

# Vacuum-assisted drainage in cardiopulmonary bypass: advantages and disadvantages

## *Sistema a vácuo na circulação extracorpórea: vantagens e desvantagens*

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### *Abstract*

Systematic review of vacuum assisted drainage in cardiopulmonary bypass, demonstrating its advantages and disadvantages, by case reports and evidence about its effects on microcirculation. We conducted a systematic search on the period 1997-2012, in the databases PubMed, Medline, Lilacs and SciELO. Of the 70 selected articles, 26 were included in the review. Although the vacuum assisted drainage has significant potential for complications and requires appropriate technology and professionalism, prevailed in literature reviewed the concept that vacuum assisted drainage contributed in reducing the rate of transfusions, hemodilutions, better operative field, no significant increase in hemolysis, reduced complications surgical, use of lower prime and of smaller diameter cannulas.

**Descriptors:** Cardiopulmonary Bypass. Review. Thoracic Surgery.

### INTRODUCTION

Cardiopulmonary bypass (CPB) is a set of machines, devices, tubes and techniques that temporarily replace the pump and ventilatory functions of the heart and lungs, respectively, while these organs are excluded from the circulation by surgical event<sup>[1]</sup>.

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### *Resumo*

Revisão sistemática sobre drenagem assistida a vácuo na circulação extracorpórea, demonstrando seus benefícios, desvantagens, por relatos de casos e evidências sobre seus efeitos na microcirculação. Realizou-se pesquisa sistemática, no período de 1997-2012, nas bases de dados do PubMed-Medline, Lilacs e SciELO. Termos: “circulação extracorpórea”, “vácuo”, “drenagem”, “cirurgia cardíaca” e suas correspondentes traduções, em condições variadas. Dos 70 artigos selecionados, 26 foram incluídos na revisão. Embora a drenagem assistida a vácuo possua potencial significante de complicações e exija tecnologia e profissionalismo respectivo adequado, prevaleceu na literatura revisada o conceito de que a drenagem assistida a vácuo contribuiu na redução no índice de transfusões, hemodiluições, melhor campo operatório, não aumento de hemólise significativa, redução de complicações pós-cirúrgicas, uso de menor prime e uso de cânulas de menor calibre.

**Descritores:** Circulação Extracorpórea. Revisão. Cirurgia Torácica.

The CPB circuit has two reservoirs, and the venous reservoir receives blood from the venous drainage and the cardiectomy reservoir receives blood from the operative field, recovered by aspiration. In addition, it has oxygenator coupled to a heat exchanger. Between the oxygenator and the arterial cannula an arterial line filter is installed. Some equipments are used according to the method of the team, as the pre-by-

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Abbreviations, acronyms and symbols	
CPB	cardiopulmonary bypass
VAD	vacuum assisted drainage
TNP	topical negative pressure
CVP	central venous pressure

pass filter, cardioplegia system as well as the use of the vacuum system.

The use of vacuum-assisted drainage system (VAD) emerged in an attempt to reduce the deleterious effects of hemodilution and with the advent of minimally invasive surgery has gained prominence, in addition to be used in heart<sup>[2-5]</sup> surgeries.

The vacuum technique consisted of using negative pressure in the venous reservoir, allowing the active drainage vein, eliminating the principles of gravity and siphoning<sup>[6]</sup>. This way it is possible to shorten the circuit, reducing the prime volume, hemodilution and possibly the incidence of blood transfusion<sup>[2-5]</sup>.

The systematic review aimed to examine the use of VAD in CPB citing its advantages and disadvantages through case reports and evidence about its effects on microcirculation.

## METHODS

Systematic research was performed, including articles published in Portuguese and English, in the period 1997 to 2012.

The reference search was performed in the databases of the following databases: PubMed-Medline (<http://www.ncbi.nlm.nih.gov/pubmed>), Lilacs (<http://lilacs.bvsalud.org/>), SciELO (<http://www.scielo.org/php/index.php>) using the keywords: “bypass”, “vacuum”, “drain”, “heart surgery” and its corresponding translations and synonyms, in varied conditions.

The reviews on the subject and reference lists of included articles were consulted in search of new items for inclusion in this study.

Table 1. Overview of randomized studies that examined the use of vacuum assisted drainage.

Characteristics	Number of studies (references)
Reduction in transfusion	7 [8-12,18,21]
Reduction in hemodilutions	7 [9,12,18,20,22]
Better operative field	2 [9,24]
Non-significant hemolysis	7 [10,18,19,20,22,26]
Reduction in postoperative complications	2 [10,18]
Lower prime volume	7 [10-12,17,18,20,21]
Smaller cannulas diameter	4 [11,18,20,24]
High risk	2 [13,34]
Limitations	3 [12,17,19]
Air Embolism	5 [11,13,16,18,19]

After this step, the process of selecting studies for examining titles and abstracts was initiated. The first inclusion criterion used was identification of relevant studies, whereas those in which the drainage system was the main subject of the article (Table 1). At this moment, all studies that only cited vacuum as a method used in surgeries and/or described events were excluded.

## Summary of Data

47 articles were found using the keywords, in the first search in the PubMed-Medline and 23 articles in SciELO-Lilacs.

Through analysis of the abstracts included in this phase, we defined as criteria for recovery of full articles: case report, systematic reviews, meta-analyzes, randomized controlled trials, whose results dealt with the direct effect of the use of vacuum in the patient (positively or negative). The review was concluded with the reading of 27 full articles.

The 27 studies analyzed were divided into three groups: (I) reported cases with the use of vacuum drainage (n=3); (II) use of vacuum in surgical processes and their influence on hemodynamic (n=5); (III) use of vacuum pump procedures and their evaluation (n=19).

In group I, there were three case reports, two of which describe methods that were successful and one with accident using the vacuum technique. Shin et al.<sup>[7]</sup> used the vacuum drainage in surgery for tumor in the right atrium. At the end of the procedure the technique was assessed as effective, allowing the removal of the tumor in a safe and simple way. Similarly, Fukuda et al.<sup>[8]</sup> describe the surgery of the tricuspid valve in a patient with severe congestion caused by insufficient heart valve with calcified tissue. At the end of the study, the authors report a successful procedure citing that hemolysis caused by the method was insignificant and the patient remained stable postoperatively, with minimal bleeding and improvement in edema of the lungs and kidneys.

Gregory et al.<sup>[9]</sup> in a case report, mentioned massive air embolism in patient who underwent the Fontan operation. The problem occurred in the venous reservoir pressurization caused by suction pad that blocked the air flow from within the reservoir. Therefore they recommend the deep knowledge of the perfusionist on the material used in order to avoid this type of accident.

In group II, five studies using vacuum as treatment of surgical wounds and/or abscess have been described. Petzina et al.<sup>[10]</sup> in their study showed that the use of vacuum system generated immediate reduction in cardiac output and systolic volume, as well as the left ventricular end-diastolic volume. Kadohama et al.<sup>[11]</sup> in a case report, also demonstrated the efficacy of using vacuum to post sternotomy, even in pediatric patients, as well as Anne et al.<sup>[12]</sup> who mentioned the efficiency of the vacuum in wound closure in mediastinum. Lindstedt et al.<sup>[13]</sup> showed the benefits of vacuum treatment on myocardial microcirculation.

Finally, Chen et al.<sup>[14]</sup> demonstrated that a vacuum assist to aid in wound scarring can be used for its benefits such as to restore the integrity of the basement membrane, reducing the endothelial space and edema, blood vessel patency, increasing their diameter and capillary volume and stimulate angiogenesis.

In group III were analyzed the following characteristics: blood transfusion, hemodilution, surgical field, hemolysis, postoperative complications, prime volume, size of the cannulas used, air embolism, limitations and risks of the technique.

## DISCUSSION

The development of research in CPB has helped to clarify doubts of some procedures, often for non-scientific reasons, but from experience in the surgical routine. This systematic review shows that the use of a vacuum drainage system can be effective, safe, providing new techniques to be performed.

Analyzing three case reports found (group I), we observed that in one case there was an accident with massive air embolism. Gregory et al.<sup>[9]</sup> reported that the accident was not caused solely by the vacuum system used, but suction pad not suitable for the procedure, which generated the pressurization system. Replacing the suction pad for another that could maintain and facilitate the flow of air with the environment, the procedure has become safe. Thus, the author calls attention to the materials used in the procedure, which can cause accidents when unknown by professionals.

On analysis, it was observed that 79% (n=15) of the authors consider that the technique of vacuum assist provides benefit to the procedure and/or patient. The reduction in the number of transfusions<sup>[5,6,15-19]</sup> contributes to not overload in blood banks. The reduction occurs by improving venous drainage and, consequently, no need for volume increase in the venous reservoir to maintain levels of security against ingress of air into the system.

The lower use of blood products contributes to reduction of postoperative<sup>[16,20]</sup> complications, and the technique offers reduced total prime<sup>[5,16-21]</sup> reducing hemodilution<sup>[5,6,18-21]</sup> and maintaining hematocrit and hemoglobin levels at acceptable levels. There was disagreement with respect to generation of hemolysis by the use of a vacuum. Most authors<sup>[16,18,20,22-25]</sup> considers that hemolysis caused in procedures with negative pressure procedures were similar to hemolysis in gravitational drainage. However, when comparing vacuum drainage with drainage by centrifugal pump, Cirri et al.<sup>[26]</sup> showed that the vacuum drainage causes higher degree of hemolysis, according conclusions confirmed by Gregoretto et al.<sup>[27]</sup>. However, Lau et al.<sup>[28]</sup> and Shin et al.<sup>[24]</sup> disagree, showing similar levels of hemolysis.

Another reported benefit was the improvement in visualization of the operative field with the reduction of blood, resulting in greater security and convenience to the procedure<sup>[6,24]</sup>. The limiting venous drainage promotes more congested surgical field and imposes difficulties in viewing by the surgeon. The possibility of using smaller diameter tubes is another important factor<sup>[17,18,20,24]</sup>. This possibility is explained because the vacuum system improves the flow rate through the cannula, allowing greater flow.

With this, one can use smaller caliber of venous cannulas, which improves visualization during surgery, without compromising venous drainage. It also allows cannulation of smaller vessels. The vacuum drainage is closely related to minimally invasive surgeries advocating small surgical incisions and optimization of the operative field. However, due to the benefits this type of drainage can be used in normal infusions, provided that safety measures are taken: (i) the use of own modern equipment, (ii) the use of filters and (iii) knowledge of the technique by the perfusionist<sup>[29]</sup>.

Only two authors considered the type of drainage analyzed as being at high risk<sup>[29,30]</sup>, being a procedure with high probability of accidents due to the rapid rate at which the volume changes in the reservoir. Even with such statement, the studies conclude that the procedure is effective and safe, because even with the condition of rapid change in volume in the reservoir, the experience in the described cases confirms the viability of an efficient procedure together with technical mastery.

Davila et al.<sup>[30]</sup> stated that the procedure has risk because the technique is different from the usually practiced, forcing the perfusionist to have knowledge of the system. In a vacuum pump system, the system must be built to allow alternatives in cases of accidents. In the specific situation of use of negative pressure, blood circulation methods and depressurization of the tanks must be designed to provide safe procedure. Exemplifying the fact, Davila et al.<sup>[30]</sup> demonstrated that simple change in the valve position of the circuit assembly can generate pressurization system, preventing or hindering the correction of the accident.

In our survey, air embolism was reported in five studies<sup>[17,18,22,29,31]</sup> showing that the venous vacuum assistance produced almost 10 times more embolism in the arterial line compared to the gravitational line, despite the use of suitable equipment. The aforementioned embolism refers to the production of microbubbles in the fluid due turbulence produced during the passage through a narrow tubing under a high pressure. The same studies show that only by comparing the length of the methods of vacuum and gravity, in a situation of air into the venous line circuit by the venous line, the vacuum allows more volume of air into the system. This suggests potential danger, especially

in the use of prime reduced, as with lowered volume levels in the reservoir the turbulence generated in CPB can allow air embolism.

The other authors cited confirm the possibility of embolism, however claim to be controllable the risks of this involvement, since the perfusionist has knowledge of the applied technique, knowing the limitations and risks involved. Even with increased chances of accidents, Carrier et al.<sup>[32]</sup> and Murai et al.<sup>[25]</sup> argue that the use of vacuum does not increase the chance of neurological and general complications, confirming the theory that the risks can be controlled.

In addition to the risks mentioned above, some limitations on vacuum technique are taking into account by some authors as Colangelo et al.<sup>[22]</sup>, who reported the technique as costly, while mentioning the procedure using centrifugal pump to perform the drainage. However, the statement becomes fragile. It is of global knowledge that there are other methods of lower cost for the procedure, such as: (i) use of the monitor to control the vacuum from the vacuum system installed in operating rooms, (ii) vacuum pumps and (iii) roller pump.

Another limitation is cited by Taketani et al.<sup>[5]</sup>, affirming that the vacuum procedure presents instability due to imprecise control of negative pressure. However, this limitation is overcome when using valves or monitors that control levels of negative pressure.

The survey also included studies that deal with the influence of vacuum in hemodynamic parameters, especially on the microcirculation. Currently, there is little knowledge about the effects of the vacuum in the microcirculation, a place that really cares perfusionists, because in this area it is difficult to achieve blood perfusion. There are studies reporting the effectiveness of vacuum treatment<sup>[10-12]</sup> as that detailed by Gustafsson et al.<sup>[33]</sup> on surgical wounds such as post sternotomy mediastinitis. The mechanism by which the topical negative pressure (TNP) promotes wound healing is by stimulating blood flow in the periphery of the wound and skeletal muscle. The mechanical stress and pressure gradient through the tissue cause increased blood volume in the area. Both mechanical stress or increased blood flow are known to stimulate endothelial proliferation, capillary budding and angiogenesis<sup>[34]</sup>.

Seeking to use knowledge of TNP for improved myocardial microcirculation, Lindstedt et al.<sup>[13]</sup> performed a study with 6 pigs simulating myocardial ischemia by occluding the left posterior descending artery and using the TNP as a way to improve the microcirculation. The results proved that the use of 50 mmHg of topical negative pressure stimulated a 25 mm depth perfusion in the skeletal muscle and there was a doubling of the blood flow in the myocardium detected using Laser Doppler.

Petzina et al.<sup>[10]</sup> performed a sternotomy in 6 pigs and treated the surgical wound using vacuum, and demonstrat-

ed that the use of negative pressure reduced cardiac output and stroke volume of the animals undergoing the surgical process. This procedure would be used in patients with deep sternal infections that have ischemic heart failure. Concomitant to this, Chen et al.<sup>[14]</sup> show the effects of the vacuum in the microcirculation. The author studied wounds in rabbits, analyzing the speed of capillary blood flow, as well as its size, capillary density, the structure of the endothelium and the healing process.

The best rated pressure level was -10 kPa, which achieved maximum speed of blood in the capillaries in 4 minutes and remained with this flow for a longer time. After the completion of the wounds on the rabbits' ears, it was observed in the tissue: turgid mitochondria, membrane-targeting, large endothelial spaces, few cell junctions and many pinocytotic vesicles. After 2 minutes of use of vacuum, the capillaries become more round, the endothelium cubic and the basal membrane were almost completely recovered. In 10 minutes, the capillaries become elliptical and dilated. In 30 minutes capillary sprouts emerged as villous processes, meaning angiogenesis. In 2 hours new vessels were found, the endothelial spaces have been reduced and cell junctions were firmer. In 24 hours we observed reduction in pinocytotic vesicles. In the control group, in 3 days was still observed fragmented cell membrane and diverse cell membrane. We attribute to these facts the increased blood volume caused by stimulation of negative pressure gradient, favoring membrane integrity, resulting in reduced permeability, which consequently will reduce edema formation and thus heal the site quickly.

Transposing this study for the cardiopulmonary bypass, even in different conditions, we think that the use of vacuum can benefit the microcirculation, promoting better tissue perfusion and minimizing interstitial edema caused by inflammation and by changing flow regime generated by cardiopulmonary bypass. A study that still needs to be performed.

Munster et al.<sup>[35]</sup> reported the perfusion procedure with the aid of vacuum in 54 patients. The system described in the study is similar to that normally used in cardiopulmonary bypass with addition of negative pressure monitor, disposable pressure transducer and "Y" connector to attach the tank to the vacuum source. The relief valve of the venous reservoir already composed the system and therefore it did not have to be added. By using this system, the author claims to have enabled the heart to be always empty, as well as allowed the use of smaller cannulas facilitating the surgical procedure. Other factors were reported as the maintainability of patient's central venous pressure (CVP) close to zero, reducing the addition of 250 ml of prime fluid on average and no haemolysis was observed postoperatively.

With these data, Munster et al.<sup>[35]</sup> reiterate the authors previously cited of some benefits of using negative pressure in CPB, adding that the procedure used is low cost and benefits the patient during the infusion, by reducing the patient's

CVP, thereby improving venous drainage and reducing preload momentarily until the CPB. The effect of better venous drainage allows the perfusionist maneuvers, depending on the hematocrit (greater than 25%) and hemoconcentration. This procedure can reduce the excess liquid, even reducing – after CPB – the preload on the myocardium, as well as reducing the formation of edema in the patient, resulting in significant improvement in clinical outcome.

### CONCLUSION

In conclusion, although the VAVD has significant potential for complications and requires technology and appropriate professionalism, it prevailed in the reviewed literature the concept that the VAVD contributed in reducing the rate of transfusions, hemodilutions, better operative field, no significant increase in hemolysis, reduced postoperative complications, smaller use of prime and smaller cannulas diameter.

Authors' roles & responsibilities	
EBCF	Data Survey, review of articles and textual construction
FALM	Reviewer
LNGC	Reviewer
IN	Reviewer and author responsible for publishing

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