Invasive Hemodynamic Monitoring in the Postoperative Period of Cardiac Surgery

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Objective *– To assess the hemodynamic profile of cardiac surgery patients with circulatory instability in the early postoperative period (POP).*

Methods *– Over a two-year period, 306 patients underwent cardiac surgery. Thirty had hemodynamic instability in the early POP and were monitored with the Swan-Ganz catheter. The following parameters were evaluated: cardiac index (CI), systemic and pulmonary vascular resistance, pulmonary shunt, central venous pressure (CVP), pulmonary capillary wedge pressure (PCWP), oxygen delivery and consumption, use of vasoactive drugs and of circulatory support.*

Results *– Twenty patients had low cardiac index (CI), and 10 had normal or high CI. Systemic vascular resistance was decreased in 11 patients. There was no correlation between oxygen delivery (DO_2) and consumption (VO_2), p=0.42, and no correlation between CVP and PCWP, p=0.065. Pulmonary vascular resistance was decreased in 15 patients and the pulmonary shunt was increased in 19. Two patients with CI < 2L/min/m^2 received circulatory support.*

Conclusion *– Patients in the POP of cardiac surgery frequently have a mixed shock due to the systemic inflammatory response syndrome (SIRS). Therefore, invasive hemodynamic monitoring is useful in handling blood volume, choice of vasoactive drugs, and indication for circulatory support.*

Key words: cardiac surgery, Swan-Ganz catheter

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Received on 10/28/98
Accepted on 01/27/99

In 1945, Leniz Dexter performed the first catheterization of the pulmonary artery to diagnose congenital heart disease [1]. The history of the clinical hemodynamic monitoring began after the publication by Swan and Ganz introducing the use of the balloon catheter for the pulmonary artery, in 1970 [2]. The use of the Swan-Ganz catheter (SGC) has increased each year throughout the world, despite being an invasive and expensive procedure [3]. In 1975, it was employed in 7.2% of the patients with acute myocardial infarction (AMI), increasing to 19.9% in 1984 [4].

Since the report by Gore et al [4] on the use of the SGC in patients with AMI, where a higher mortality was shown in patients monitored with the SGC as compared with those monitored with the central venous catheter (CVC), there has been great controversy in the literature about the costs and benefits of that type of monitoring [5-8].

The dispute culminated with the publication of an editorial by Dalen and Bone[3] asking for the suspension of the monitoring with the SGC until randomized and comparative studies could be performed to better define the risks.

The objective of our study was to analyze, retrospectively, the hemodynamic profile of patients undergo-ing cardiac surgery with circulatory instability in the early postoperative period (POP), discuss our experience and the benefits obtained with the SGC in this category of patients.

Methods

A retrospective study was performed. We analyzed the medical records of all patients who underwent cardiac surgery and were admitted to the intensive care unit of the HC-UNICAMP, in the years of 1995 and 1996, and who required hemodynamic monitoring with the SGC due to hemodynamic instability in the early POP.

In all patients with instability following cardiac surgery, the first drug used for hemodynamic support was dopamine. Those patients who remained hypotensive (systolic pressure <90mmHg) with 10µg/kg/min of dopamine underwent invasive hemodynamic monitoring with the SGC. The need for a second drug (dobutamine, nora-

drenaline or sodium nitroprusside) or circulatory support was determined only after invasive monitoring.

The following parameters were assessed: cardiac index (CI), pulmonary (PVR) and systemic vascular resistance (SVR), pulmonary shunt, oxygen delivery and consumption, and correlation between central venous pressure (CVP) and pulmonary capillary wedge pressure (PCWP). The use of vasoactive drugs and their indications due to the measurements obtained through monitoring were also evaluated, as was the use of circulatory support in patients with CI <2L/min/m^2.

The Pearson correlation coefficient was used for the statistical analysis, with a level of significance of 5% ($p<0.05$).

Results

During 1995 and 1996, 306 patients in the POP of cardiac surgery were admitted to the intensive care unit of the HC-UNICAMP.

Thirty of these patients, with a mean age of 57.72±14.37 years, were monitored with the SGC due to hemodynamic instability in the early POP. Twenty-one of these patients were males. Their types of surgery are listed in table I.

The following hemodynamic measures were obtained: CI – 20 patients had CI <3.5L/min/m^2; 7 patients had CI >4.1L/min/m^2; and 3 patients had values of CI within the acceptable range (3.5-4 L/min/m^2). The minimal value found was 1.35L/min/m^2, the maximal was 6.84L/min/m^2 and the mean was 3.14±1.36L/min/m^2 (fig. 1).

Table I - Diagnosis of patients monitored with the Swan-Ganz catheter

Mitral replacement	6
Second mitral replacent	1
Mitral valvoplasty	1
Mitral replacement + revascularization	1
Mitral replacement + tricuspid plasty	1
Aortic replacent	1
Aortic replacement + revascularization	1
Secondaortic replacement + revascularization	1
Second aortic-mitral replacement	1
Aortic-mitral replacement + revascularization	1
Aortic dissection	1
Myocardial revascularization	14
Total	30

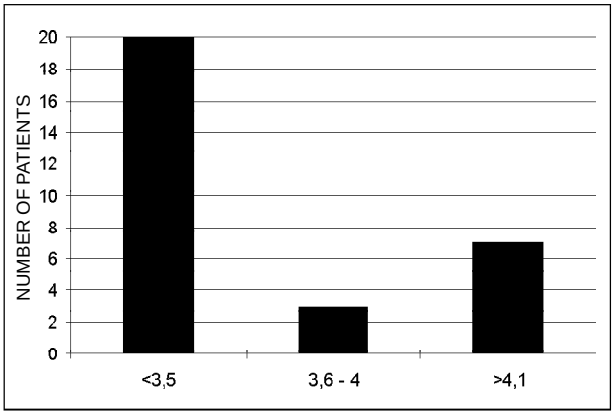

Fig. 1 – Cardiac index CI L/min/m^2. Mean value 3.14 ± 1.36; min 1.35; max 6.84.

Ten patients had a normal systemic vascular resistance (SVR); 11 patients had SVR <800 dyn/sec/cm^5 and 9 patients had SVR >1201 dyn/sec/cm^5. The minimal value was 312 and the maximal value was 2425 dyn/sec/cm^5 (fig. 2).

In 11 patients, the PVR was normal; in 15 patients, PVR was <150 dyn/sec/cm^5 and in 4 patients, PVR was >250 dyn/sec/cm^5 (fig. 3).

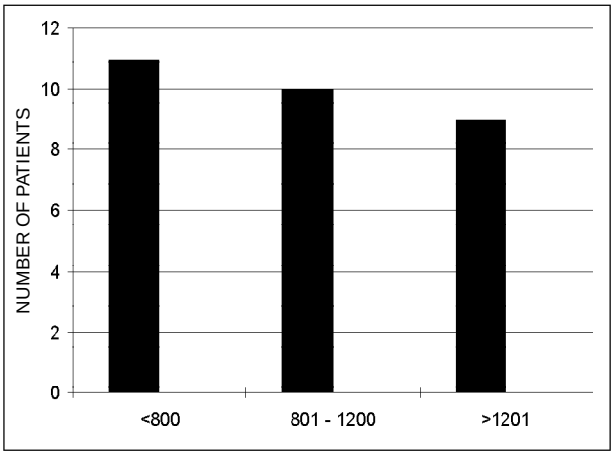

Fig. 2 – Systemic vascular resistency. SVR- dyn/s/cm^5.

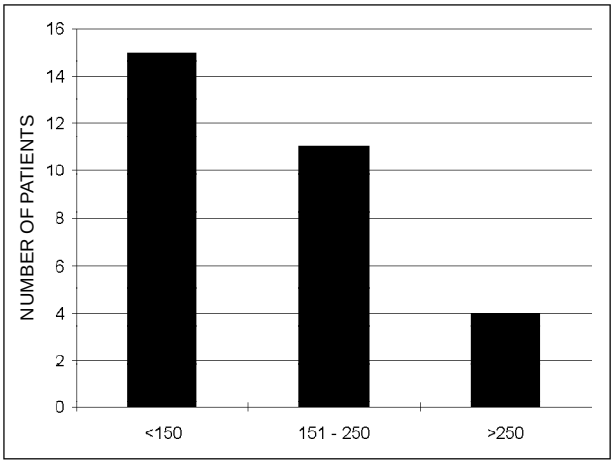

Fig. 3 – Pulmonary vascular resistency. PVR- dyn/s/cm^5.

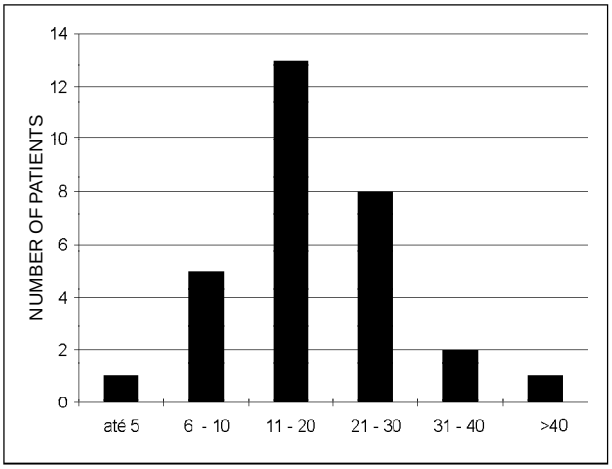

Fig. 4 – Pulmonary shunt. Pulmonary shunt %.

One patient had an acceptable pulmonary shunt (up to 5%); in 5 patients it ranged from 6 to 10%; in 11 patients from 11 to 20%; in 8 patients from 21 to 30%; in 2 patients from 31 to 40%; and in 1 patient >40% (fig. 4).

The mean value for DO_2 was 656.07±231.9mL/min/m^2 and for VO_2 was 282.52±139.43mL/min/m^2. There was no correlation between DO_2 and VO_2 (p=0.42) (fig. 5). There was also no correlation between CVP and PCWP (p=0.065) (fig. 6).

The vasoactive drugs used according to data obtained during monitoring are listed in table II.

Dobutamine was used in one patient; dopamine in 4; association of dobutamine and dopamine in 10 patients; association of dobutamine, dopamine and norepinephrine in 9 patients; association of dopamine and norepinephrine in 4; association of dobutamine, dopamine and sodium nitroprusside in 2; and association of dobutamine and sodium nitroprusside in one patient.

Five patients had CI <2L/min/m^2 and required circulatory support. Table III shows the values for CI and SVR, drugs used, type of circulatory support and outcome of each patient. Mechanical circulatory support was used in only 2 patients.

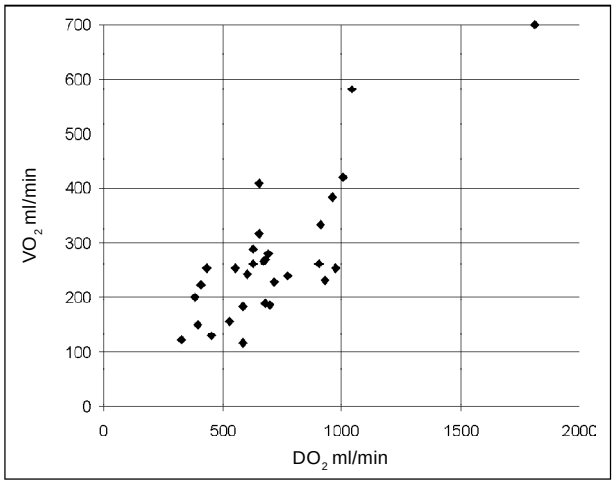

Fig. 5 – Correlation between DO_2 and VO_2 (ml/min). There was no significant correlation between DO_2 and VO_2 (p = 0.42).

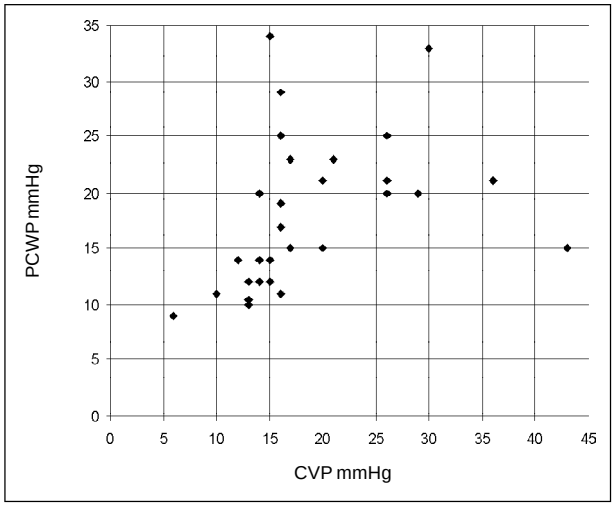

Fig. 6 – Correlation between central venous pressure (CVP) and pulmonary capillary wedge pressure (PCWP). There was no significant correlation between PVC and PCWP (p = 0.065).

Table II - Vasoactive drugs used

	Number of patients
Dobutamine	1
Dopamine	4
Dopamine + dobutamine	10
Dopamine + dobutamine + noradrenaline	9
Dopamine + noradrenaline	4
Dobutamine + dopamine + nitroprusside	2
Dobutamine + nitropusside	1
Total	30

Table III - Patients with cardiac index < 2.0 L/min/m^2

	CI/SVR	Circulatory support	Drugs	Outcome
1	1.9/1369	IAB	Db, D, SN	-
2	1.6/1134	Bleeding	Db, D	-
3	1.6/1653	IAB + CP	Db, D, SN	+
4	1.8/1140	Leriche's Syndrome	Db, D	-
5	1,35/2425	-	Db, SN	+

CI/SVR- cardiac index / systemic vascular resistance; Db- dobutamine; D-dopamine; SN- sodium nitroprusside; +: good outcome; -: death; IAB: intraaortic balloon; CP: centrifuge pump.

One patient had significant bleeding, another had Leriche's syndrome, and another patient improved after using vasoactive drugs. In these cases, therefore, circulatory support was not employed.

There were no complications deriving from the use of the SGC.

Among the monitored patients, 16 died and 14 had a good outcome.

All patients without initial hemodynamic stability, who did not use the SGC, did not die. In the whole group, the mortality rate was 5.25%. Of all patients with hemodynamic instability monitored with the SGC, 3 had preoperative ejection fraction (EF) <40% and 2 died; from the 7 patients with EF between 40% and 55%, 5 died; from the 20 patients with EF >55%, 9 died. Among the 16 patients who died, 2 had coronary heart disease in 2 arteries, 5 patients in 3 arteries, and 3 patients had coronary heart disease asso-ciated with valvular heart disease. From the patients with valvular heart disease who died, 4 had single-valve disease and one patient had a double-valve disease. One patient with cardiomyoplasty evolved with severe systemic inflammatory response syndrome (SIRS) in the POP and died. Seven patients who died had chronic obstructive pulmonary disease, 4 had diabetes mellitus and 2 had chronic renal failure.

Discussion

Invasive hemodynamic monitoring with the SGC has a broad use in situations of hemodynamic instability in critically ill patients.

In the United States, around 1 million catheters are used per year for hemodynamic monitoring at a cost of 2 billion dollars [3].

Gore et al [4], in a study published in 1987 on the use of SGC in patients with complicated AMI, observed a higher mortality in the group monitored with the SGC as compared with the group monitored with the CVC. That study was neither prospective nor randomized, allowing us to assume that the patients monitored with the SGC were in a more critical condition. After that study, many others were published in the search for the answer to the question: is it worth spending so much money on a monitoring procedure that does not increase the patient's survival? [5-8]

We retrospectively evaluated 30 patients who had undergone cardiac surgery. These patients had hemodynamic instability in the early POP and underwent invasive hemodynamic monitoring with SGC. Our study showed that in the POP of cardiac surgery, most of the patients had hemodynamic instability resulting from mixed or hyperdynamic shock due to SIRS.

Measurements obtained by hemodynamic monitoring defined our therapeutical management and, in 13 patients, norepinephrine was used to enhance the vascular tonus. Sodium nitroprusside was used in only 3 patients (table II).

Another point to be stressed is that we did not find the correlation between CVP and PCWP. It is known that the control of the blood volume based only in the measurement of CVP is not safe.

Hemodynamic monitoring also guided us in the indication for mechanical circulatory support in patients with CI <2L/min/m^2. Circulatory support with the centrifuge pump associated with the intraaortic balloon was used in one patient and, in another patient, only the intraaortic balloon was used.

Davies et al[9] also concluded that monitoring with the SGC was useful for orienting the control of the blood volume, the use of vasoactive drugs and even the choice of the anesthesia employed in 220 surgical patients.

We found no correlation between DO_2 and VO_2, as previously observed by Routse et al [10].

As the hemodynamic monitoring with the SGC is a very invasive and expensive method, less invasive and expensive methods are currently being investigated.

Transesophageal Doppler echocardiography might be a solution to this problem; however, the values obtained with this method vary greatly when compared with those obtained with the SGC [11].

Thoracic bioimpedance has similar limitations. Thomas et al [12] compared cardiac output (CO) measurement with bioimpedance and SGC in 28 patients after myocardial revascularization. In intubated patients, bioimpedance showed up to 30% smaller values than those obtained with the SGC.

Monitoring with the SGC has its risks and complications. In our study, however, the patients monitored with the SGC showed no complications related to the use of the catheter.

Nishikawa et al [13] divided the complications into two groups: those caused by the venous puncture and those due to the SGC. Pneumothorax had an incidence of 1% to 6% and arrhythmias of 30% to 60%. In the 1970s, pulmonary infar-ction had an incidence of up to 7.2%; after the use of intra-flow, however, the risk was practically abolished.

The incidence of thrombosis inside the cardiac chambers, where the catheter passes, was 30%, in the postmortem studies. Rupture of the pulmonary artery occurred in 0.1% to 0.2% and sepsis in 1% of the patients.

During the measurement of the CO, several errors can occur due to temperature, injected volume, time of injection, administration of fluids, hypotension, slow flow, incorrectly positioned catheter, shunts and other problems.

Wallace et al [14] found great differences in the values of CO measured with the use of saline solution at room temperature, when compared with the values obtained using a cold saline solution.

In 1989, Tuman et al [15] assessed morbidity and mortality in 1,094 patients with complicated AMI, comparing monitoring with CVC and SGC and found no difference. Zion et al [16] compared both modalities of monitoring in 371 patients and observed a higher mortality in patients with severe ventricular failure monitored with SGC. Out of our 30 patients monitored with the SGC, 16 died and 14 survived.

From the patients who died, 9 had a normal EF in the preoperative period. They developed hemodynamic instability due to SIRS or mixed shock, which led to multiorgan failure and death. Patients with triple coronary heart disease or association of coronary heart disease with valvular heart disease were at a higher risk. With regard to previous diseases, chronic obstructive pulmonary disease (COPD) had the highest risk and almost half of the patients (7) who died, had COPD associated with cardiac disease.

Pearson et al [8] evaluated the cost/benefit ratio of three modalities of monitoring after cardiac surgery, in 226 patients: CVC, SGC, and SGC plus continuous venous saturation. This randomized study showed a much higher cost in patients monitored with the SGC, with no differences in mortality; however, patients monitored with CVC and with higher instability were randomized again for the two other modalities of monitoring. At the end of the research, only 28 patients out of 226 were monitored with the CVC.

In the review by Matthay et al [5], the success rate of the values of the PCWP and CO, through the clinical evaluation of intensive care unit patients, did not reach 50%. This confirmed our opinion that in cases of cardiac surgery with hemodynamic instability, it is impossible to manage the patient without invasive monitoring, which defines the type of hemodynamic alteration and the appropriate vasoactive drugs to be used.

The Ontario group organized a prospective and randomized study [17] comparing monitoring with the SGC and CVC, but they could only gather 33 patients, because the physicians refused to leave the critically ill patients without invasive monitoring due to ethical reasons. Guyatt et al [17] published the results obtained in these 33 patients showing the same mortality with the two modalities of monitoring.

Discussion about the use of the SGC called so much

attention to the intensivists, that the journal *Chest* published a series of letters with the title: "Defenders of the pulmonary artery catheter" [18].

The consensus statement about the use of the SGC in cardiac surgery published by the journal *Critical Care Medicine*, in 1997 [19], defined that invasive hemodynamic monitoring with SGC could be useful in patients undergoing high-risk car-diac surgery, with impairment in ventricular function, con-cluding that there were no scientific bases to justify the temporary suspension of the use of the SGC. The discus-sion, however, continues [20,21].

We conclude that hemodynamic monitoring with the SGC is fundamental in patients undergoing cardiac surgery, who have hemodynamic instability in the POP. The value of PCWP is important to assess the blood volume of the patient; measurement of SVR is fundamental for the choice of vasoactive drugs, and the CI is fundamental in the indication for circulatory support.

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