Simple On-Site Assembled Blower-Mister Device Provides Sufficient Humidification and Visualization in Off-Pump Surgery

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To effectively perform an anastomosis on a coronary artery under beating heart conditions, the anastomotic site must be cleared of blood to allow visualization for accurate suturing. We describe a simple, cost effective, on-site assembled blower-mister system.

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In off-pump coronary artery bypass grafting and in minimally invasive coronary procedures, optimal view of the anastomosis site is essential for anastomosis quality. However, coronary blood flow frequently compromises a clear view of the opened coronary vessel. Several visualization devices are available on the market to create a perfectly bloodless surgical field. Humidified air has been shown to safely and effectively clear arteriotomies of excessive blood, thereby supporting accuracy and expedition of suturing. We developed a simple blower-mister device that can easily be reproduced. The device provides excellent visualization by delivering a controllable amount of humidified carbon dioxide (CO_2).

Technique

A standard pressure monitoring line of 180 cm in length provides CO_2 flow, whereas a standard intravenous set allows inflow of saline solution. Both lines are connected with a three-way stop-cock connected to a bulbous steel cannula of 1.2 mm or 1.5 mm inner diameter. The set is compatible with all standard equipment in a conventional cardiovascular operating room. Although the fluid line can be connected to a standard infusion, the gas line is connected to a standard medical carbon dioxide source (Fig 1). The gas line is armed with a micro-filter. The device delivers a constant jet of humidified CO_2 to effectively eliminate blood from the anastomotic site. The bulbous cannula is kept at a distance of 5 to 10 cm from the coronary artery and allows precise targeting of the humidified CO_2 jet. With the standard calibrated inflow valve the CO_2 jet can be adjusted and controlled. In our experience, optimum CO_2 flow ranges between 1 and 4 L/min depending on the diameter of the respective cannula. As cannulas of different gauge can be used, the system readily adapts to the individual size of the patient's coronary artery. Sufficient humidification of the CO_2 stream was maintained by constant flow of saline between 20 and 50 mL/min. In order to prevent desiccation of the graft and the surrounding tissue we evaluated the appropriate velocity and power of the jet in cadaveric

Fig. 1. Components of the blower-mister system (from left to right): flow-regulator of the carbon dioxide source, filter, bulbous cannula, and intravenous bag with pressure cuff.

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Table 1. Effective Pressure Dependent on Gas Flow and Cannula-Size

	Cannula-Diameter			
CO_2 - flow (L/min)	∅ 1.0 mm	∅ 1.2 mm	∅ 1.5 mm	∅ 2.0 mm
0.5	109 mm Hg	91 mm Hg	31 mm Hg	4 mm Hg
1.0	260 mm Hg	153 mm Hg	48 mm Hg	11 mm Hg
1.5	492 mm Hg	208 mm Hg	81 mm Hg	16 mm Hg
2.0	547 mm Hg	299 mm Hg	93 mm Hg	23 mm Hg
2.5		403 mm Hg	148 mm Hg	29 mm Hg
3.0		581 mm Hg	188 mm Hg	39 mm Hg
3.5			210 mm Hg	47 mm Hg
4.0			286 mm Hg	56 mm Hg

pig hearts and thereafter during initial clinical application on the beating heart. We arrived at an optimum CO_2 jet pressure ranging from 50 to 150 mm Hg measured by a pressure transducer temporarily incorporated into the system. When using pressure less than 50 mm Hg the field was not entirely cleared, whereas using pressure greater than 150 mm Hg the tissue in the surgical field was dry (Table 1).

Comment

Good visualization is essential for anastomosis quality in off-pump surgery. Two features are important: (1) proper visualization of the anastomosis site regarding blood flow and (2) prevention of endothelial damage. Several techniques have been developed that aim at the provision of a bloodless field during the anastomosis procedure. For occlusion of the coronary artery and stabilization of the target vessel, encircling tourniquet sutures have been applied proximal and distal to the area of anastomosis [1, 2]. As an alternative, temporary intraluminal shunts were developed allowing blood supply to the myocardium distal to the anastomosis [3].

We recently demonstrated the superiority of intraluminal shunts in comparison with tourniquet occlusion in terms of preservation of intimal integrity in a chronic study [4]. The efficiency of hemostatic tourniquet occlusion is limited as it may provoke coronary intimal lesions when applied with too much force. On the other hand, residual flow into the anastomotic region may still occur even with an appropriately (slightly oversized) sized intraluminal shunt in place. Fortunately residual blood flow can be eliminated by using a blower. However, high velocity air jets can desiccate the intima with the consequence of irreversible endothelial damage. A simple and ingenious solution for this problem was found by humidifying the air blown onto the site of the anastomosis. Using scanning electron micrographs, Okazaki and colleagues [5] and Hoerstrup and colleagues [6] demonstrated that application of humidified gas by the so-called "blower-mister" did indeed prevent alteration of endothelial cells.

Blower-misters for off-pump procedures are now commercially available. However they are disposable devices and they are quite expensive. In the light of increasing budgetary restrictions we searched for a simple, cost-effective alternative to those devices. In an initial feasibility study, which was approved by the Animal Care and Use Committee of the Friedrich Schiller University Jena, our simplified blower-mister was evaluated on cadaveric pig hearts with no negative side effects on the intima. Thereafter we used the blower during clinical beating heart procedures. In an early experience with 56 patients and a total of 123 coronary anastomoses, we did not find signs of marked desiccation or intimal trauma of either the graft or the coronary artery, whereas a clear view of the anastomosis was maintained even in the presence of considerable residual coronary blood flow. Therefore we consider our invention as safe, efficient, comfortable, and particularly attractive for monetary reasons; roughly estimated the disposable components: pressure line, transfusion set, and micro-filter costs are less than 4 Euro ($4 to $5 Euro), and the standard bulbous steel cannula can be resterilized. We used CO_2 instead of O_2 because of the 20-fold higher solubility of CO_2 in blood. Theoretically these properties can minimize air embolization of the coronary arteries, which were described in case report forms by other authors [7, 8]. Furthermore, consequent use of an intraluminal shunt may help to prevent any air embolization because of the occlusion provided by the shunt olives.

In conclusion, a useful blower-mister with excellent clinical performance can be assembled on-site utilizing standard components with very cost-attractive conditions and special equipment is not required.

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