Analysis of Intra-Aortic Balloon Performance in Open-Heart Surgery

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Abstract

A failing heart can be supported in several ways, including cardiopulmonary bypass pumps (CPB), extracorporeal membrane oxygenators (ECMOs), and other types of auxiliary heart pumps. The intra-aortic-balloon-pump (IABP) is one technique of internal counter-pulsation that supports maintaining the circulatory system It continues to be used as a vascular support device to critically unwell cardiac patients. Many recent studies have focused on the problems of the (IABP) in open-heart surgery, while other researchers concentrated on the positioning and size of the balloon, some of them studied the timing of the balloon's inflation and deflation. this paper has reviewed a brief Introduction, the basic principles of the balloon, how to trigger the balloon pump as well as the use of IABP in Coronary Artery Bypass Graft (CABG), balloon mistiming of inflation and deflation, balloon timing usage within open-heart surgery and finally a balloon position and sizing.

Keywords: Intra-Aortic Balloon Pump, Open-Heart Surgery, Counter-Pulsation, Mistiming.

تحليل أداء بالون الشريان الأبهري في جراحة القلب المفتوح

زينب اياد وجيه، صادق جعفر حمندي، وسام صالح العبيدي، جورجيس تيدي

الخلاصة:

يمكن دعم القلب الضعيف بعدة طرق، بما في ذلك مضخات المجازة القلبية الرئوية (CPB)، والاكسجه الغشائيه خارج الجسم (ECMOs)، ومضخات القلب المساعدة الأخرى. احدى هذه الوسائل هي مضخة البالون الابهري (IABP) وهي إحدى تقنيات النبضات الداخلية المضادة الذي يبقى جهاز دعم الدورة الدموية الأكثر استخدامًا لمرضى القلب المصابين بأمراض خطيرة. ركزت العديد من الدراسات الحديثة على مشاكل (IABP) في جراحة القلب المفتوح، بينما ركز باحثون آخرون على موضع وحجم البالون ، وقام بعضهم بدراسة توقيت تضخم البالون وانكماشه. استعرضت هذه المقالة تاريخًا موجزًا لـ (IABP) ، والمبادئ الأساسية للبالون ، وكيفية تشغيل مضخة البالون بالإضافة إلى استخدام IABP في تطعيم مجازة الشريان التاجي CABG ، وضبط توقيت البالون للتضخم والانكماش ، وتوقيت البالون الاستخدام في جراحة القلب المفتوح وأخيرًا وضع البالون وحجمه.

1. Introduction

Since the late 1960s, cardiac surgeries have used the (IABP) as a myocardial assist device. When he published about enhancing coronary blood flow via postponing a arterial pressure pulse using animal models in 1952, Kantrowitz initially put out the concept of altering overall timing of pressure occurrences during a heartbeat [1]. IABP usage increased systemic arterial pressure but also urine production in two patients having cardiogenic shock, and one of them lived and was released from the hospital, according to Kantrowitz's 1968 report [2]. the device was first introduced in Iraq in 1975 at the Ibn al-Bitar center for cardiac surgery but at that time it was rarely used because of the lack of helium gas that the device needed to fill the balloon. Since that time the IAB was used in cardiac surgery with patients that failed to separate from the heart-lung machine. 200 patients undergoing open heart surgery over the course of the previous five years used the IABP. It is a quick and efficient way to provide temporary cardiac support, particularly for elderly individuals. Additionally, shorter surgical procedures have better postoperative results [3]. The IAB P's major effect is to assist the failing left ventricle and maintain cardiac output; the effect on the right ventricle is indirect and not completely understood.

By enhancing coronary blood stream through the diastolic portion of the cardiac cycle and relieving left ventricle stress through the systolic phase, the IABP is intended to improve myocardial perfusion. Out-of-hospital cardiac arrest patients have employed IABP as one of the percutaneous mechanical circulatory supports [4].

2. Basic principles of the intra-aortic balloon pump

The fundamentals of counter-pulsation by IABP and the induced hemodynamic changes were described in 2005 by Theodoros and Christodoulou from Greece. although it has been made clearer how biological processes alter IABP acute hemodynamic performance in a significant way [5]. The relationship between cardiac flow and the arteries' wall stress, as well as the hemodynamic impact of (IABP) upon that blood perfusion of both the coronary artery, brain, and lower limb, remain unresolved [6].

The major hemodynamic impacts of IABP treatment are preload, afterload, as well as aortic pressure changes brought on by an external force. By boosting the ischemic myocardium's oxygen supply and lowering cardiac oxygen requirement (consumption), these modifications enhance the cardiac energy balance. Counter-pulsation is due to the rapid inflation then deflation of IAB into thoracic aorta in sync with cardiac activity. The favorable IABP effects finally result in aortic mass displacement and pressure alterations. In 2008 Yoshiyuki Takami and Hiroshi Masumoto from Japan analyzed the Influence of (IABP) on Graft flow in Coronary Surgery. In 84 patients who underwent prophylactic IABP, 172 grafts were examined intraoperatively with a transit-time flowmeter. On and off IABP, the following measurements were taken for each graft: mean flow, maximal flow, pulsatility index, as well as a diastolic filling index. The study showed that the IABP significantly increased CABG graft global flow and also its diastolic components [5].

The long-term effects of intra-aortic balloon pumps (IABP) on all-cause mortality were examined in a 2018 study by Holger and colleagues in patients with acute myocardial infarction complicated by cardiogenic shock at 6 years. At the 6-year follow-up after randomization, the clinical outcomes revealed no discernible difference in mortality between the IABP group and control [7].

In 2014 V. Gramigna *et al.* evaluated the pulsed cardiopulmonary bypass and aortic blood flow pattern. The balloon inflation increased blood flow in epiaortic arteries, with the left subclavian artery seeing the greatest increase of 25% and the thoracic aorta experiencing the greatest decrease of nearly 68%, and the blood flow pattern in these arteries changed from swirling to constant during IABP-induced pulsed CPB as compared to regular CPB with a linear flow, according to the study's major findings [8].

In order to assess IABP augmentation frequencies on hemodynamics, computational fluid dynamics were used (CFD), Maria V. Caruso *et al.* from Italy studied the effect of weaning on aortic hemodynamics with organ perfusions in 2019. There have been studies on full help (1:1), moderate assistance (1:2, and 1:3), and poor support (1:4). For the comparison, the same boundary conditions were applied. The findings showed that the ratios affect human perfusions differently and that the balloon's presence in the aorta significantly changes its hemodynamics. Additionally, data indicated that there was a notable change between 1:2 and 1:3 frequencies and that the 1:4 ratio was preferable to the 1:3 ratio for the weaning of counterpulsation treatment [9].

Jos R. Jansen *et al.* in 2019 studied the real-time cardiac output. The real-time cardiac output measurements in mechanically assisted patients were examined by Jos *et. al.* in 2019. They came to the conclusion that the cardiac output was particularly significant and might enable early assessment of the efficacy of IABP or the requirement for escalation to another type of mechanical cardiac support ut measurements in mechanically assisted patients and concluded that the cardiac output was particularly important and might allow early determination of the effectiveness of IABP or the need for escalation to another type of mechanical cardiac support [10]. IABP counterpulsation is still widely used Because its advantageous physiological effects, it is already in its sixth decade of clinical usage. The simple, low-risk method of afterload reduction enhanced myocardial oxygen balance [11].

The definition of counterpulsation, which described balloon inflation in diastole and deflation in early systole, was provided in 2009 by Murli Krishna and Kai Zacharowski from the UK. Blood in the aorta is "displaced in volume" by balloon inflation both proximally and distally [2]. where the major goal of IABP treatment was to improve overall the ejection fraction of the failing heart by facilitating an improvement in myocardial oxygenated blood and a reduction in myocardial oxygen demand. IABP increases diastolic pressure at the beginning of diastole and decreases LV afterload at the end of diastole.

Two main parts make up the IABP device: a console with a pump to drive the balloon, and a double-lumen catheter with a balloon attached at its distal end. As seen in the figure below, a pump is used to deliver helium gas into a polyethylene balloon during inflation [12].

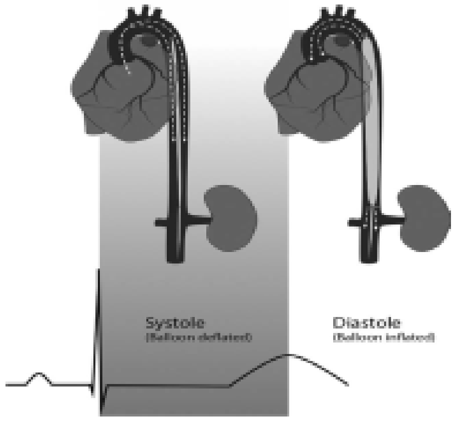

Figure (1): Diastolic inflation increases coronary blood flow as well as perfusion pressure. Left ventricular afterload is decreased by deflation during systole.

3. Triggers for the IABP

The driving console may be set up to react to electrical or pressure inputs by inflating or deflating balloons [12].

Electrocardiography Trigger occurs when the aortic valve closes and opens, alternatively, causing the IABP to inflate and deflate.

Pressure Trigger: When the IABP cannot accurately detect left ventricular systole and diastole or when the ECG is of low quality, the pressure trigger mode is frequently used.

internal trigger: asynchronous trigger mode, is often configured to augment at an average heart rate of 80 beats per minute.

Pacer Triggers IABP augmentation is started based on the ventricular spike.

Atrial Fibrillation Trigger Some IABP consoles provide a trigger mode for atrial fibrillation. The computer will assess the height as well as slope of a QRS complex in this mode, that has been deflected either positively or negatively. The pump will sense an R wave to determine the deflation time.[13]

To reduce the incidence of both the alarm fatigue phenomena and to provide patients who depend on this technology with safer care, it is crucial to managing the alarms of this equipment [14].

4. Use of IAPB During (CABG) Surgery

Widespread use of IABP has been made to increase coronary perfusion and reduce CABG related complications. The most cause of mortality was a refractory biventricular failure, which did not improve enough to permit weaning off cardiopulmonary bypass [15].

Giuseppe F. Serraino *et al.* conducted a study in 2011 intending to evaluate the use of an intra-aortic balloon pump throughout the cardioplegic arrest. where the outcomes indicated that patients who undergo (CABG) demonstrated a reduction in endothelial initiation and enhanced its function. wherein 501 CABG patients were randomly split into two groups: (A=270) (CPB) and (B =231) automated 80 beats/min IABP. The researchers came to the conclusion that the pulsatile perfusion decreased vasoconstrictive reflexes, improved oxygen consumption, and decreased tissue acidosis. As a result, they discovered that pulsatile flow improved renal function when the splanchnic organ was examined. Additionally, it was demonstrated that patients receiving preoperative IABP did not have any additional risks when IABP was used in automated mode during cross-clamping, but that whole-body perfusion was greatly improved [16].

IABP side effects that are often documented include hemorrhage, aorto-iliac damage, and thrombocytopenia. Due to the cardiac issues that initially necessitated this treatment, there is a significant rate of early and in-hospital death for patients requiring IABP support [17].

In patients with cardiac surgery having CABG, the administration of perioperative IABP considerably improves transesophageal echocardiography derived indices of diastolic function, which is consistent with a positive influence on LV relaxation [18].

The risk factors for the preoperative plasma creatinine level in 177 individuals were published in 2021 by Hector Hugo from Mexico. The prophylactic usage of the IABP reported in meta-analyses to date has been highly erratic, and the risk factors connected to it have been numerous and varied. IABP use in various operations has continued to vary as a result of the lack of supporting data.[19]

The majority of studies have shown a promising survival benefit for CAD patients receiving surgical therapy. However, it is claimed that low cardiac output syndrome as well as mortality in CABG are predicted by significant LV dysfunction (ejection fraction 35%) [20].

In our research at Ibn al-Bitar Center for Cardiac surgery in 2023 on the development of a predictive model for intra-aortic balloon pump requirement in high-risk (CABG) patients was an important contribution to the field of cardiac surgery. The study was based on data collected from forty patients, and it aimed to develop a predictive model using SPSS regression analysis based on preoperative data. The results of the study showed that the developed predictive model can accurately identify high-risk CABG patients who are likely to require intra-aortic balloon pump (IABP) support. This finding has important clinical implications, as it can help clinicians to improve risk stratification and decision-making in high-risk CABG patients.

The use of predictive models in cardiac surgery has been gaining popularity in recent years. These models help clinicians to identify patients who are at a higher risk of complications, such as bleeding, stroke, or death, and to tailor their treatment accordingly. The predictive model developed in this study is a step forward in this direction, as it focuses specifically on the use of IABP support in high-risk CABG patients.

One of the strengths of this study is its use of preoperative data to develop the predictive model. This approach has several advantages over postoperative data analysis, as it allows clinicians to identify patients who are at a higher risk before the surgery and to take appropriate measures to minimize that risk. Additionally, the study was conducted at a reputable cardiac center, and the sample size was adequate to develop a robust predictive model.

5. Some of the Complications Associated With IABP

For patients who have severe coronary artery disease, cardiogenic shock, and myocardial infarction (MI), counter-pulsation treatment is still used [11].

The transient decline of peripheral pulse, limb ischemia, thromboembolism, aortic dissection, moreover hematoma, bleeding from the wound, infection, balloon rupture (which can result in a gas embolus), hemolysis, and malposition leading to cerebral or renal compromise were some of the complications associated with IABP. Haralabos P. *et al.* have discovered new risk variables that are connected to the emergence of negative consequences when providing help to (IABP). 2011 research revealed that problems from intra-aortic balloon pump therapy were reduced and that the length of the pump therapy had an impact on complications from thrombosis and infection [21].

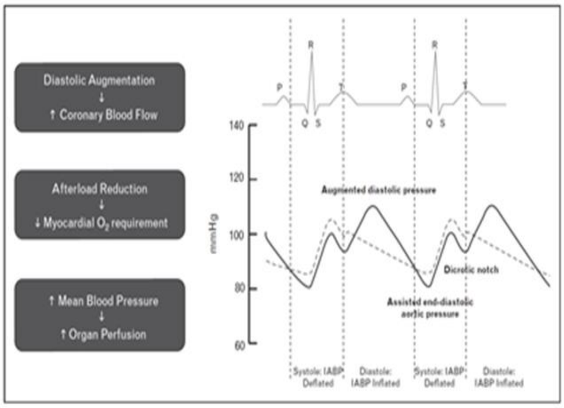

Figure (2): criteria to ensure optimal timing of an IABP

The impact of both the microcirculation and its interaction with mechanical assist devices has been spotlighted by Kalpa De Silva and colleagues. Where in 2014, a study of IABP, found that the presence of functioning self-regulation prevented a substantial increase in coronary flow speed in response to intra-aortic balloon counter-pulsation [22].

In the same year, the randomized trial data made by Abdul R. Ihdayhid *et al.* meta-analyses confirmed the safety of IABP but offered little to no evidence for its effectiveness in treating high-risk MI, MI complicated by cardiogenic shock, or the use of preventive IABP in high-risk PCI and CABG, indicating that more research was required [23].

In 2015, Ahmed *et al.* studied how IABP affected postoperative renal function. Their research showed how counter-pulsation improved human renal perfusion following surgery [24].

6. Balloon mistiming of inflation and deflation

The most widely used short-term mechanical circulatory assistance device at the time was the (IABP), which was frequently used to transition patients from CPB to a left ventricular assist device or to combine with ECHMO support [25].

Instead of using a standard procedure, the ideal frequency and timing of IABs may need to be determined based on the hemodynamic demands of each individual patient [26].

It was unclear whether (IABP) counter-pulsation was effective during arrhythmic episodes. For real-time IABP inflation timing regulation, an algorithm was used to estimate the dicrotic notch within a beat. In 2002, Andrea Donelli and colleagues developed a technique for identifying and detecting a dicrotic notch in real-time utilizing aortic pressure waves. The dicrotic notch, which was discovered at the initial negative dip in the computed flow, was identified using a percentage of the decreasing flow. The efficiency of a real-time dicrotic notch prognosis algorithm (RTDND) during severe arrhythmia was assessed using the aortic pressure signals from 12 patients. In 98.1% of cases, the RTDND was capable of recognizing the dicrotic notch. A minimum of 30 seconds of pressure tracing during arrhythmia was recorded from each patient. Heart rate (HR), aortic pulse pressure (Pp), and systolic ejection time were analyzed. They came to the conclusion that the descending flow signal's detection of the dicrotic notch might be utilized as a real-time IAB inflation trigger as in IABP [27].

Aortic pressure was used in 2004 by Italian researchers Jan J. Schreuder *et al.* to determine the real-time aortic flow. With the help of a fraction of the computed peak flow, the dicrotic notch was predicted. The timing for automatic IAB deflation and inflation was regulated at the dicrotic notch, where the aortic flow was calculated from the aortic pressure. Our method successfully located and predicted the dicrotic notch in aortic pressure signals exhibiting cardiac arrhythmia in both animal and human samples [28].

In 2007 Melissa K. Osentowski and David W. Holt from Nebraska Presented a study that evaluated the efficacy of IABP timing using the auto-timing mode with the Datascope. The correct timing of the inflation and deflation of this device was critical to the patient. Their study's objectives were to evaluate the automatic timing of inflation and deflation and to raise awareness about the dangers of making patient treatment decisions purely based on technology rather than clinical judgment. 165 IABP patients' timing data were gathered using Datascope series consoles.

An IABP that is administered at the wrong time may have less effect on the patient and might cause harm.

After the aortic valve closed, there was late inflation. The coronary perfusion was not adequate as a result. Early deflation led to the possibility of retrograde coronary and carotid blood flow, as well as less than adequate coronary perfusion. Early deflation may also result in an inadequate reduction in afterload and an increase in myocardial oxygen demand. Early inflation occurred before a dicrotic notch and it would cause the aortic valve to close prematurely, increasing ventricular wall stress and the demand for myocardial oxygen because of both the left ventricular end-diastolic volume as well as pressure rose. The afterload was not reduced as a result of the late deflation, and the afterload was likely increased by the reactance on left ventricular ejection. The left ventricle ejected against greater resistance from the inflated balloon, resulting in a rise in myocardial oxygen consumption. With late balloon deflation, the cardiac cycle may also experience an extended isovolumetric contraction phase [29].

Although a fairly straightforward principle, the interaction of IABP with the cardiovascular system is still difficult and controversial. The creation of a numerical model of IABP was the main goal of Italian Claudio De Lazzari *et al.* in 2020. The model was developed in CARDIOSIM, a modular software cardiovascular system simulator utilized in research and virtual learning environments. The aorta, thoracic, and two abdominal passages were modeled with resistances, inertances, and compliances before the IABP was put into the systemic bed. The inclusion of compliances attached to an IABP generator and resistances allowed the balloon's action to be replicated in each aortic tract. The IABP generator was able to alter IABP time and replicate balloon pressure. The findings indicated that the models accurately captured the ordinary effects brought on by IABP support. Additionally, once IABP ratio was '1:1, 1:2, and 1:4' they simulated the effects the device would have on the hemodynamic variables. The results of the simulations were demonstrated to be positive. The system of CARDIOSIM that was presented in their work enables the simulation of the effects brought on by mechanical ventilatory support. When patients with COVID-19 need mechanical circulatory support devices, this facility could be crucial to their care [25].

7. Balloon Timing within open-heart surgery

Although there has been a lot of research on the effectiveness of the IABP in cardiac surgery, several researchers have considered preoperative or postoperative outcomes. 48 high-risk patients went through redo CABG and were randomly assigned to one of two groups: the group receiving preoperative IABP treatment (24 patients) on average two hours prior to cardiopulmonary bypass, and the control group (24 patients) receiving no preoperative IABP treatment. The outcomes revealed that group 1's time on cardiopulmonary bypass was shorter and that there were no hospital deaths, as opposed to four hospital deaths in the control group. In 1997, Jan T. Christenson et al. came to the conclusion that preoperative IABP treatment in increased redo CABG patients was indeed an efficient method for preparing such patients for myocardial revascularization in such a situation as free from ischemia as possible, leading to significantly lower hospital mortality, very few postoperative episodes of low cardiac output, and shorter stays in the intensive care unit and the hospital [30].

The study included 391 individuals having cardiac low-output syndrome that had open-heart surgery and received an IABP implanted. In 2000, Harald et al. reported that the goal of the study was to be able to predict the success or failure of IABP support early, which was offered as a substitute in cases with low-output syndrome despite receiving IABP aid.. Furthermore, the study shows that IABP implantation success in patients suffering from cardiac low-output syndrome can be expected 1 hour after implantation [31].

In 2010, Sharath R. Hosmane and Alan George Dawson from the UK studied the effect of IAPB undergoing CBP. they found that when the IABP was turned to an internal trigger mode of 80 bpm a confers beneficial effects happened by increased perfusion to vital organs through a pulsatile flow [32].

Christina Kolyva et al. from the United Kingdom created a mimic circulatory system (MCS) in 2010, to simulate an environment for vitro experiments as well evaluated with the (IABP). The MCS was made out of a 14-branch polyurethane compound aortic model and an artificial left ventricle (LV). Capillary tubes of various sizes and syringes with various air volumes, fitted at the outlets of the branches, respectively, were used to simulate the physiological distribution of terminal resistance as well as compliance however according to published data. The aortic branches' ends were connected by a common tube that mimicked the venous system, while atrial pressure was provided by an overhead reservoir. An IABP was used to control a 40-cc balloon that was set up to counter pulsation with the LV. It was intended for the mock cycle to be utilized for testing other VADs and investigating further hemodynamic issues in vitro once early tests with the IABP were successful [33].

In 2012, Giuseppe et al. investigated whether patients receiving coronary artery bypass grafts (CABG) would have better organ function and less endothelial activation if an intra-aortic balloon pump (IABP) had been used during the cardioplegic arrest. A total of 501 CABG patients were divided into two groups at random: those who received a linear CPB (Group A) and those who received an automatic, 80 beats per minute IABP-induced pulsatile CPB (Group B).The study showed that maintaining a steady-pulsatile flow (in vitro) caused a steady shear stress on the endothelial cells, and examined hemodynamic response, coagulation, fibrinolysis, and other variables. Endothelial cell activation was brought on by the conversion of pulsatile to linear flow, which had an impact on the inflammatory, hemostasis, and environmental hemorheology pathways. The results showed that the pulsatile flow provided by IABP enhanced all body perfusion and decreased endothelial activation during CPB [16]. In order to avoid or cure low cardiac output syndrome, cardiac surgery frequently uses the intra-aortic balloon pump (IABP). The best time to insert an IABP is still being debated despite being widely used and serving as the first-line treatment in patients who are hemodynamically unstable despite taking the maximum amount of medication.

Aslihan Kucuker and colleagues from Turkey conducted a study in 2013 that analyzed the hospital outcomes of individuals receiving IABP before, during, and then after cardiac surgery. In 121 patients, IABP was utilized. Preoperative IABP insertion was performed in nine patients, intraoperative insertion was performed in 76 patients to facilitate weaning from CPB, as well as postoperative insertion was performed in 36 patients in the ICU due to persistent hemodynamic instability.

The findings suggested that results from early-intraoperative IABP insertion were significantly more positive than those from late-postoperative IABP insertion. Because of this, a surgeon should consider injecting IABP early in the operating theater rather than attempting to wean from CPB if they are having trouble doing so with modest levels of inotropes. However, the need for IABP all through cardiac surgery should have been viewed as a risk factor, a sign of a poor prognosis, and was linked to a higher mortality rate. The study also demonstrated that patients who had postoperative IABP insertion had the least favorable outcomes [34].

A total of 1149 patients underwent CABG in 2012, of whom 90 had IABP inserted and of whom 30 met the criteria for inclusion. Out of 30 patients, 10 had IABP placement before surgery, 10 during surgery, and 10 after. In highly-risk surgery patients with (CABG), the effectiveness and expense of preoperative (IABP) treatment on cardiac performance during and after surgery, improved hemodynamic stability, decreased mortality and morbidity, and the best timing was to be assessed. The study showed pre-operative IABP therapy was effective as well as a safe supportive modality that significantly decreased the risk for hemodynamic instability, improved cardiac performance, reduced the need for inotropic support, decreased the rate of hospital mortality and post-operative morbidity, improved survival, and significantly cut the length of stay in the ICU and hospital, making it cost-effective [35].

According to the timing of pre - operative IABP placement in 2013, patients were divided into two groups: (A) less than 2 hours and (B) more than 2 hours. The results indicate that prophylactic IABP (more than 2 hours preoperatively) might improve clinical prognosis. The timeframe of IABP support, ICU length of stay, duration of hospital stays, and cost of hospital treatment were significantly higher in the A than in Group B. A shorter hospital stay seems to be linked to earlier prophylactic IABP, but the risk of complications and hospital costs don't seem to be affected. The concept behind the improvement was that earlier prophylactic IABP and longer IABP support could keep hemodynamics stable, improve the myocardial oxygen demand and supply ratio, and lessen ventricular wall stress during the perioperative period [36].

In 2017 Giuseppe Gatti et al. encouraged reasonable use of the intra-aortic balloon pump (IABP) prior to heart surgery, where in 573 patients, a coronary surgery was done. Prophylaxis (n = 147), unstable angina (n = 239), and rapidly deteriorating hemodynamics (n = 202) were the criteria for IABP. Multivariable approaches were used to examine the baseline features of the patients. The primary findings demonstrated that preoperative utilization of IABP in cardiac surgery was safe throughout the trial period, even for high-risk patients. [37]

IABP which was first used in clinical care by Dr. Adrian Kantrowitz in the 1960s, has remained a crucial therapy in the treatment of CAD patients [38].

In 2018, research by Litton et al. investigated the prophylactic role of (IABC) in patients undergoing CABG who were at increased risk for low cardiac output syndrome. The prospective study, which included 13 cardiac centers in total, sought to quantify six-month mortality and patient quality of life. Even though they were a high-risk group, CABG surgery was still linked to a noticeable rise in quality of life at six months. IABC use before surgery was uneven overall. The significance and viability of a crucial prophylactic IABC RCT were supported by these findings [39].

Another prospective observational study was Published in 2019 by Ken Nakamura et al. to define the preoperative characteristics as well as results of patients who received prophylactic IAB. There were no appreciable differences in the 30-day postoperative mortality rates or major cardiac or cerebrovascular events between the preventive IABP collection and a non-prophylactic IAB collection. The study showed that preventive IAB in elevated patients having CABG is an effective choice considering the lack of IABP-related problems [40].

In 2019, Greek researchers George Samanidis and Georgios Georgiopoulos investigated whether intraoperative versus preoperative placement of an IAB was linked to shorter hospital stays or lower 30-day mortality among patients undergoing cardiac surgery. They employed a multi-variate linear model, adjusting for preoperative myocardial infarction, preoperative elective surgery, isolated coronary bypass grafting, gender, age, CPB time, and aortic cross-clamp time.

Patients who required the insertion of an IAB during the pre- or post-operative phases of cardiac surgery experienced significant 30-day mortality as a whole [41].

8. Balloon catheters sizing and balloon volume

The aorta's size is influenced by a patient's height, weight, in addition age. The optimum balloon for every patient must measure as from left Subclavian artery to the celiac artery launch, be inflated to either a diameter of 90 to 95% of both the descending aorta, with a volume equal to the blood flow through aorta at any given time.

The length of the balloon, but not its capacity, was substantially associated with changes in visceral perfusion under IABP support [42].

The quantity of blood in the aorta shortly before to inflation, limits the balloon's capacity to expand, so aortic volume increases in between shock mean pressure around 30 to 40 mm Hg as well as a normal mean pressure of 80 to 90 mm Hg.

According to Kantrowitz et al. the aorta's elasticity, increases in pumping volume had no effect on effectively pumping the balloon; instead, they only caused the aorta to distend. The most common IABC balloon size used for adult patients (82% of the time) is 40 cc. Even while a volume of 40 cc is acceptable in many clinical circumstances, it is emphasized that an IAB that is too big or too small tends to reduce the cardiac benefit while increasing vascular morbidity. Patients who are taller have utilized 50 cc balloons. The maximum amount of diastolic augmentation occurs once the balloon volume plus stroke volume were equal. If the stroke volume seems to be very low (25-30 ml) or very large, augmentation will be reduced (95–100 ml) [43].

9. Position of the balloon inside the aorta

Fluoroscopy or a chest x-ray is used to confirm the correct balloon placement because it is necessary to place the balloon 1-2 cm underneath the left subclavian artery's origin and above the branches of the renal artery in order to prevent arterial tributary obstruction. The root of renal arteries might get obstructed if the balloon is positioned too low, which would obstruct normal renal perfusion. When the catheter is positioned too high, the left subclavian or even the left carotid artery could become blocked [5]. TEE can be used to aid with its position in the intubated patient during intraoperative procedures, even though it is generally done in the cardiac catheterization lab via fluoroscopic guidance [44].

The femoral artery is utilized to insert a bendable catheter and polyethylene balloon on one end into the descending thoracic aorta.

The IABP catheter's tip rarely perforates the aorta, unless it is positioned in the aortic arch. Placement of the IABP catheter was simple and done correctly under fluoroscopic guidance.

Figure (3): kinking of the IABP catheter

Neither a fluoroscopic nor radiographic examination could detect kinking of the IABP catheter [45].

As the balloon gets closer to the aortic valve, the diastolic pressure rises. Due to regional anatomical constraints, the ideal balloon location would be when the tip is situated distant to an aortic take-off in the left subclavian artery. The renal vessels should be above the proximal balloon end. Improper balloon placement leads in decreased diastolic augmentation, vascular morbidity owing to direct intimal injury, plaque deformation, embolization, or, finally, direct artery lumen obstruction [43].

(IABP) a tip is believed to be best positioned using the aortic knob as a radiographic landmark. This, however, has not been formally studied. In 2007, Jin-Tae Kim et al. investigated the reliability of the aortic knob as a landmark for orienting the IABP and contrasted it with the carina, another potential landmark. As a result of variations in the origin of the LSCA on the aortic arch, the results suggested that the aortic knob might not be a reliable radiographic landmark for IABP tip positioning, whereas the carina might be. In 95.3% of the study population, the LSCA originates 35-55 mm above the carina [46].

In 2010, Ardawan et al. from Germany visceral arterial compromise Throughout intra-Aortic balloon counter pulsation Treatment researched. The proximal balloon position was correct in 96.8% of cases, but only 38.1% were appropriate, according to the common research results of balloon malposition of visceral arterial compromise on computerized tomographic imaging. So, malposition IABP was thus frequently found by CT for various reasons, including an anatomical-to-balloon length mismatch and the proximal balloon's incorrect position. Therefore, shorter balloon sizes than recommended and better positioning techniques had to be taken into account [47].

In 2011, Matthew A. Klopman et al. shown that high-risk CABG surgery patients may benefitted from the installation of an IABP before to the commencement of the surgery. The Seldinger technology (thin-wall needle technique) was used most frequently to implant the IABP percutaneously using the femoral arteries. In order to avoid occluding the arch vessels or significant abdominal branches, it was crucial that the balloon portion of the IABP lay between the left subclavian artery and any visceral arteries, regardless of the entry site. This was done by performing a systematic Transesophageal Echocardiogram (TEE) assessment before, during, and after the IABP was implanted. This allowed for the periodic evaluation of function [48]. With a membrane length between 22 to 27.5 cm also an inflated diameter of 15 to 18 mm, the (IABP) has primarily been used in adults with a 40-cc and occasionally a 34-cc balloon volume.

In 2011A statistical technique has been presented to accurately size IAB by predicting the distance between the left subclavian artery and celiac axis. Haralabos Parissis et al. from the UK discovered that performance of balloons is directly linked to arterial pressure, and as arterial pressure increases, so do the potential advantages of IABP. The balloon's performance was also impacted by heart rate. Heart rate increases as balloon inflation time decreases and diastolic augmentation increases. Aortic elasticity is represented by ratio between aortic pressure with aortic volume, and decreasing aortic flexibility lowers total diastolic augmentation. The nearer the IABP came to the aortic valve, the greater the enhanced diastolic augmentation was. [49].

The position resulted in the greatest coronary artery flow augmentation while minimizing the risk of embolization to cerebral vessels and obstruction of the LSCA, and it was confirmed in 2012 by Vijish Venugopal. He proposed a simple and dependable technique for properly positioning the (IABP) catheter in the intensive care unit without the need for any sophisticated or expensive equipment. In his technique, He had used left radial arterial track disappearing as a reference for tip location while the IABP catheter is driven along a guidewire [50].

10. Conclusion

The most popular technique of left ventricular support continues to be IABPs, and timing of IABPs is essential for delivering optimal hemodynamic support. Based on the research, the timing technique that best supports counter-pulsation therapy's purpose while avoiding timing mistakes that are detrimental to left ventricular function should be selected after determining the therapy's goal.

The results indicated the advantages of pulsatile perfusion, which include a decrease in vasoconstrictive reflexes, improved oxygen consumption, and a decrease in tissue acidosis. The (IABP) has indeed been extensively utilized for increase cordial-coronary perfusion and reduce problems in CABG. This study also found that pre-operative IABP therapy is a reliable as well as safe supportive modality that improves cardiac function, reduces the need for inotropic support, increases survival, considerably reduces ICU and Hospitalization times, and lowers hospital mortality and post-operative morbidity rates, making it a cost-effective therapeutic choice for high-risk patients receiving CABG. Future studies should focus on addressing these issues and offering more detailed recommendations to support clinical decision-making and patient outcomes.

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