
- Surgery requiring hypothermia below 32 degrees Celsius or circulatory arrest

Optimal device for CO2 deairing

Primary Outcomes:
- Effectiveness in the elimination of gaseous microemboli on the TEE.
- HIT on the Transcranial doppler.
- Assessment of systemic acidosis based on blood gas analysis.

Secondary Outcomes:
- CPB Time
- Aortic clamping time
- Debubbling time
- Mortality
- Morbidity (Per and post op)
- Decompensation and / or presence of fibrillation
- Extubation time
- Length of stay in intensive care

Optimal device for CO2 deairing

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