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Does pulmonary hypertension affect early-term outcomes of off-pump coronary artery bypass surgery?

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SUMMARY

OBJECTIVE: This study aimed to investigate the effect of preoperative pulmonary hypertension (PHT) on postoperative early mortality and morbidity in patients undergoing off-pump coronary artery bypass grafting (CABG).

METHODS: A total of 1107 patients undergoing elective first-time off-pump CABG between January 2011 and April 2022 were included in this retrospective observational cohort study. The patients were categorized into two groups according to their preoperative systolic pulmonary artery pressure (SPAP) values. The PHT group (n=104) consisted of patients with a SPAP value >30 mmHg, while the non-PHT group (n=1003) consisted of patients with a SPAP value ≤30 mmHg. Patients' preoperative demographics and clinical features, operative data, and postoperative outcomes were recorded and then compared between the groups.

RESULTS: In the PHT group, the median age was significantly higher (66 vs. 63 years, p=0.001) and the median left ventricular ejection fraction level was significantly lower (45 vs. 50%, p=0.045) as compared to the non-PHT group. Additionally, the PHT group included a significantly greater percentage of patients with chronic obstructive pulmonary disease (22.1 vs. 7.4%, p=0.019). As perioperative early-term outcomes, complications, and mortality were considered, the groups were statistically similar, and there were no significant differences between the groups, except for the development of atrial fibrillation.

CONCLUSION: For the first time in the literature, this study revealed that mild PHT (mean SPAP=38.9±8.7 mmHg) did not significantly affect early-term outcomes of off-pump CABG.

KEYWORDS: Pulmonary hypertension. Outcomes. Mortality. Morbidity. Coronary artery bypass grafting.

INTRODUCTION

Pulmonary hypertension (PHT) is defined as mean pulmonary arterial pressure (MPAP) ≥25 mmHg at rest, assessed by right cardiac catheterization[1]. While various pathological conditions such as left-sided heart diseases, chronic pulmonary diseases, chronic thromboembolic PHT, and collagen tissue diseases are responsible for the etiology of PHT, it is always virtually related to worsening symptoms, increased morbidity, and mortality, regardless of underlying pathological conditions. PHT is reported to influence about 1% of the world's population, and more than half of the patients with cardiac failure might be influenced by this clinical entity[2,3]. Thus, physicians may frequently expect to encounter patients with PHT in daily clinical practice. Moreover, cardiac surgeons may also frequently encounter patients with PHT in their surgical practice and operate on them as well.

The existence of PHT in patients scheduled for coronary artery bypass grafting (CABG) surgery could be easily determined using cardiac catheterization or, more often, transthoracic echocardiography, which is a noninvasive, radiation-free, and contrast-free method. These aforementioned methods give an idea on possible perioperative risks and are also important to take preventive measures against potential adverse events. Although PHT has historically been considered as a significant risk factor for poor outcomes in patients undergoing CABG, there are a limited number of studies examining the effect of PHT on the outcomes of CABG surgery. Moreover, the limited studies on this subject in the literature are inconsistent and also contain some unanswered queries[4,5]. On the contrary, almost all of these limited studies have been conducted in conventional on-pump CABG patients, and, to the best of our knowledge, there is no study in the literature investigating the effect of PHT on early-term outcomes of off-pump CABG. Thus, we designed this study to investigate whether PHT affects early-term surgical outcomes in patients undergoing off-pump CABG.

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METHODS

Ethical considerations

The study was started once approval was obtained from the institutional clinical research ethics committee (decision number: 2022/136, dated 10.05.2022) and carried out according to the ethical principles of the Declaration of Helsinki. All patients were informed about the operation and perioperative process, and their verbal and written consents were obtained.

Study population and design

The study was a retrospective observational cohort study and conducted on patients undergoing elective isolated first-time off-pump CABG from January 2011 to April 2022. The study population consisted of a total of 1107 patients whose medical data were available, and the patients were categorized into two groups according to their preoperative systolic pulmonary artery pressure (SPAP) values. One group consisted of patients with SPAP value >30 mmHg (PHT group, n=104) while the other group consisted of patients with SPAP value ≤30 mmHg (non-PHT group, n=1003), based on the 2015 European Society of Cardiology and the European Respiratory Society Guidelines[6]. Patients' preoperative basic demographics and clinical characteristics, operative data, postoperative outcomes, and complications were screened, recorded for the analysis, and then compared between the groups. Primary outcomes of the study included in-hospital mortality and major postoperative complications such as low cardiac output syndrome, myocardial infarction, cerebrovascular event, mediastinitis, pneumonia requiring reintubation, and new-onset renal failure requiring hemodialysis, while secondary outcomes of the study included mechanical ventilation time, inotrope and intra-aortic balloon pump requirements, lengths of intensive care unit (ICU), and hospital stays. Patients who underwent on-pump, emergency or redo CABG, conversion from off-pump to on-pump CABG during the surgery, concomitant cardiac or noncardiac surgery, and those with a history of primary or chronic thromboembolic PH were excluded from the study.

Determination of SPAP values

Estimates were based on the averages of three cardiac cycles in sinus rhythm and five in atrial fibrillation for each Doppler and M-mode-based measurement in preoperative transthoracic echocardiography. The simplified Bernoulli Equation was used to determine SPAP values from the continuous wave Doppler peak tricuspid regurgitation velocity with right atrial pressure (RAP). We included the densest tricuspid regurgitation jet with an apparent selected peak in the continuous wave Doppler. The diameter and respiratory fluctuation in the diameter of the inferior vena cava (IVC) were used to calculate RAP: an IVC diameter of 21 mm that collapses >50% with a sniff indicated a typical RA pressure of 3 mmHg, an IVC diameter of >2.1 mm that collapses >50% with a sniff was considered an intermediate value of 10 mmHg, and an IVC diameter of >21 mm that collapses 50% with a sniff or 20% with silent inspiration was considered to have a high RA pressure of 15 mmHg.

Surgical procedure

All patients were operated on under general anesthesia and via standard median sternotomy. After the sternotomy and pericardiotomy, coronary arteries and ascending aorta were evaluated. The mostly harvested bypass grafts were internal thoracic artery (ITA), radial artery, and great saphenous vein. In patients with severe calcific and porcelain ascending aorta, the "no-touch aorta" technique was performed. Coronary anastomoses were initiated following intravenous heparin administration of 200 IU/kg and obtaining a target-activated clotting time of above 300 s. During the off-pump CABG technique, an Octopus IV tissue stabilizer was used to ensure the proper position of the beating heart. Left ITA-left anterior descending artery anastomosis was usually the first performed anastomosis to perfuse a significant myocardial area and avoid a sudden myocardial failure. Following an arteriotomy of the targeted coronary artery, a bulldog clamp and air blowing were used to provide a blood-free space during distal anastomosis. Distal and proximal anastomoses were performed with either 7/0 or 8/0, and either 6/0 or 7/0 propylene sutures, respectively. After all anastomoses were completed, the effect of unfractionated heparin was neutralized by protamine infusion, and then the operation was terminated in a standard manner.

Postoperative follow-up and medications

All patients were transferred to the ICU after the operation. During ICU follow-up, patients' invasive arterial and central venous pressures, heart rhythm, oxygen saturation, urine output, and mediastinal drainage were monitored continuously, and arterial blood gas analyses were performed at frequent intervals. Patients' hemodynamic data determined, if necessary, the initiation and maintenance of inotropic therapy and the choice of inotropic agents. Within the first 24 h after the operation, 100 mg acetylsalicylic acid, 75 mg clopidogrel, and low-molecular-weight heparin were prescribed if not contraindicated. The patients were transferred from the ICU to a standard ward once their hemodynamics were stabilized. If not contraindicated, other routine medications, including statins and β-blockers, were prescribed. Moreover, if a clinical indication arises, angiotensin-converting enzyme inhibitors, diuretics, etc., were also added to the medical treatment.

Statistical analysis

The R software was used to perform the statistical analyses[7]. The Shapiro-Wilk test was used to evaluate the normality of variables. Continuous variables with normal and abnormal distribution were presented as mean±standard deviation and median (min-max) values, respectively. Categorical variables were expressed as numbers (percentages). Continuous variables were analyzed using the Mann-Whitney U test, while categorical variables were analyzed using the chi-square test. A p-value <0.05 was regarded as statistically significant for all analyses.

RESULTS

Patients with PHT comprised 9.4% of whole study population (n=104/1107). The mean SPAP value in the PHT group was detected as 38.9±8.7 mmHg (range: 32–70).

When preoperative basic clinical features of the groups were evaluated, the median age in the PHT group was significantly higher as compared to that in the non-PHT group (66 vs. 63 years, p=0.001). The median left ventricular ejection fraction (LVEF) level in the PHT group was significantly lower than that in the non-PHT group (45% vs. 50%, p=0.045). Additionally, the PHT group included a significantly greater percentage of patients with chronic obstructive pulmonary disease (COPD) as compared to the non-PHT group (22.1% vs. 7.4%, p=0.019). In terms of other clinical characteristics and comorbid diseases, both groups were statistically similar, and there were no significant differences between the groups (Table 1).

When operative and postoperative data of the groups were compared, it was detected that only percentage of new-onset atrial fibrillation (AF) in the PHT group was significantly greater than that in the non-PHT group (41.3% vs. 22.1%, p=0.033). Apart from this, no significant differences were found between the groups in terms of intraoperative variables, perioperative outcomes, major postoperative complications, and in-hospital mortality (Table 2).

Table 1. Preoperative clinical characteristics of groups.

Variable	PHT group (n=104)	Non-PHT group (n=1003)	p-value
Age (year)	66 (40–82)	63 (35–87)	**0.001***
Gender (male)	43 (41.3%)	376 (37.5%)	0.067
Weight (kg)	77 (50–118)	77 (48–140)	0.646
Height (cm)	170 (150–190)	170 (145–190)	0.815
BMI (kg/m^2)	27.2 (18.5–42.5)	27.0 (18.0–46.2)	0.560
Obesity	24 (23.1%)	219 (21.8%)	0.277
LMCA disease	20 (19.2%)	172 (17.1%)	0.218
LVEF level (%)	45 (25–70)	50 (25–70)	**0.045***
Hypertension	75 (72.1%)	647 (64.5%)	0.246
Diabetes mellitus	44 (42.7%)	375 (37.4%)	0.322
Hyperlipidemia	46 (44.2%)	392 (39.1%)	0.284
Myocardial infarction	32 (30.8%)	331 (33.0%)	0.468
Chronic renal dysfunction	10 (9.6%)	67 (6.7%)	0.330
Chronic liver disease	1 (0.9%)	2 (0.2%)	1.000
Peripheral arterial disease	13 (12.5%)	95 (9.5%)	0.383
COPD	23 (22.1%)	74 (7.4%)	**0.019***
Previous PCI	17 (16.3%)	132 (13.2%)	0.352
Previous CVE	13 (12.5%)	70 (7.0%)	0.514
Smoking	35 (33.6%)	283 (28.2%)	0.380

PHT: pulmonary hypertension; BMI: body mass index; LMCA: left main coronary artery; LVEF: left ventricular ejection fraction; COPD: chronic obstructive pulmonary disease; PCI: percutaneous coronary intervention; CVE: cerebrovascular event. *Significant p-value.

DISCUSSION

In this study, we investigated whether PHT affects the early-term outcomes of off-pump CABG by comparing the groups of patients with and without PHT. Patients' preoperative basic clinical and demographic data as well as the intraoperative and postoperative early results were compared between the groups. The most important finding of the study was that PHT did not adversely affect early perioperative results, significant morbidity, and mortality in patients undergoing off-pump CABG, except for new-onset AF.

The existence of PHT has been generally considered to be an important risk factor affecting short- and long-term outcomes following heart surgery. Considering the recent advancements in the management of PHT following heart surgery, a greater comprehension of its effect on the results might help in the perioperative clinical management of patients with PHT. Determining the existence of PHT by simply measuring the pulmonary artery pressures with transthoracic echocardiography is important in terms of providing an insight concerning possible operative and postoperative risks and taking necessary precautions against these risks[8].

Some risk factors for cardiovascular diseases as well as comorbidities may be present in patients with PHT. Fan et al.[9]

Table 2. Intraoperative and postoperative data of groups.

Variable	PHT group (n=104)	Non-PHT group (n=1003)	p-value
LITA usage	97 (93.3%)	943 (94.0%)	0.820
Complete revascularization	96 (92.3%)	947 (94.4%)	0.484
Number of distal bypass	4 (1–5)	4 (1–7)	0.556
Extubation time (h)	6 (2–12)	6 (2–48)	0.145
Length of ICU stay (h)	24 (24–216)	24 (24–504)	0.083
Length of hospital stay (day)	5 (4–21)	5 (4–39)	0.227
Inotrope requirement	24 (23.1%)	183 (18.2%)	0.103
IABP requirement	9 (8.6%)	49 (4.9%)	0.249
Low cardiac output syndrome	7 (6.7%)	53 (5.3%)	0.508
Myocardial infarction	5 (4.8%)	32 (3.2%)	0.465
Cerebrovascular event	2 (1.9%)	35 (3.5%)	0.520
Reintubation	5 (4.8%)	35 (3.5%)	0.214
Pneumonia	7 (6.7%)	34 (3.4%)	0.177
Mediastinitis	4 (3.8%)	32 (3.2%)	1.000
Re-exploration for bleeding	4 (3.8%)	40 (4.0%)	1.000
ARD requiring hemodialysis	2 (1.9%)	28 (2.8%)	0.563
Gastrointestinal bleeding	1 (0.9%)	9 (0.9%)	1.000
New-onset atrial fibrillation	43 (41.3%)	222 (22.1%)	**0.033***
In-hospital mortality	2 (1.9%)	20 (2.0%)	1.000

PHT: pulmonary hypertension; LITA: left internal thoracic artery; ICU: intensive care unit; IABP: intra-aortic balloon pump; ARD: acute renal dysfunction. *Significant p-value.

conducted a retrospective study on a large sample size involving a total of 5401 patients with acute myocardial infarction (AMI), and patients were grouped according to their SPAP values at the time of admission. The study revealed that SPAP was related to age, low LVEF, Killip classification, and AMI site, and was also detected to be significantly associated with 6-month cardiac death after AMI. The authors eventually concluded that elevated SPAP values could be a useful marker to predict early-term prognosis following AMI. We determined that elevated SPAP value, namely PHT, was related to age and low LVEF in our study, consistent with the aforementioned study. In addition to these, COPD was also detected to be a frequent comorbid disease in the PHT group in our study population.

When the limited number of studies investigating the effect of pulmonary artery pressures and PHT on surgical outcomes after cardiac surgery were reviewed, it was observed that the studies included some methodological differences, and the results of the studies were inconsistent with each other. In the literature, some of these limited studies investigating the effect of PHT on surgical outcomes were conducted in patients undergoing conventional on-pump CABG[5,10,11], while others were conducted on patients undergoing valvular heart surgery[12,13]. In a study conducted on 177 patients undergoing conventional on-pump CABG by Çatav et al.[10], the patients were divided into three groups according to their SPAP values. Patients with an SPAP<30 mmHg were assigned to the normal SPAP group, those with an SPAP between 30 and 50 mmHg were assigned to the mild PHT group, and those with an SPAP >50 mmHg were assigned to the severe PHT group. The rates of in-hospital mortality were found to be 4.7%, 10%, and 18.9% for normal SPAP, mild PHT, and severe PHT groups, respectively, and the difference between the hospital mortalities of normal SPAP and severe PHT groups was significant. Akça et al.[5] conducted a study with a larger sample size involving a total of 1244 patients undergoing conventional on-pump CABG, and the patients were divided into two groups according to the existence of PHT (SPAP ≥30 mmHg) or absence of PHT (SPAP <30 mmHg). The study revealed that early-term mortality rates following on-pump CABG were statistically similar, and there was no significant difference between both groups with respect to perioperative early mortality, while the PHT group had a greater inotrope requirement, a longer mechanical ventilation time, and an increased length of ICU stay. Moreover, Akca et al.[11] assessed the effect of preoperative PHT on not only early-term but also long-term results by screening a larger patient population. Among 2325 patients undergoing elective isolated conventional on-pump CABG, 287 patients with high preoperative SPAP ≥30 mmHg were evaluated, and of them, 69 patients with complete data who were on follow-up were included in their study. The authors found that the long-term mortality rate was 5.79% during 33.9±17 (9–100) months follow-up period, and life expectancy was calculated as 94.7 months. As a result of these findings, PHT was indicated to be not associated with poor long-term outcomes, and CABG could be safely performed in patients with PHT. Melby et al.[12] studied whether PHT remains a risk factor for adverse outcomes on a total of 1080 patients undergoing surgical aortic valve replacement (AVR) for primary severe aortic valve stenosis. The patients were prospectively assessed and then divided into two groups according to the existence of PHT (SPAP ≥35 mmHg) or absence of PHT (SPAP <35 mmHg). The study demonstrated that operative mortality, prolonged ventilation, and length of hospital stay were significantly higher in the PHT group, and preoperative PHT was an independent risk factor for decreased long-term survival in patients undergoing AVR. Ghoreishi et al.[13] examined the impact of preoperative PHT on short- and long-term results in 873 patients undergoing mitral valve surgery for mitral regurgitation. In their study, PHT was classified as none (SPAP value <40 mmHg), mild (40≤ SPAP value <50 mmHg), moderate (50≤ SPAP value <60 mmHg), or severe (SPAP value ≥60 mmHg), and preoperative SPAP was detected to be a strong predictor of both early mortality and late survival following mitral valve surgery. In another study reviewing a total of 3343 cardiac surgery patients, the effect of PHT on perioperative morbidity and mortality, and the accuracy of the Society of Thoracic Surgeons (STS) risk model for patients with PHT were assessed. In the study, MPAP was used to determine the existence or absence of PHT, and MPAP was defined as normal (<25 mmHg), or as mild (25–34 mmHg), moderate (35–44 mmHg), or severe (≥45 mmHg) PHT. The study showed that perioperative complications and mortality increased with higher MPAP values, and both moderate and severe PHT were significantly related to increased mortality, even after accounting for STS risk. In addition, a subgroup analysis for only isolated CABG patients showed significantly increased mortality for all PHT categories (mild, moderate, and severe). The authors consequently deduced that the observed mortality rate was significantly greater than predicted by the STS model for patients with moderate and severe PHT, and the addition of PHT to the STS risk model should be considered especially in isolated CABG cases[4].

In the aforementioned studies, it was noted that the determined pulmonary artery pressure values for dividing the patients into groups were different for each study, and there was no standardization for PHT classification and definition in the existing literature. This lack of standardization can be considered as one of the possible reasons why the results of these studies are different and inconsistent. In our study, the 2015 European Society of Cardiology and the European Respiratory Society Guidelines[6] were considered when grouping patients according to whether they had PHT or not, and pulmonary artery pressure values in the guidelines were taken into account.

The most important feature of our study that can make a significant contribution to the existing literature was that it was conducted in a relatively large patient population undergoing off-pump CABG. To the best of our knowledge, this is the first study that investigates the effect of PHT on early-term outcomes of off-pump CABG. On the contrary, our study also has several limitations. The main limitations of the study are its single-centered design and retrospective nature. Another important limitation is the lack of a subgroup analysis in the form of mild, moderate, or severe PHT in the group of patients with PHT.

CONCLUSION

This study demonstrated for the first time in the literature that mild PHT had no significant effect on early-term surgical outcomes, including mortality and major postoperative complications, in patients undergoing off-pump CABG. However, further prospective well-designed studies with larger patient participation are required to support the results of our study and obtain more evident scientific information.

AUTHORS' CONTRIBUTIONS

YV: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft. **AY:** Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft. **DT:** Data curation, Investigation, Methodology, Supervision, Validation, Writing – original draft. **UTKK:** Formal analysis, Investigation, Methodology, Supervision, Writing – review & editing. **ID:** Data curation, Investigation, Methodology, Validation, Writing – review & editing. **SB:** Investigation, Supervision, Validation, Writing – review & editing. **ERU:** Methodology, Supervision, Writing – review & editing.

REFERENCES

1. Simonneau G, Montani D, Celermajer DS, Denton CP, Gatzoulis MA, Krowka M, et al. Haemodynamic definitions and updated clinical classification of pulmonary hypertension. Eur Respir J. 2019;53(1):1801913. https://doi.org/10.1183/13993003.01913-2018
2. Hoeper MM, Humbert M, Souza R, Idrees M, Kawut SM, Sliwa-Hahnle K, et al. A global view of pulmonary hypertension. Lancet Respir Med. 2016;4(4):306-22. https://doi.org/10.1016/S2213-2600(15)00543-3
3. Mandras SA, Mehta HS, Vaidya A. Pulmonary hypertension: a brief guide for clinicians. Mayo Clin Proc. 2020;95(9):1978-88. https://doi.org/10.1016/j.mayocp.2020.04.039
4. Kennedy JL, LaPar DJ, Kern JA, Kron IL, Bergin JD, Kamath S, et al. Does the Society of Thoracic Surgeons risk score accurately predict operative mortality for patients with pulmonary hypertension? J Thorac Cardiovasc Surg. 2013;146(3):631-7. https://doi.org/10.1016/j.jtcvs.2012.07.055
5. Akça B, Dönmez K, Dişli OM, Erdil FA, Çolak MC, Aydemir IK, et al. The effects of pulmonary hypertension on early outcomes in patients undergoing coronary artery bypass surgery. Turk J Med Sci. 2016;46(4):1162-7. https://doi.org/10.3906/sag-1403-145

6. Galiè N, Humbert M, Vachiery JL, Gibbs S, Lang I, Torbicki A, et al. 2015 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension: The Joint Task Force for the Diagnosis and Treatment of Pulmonary Hypertension of the European Society of Cardiology (ESC) and the European Respiratory Society (ERS): Endorsed by: Association for European Paediatric and Congenital Cardiology (AEPC), International Society for Heart and Lung Transplantation (ISHLT). Eur Respir J. 2015;46(4):903-75. https://doi.org/10.1183/13993003.01032-2015
7. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria; 2021. [cited on Oct 10, 2022]. Available from: https://www.R-project.org/.
8. Denault A, Deschamps A, Tardif JC, Lambert J, Perrault L. Pulmonary hypertension in cardiac surgery. Curr Cardiol Rev. 2010;6(1):1-14. https://doi.org/10.2174/157340310790231671
9. Fan XT, Wang SJ, Mujahid H, Ji XP. Effect of elevated pulmonary artery systolic pressure on short-term prognosis in patients with acute myocardial infarction. Angiology. 2020;71(6):567-72. https://doi.org/10.1177/0003319720909056
10. Çatav Z, Altınay L, Yavaş S, Santaş A, Paç M, Katircoğlu SF. The effect of pulmonary hypertension on surgical outcome in patients undergoing coronary artery bypass grafting. Turkish J Thorac Cardiovasc Surg. 2010;18(1):1-4.
11. Akca B, Erdil N, Disli OM, Donmez K, Erdil F, Colak MC, et al. Coronary bypass surgery in patients with pulmonary hypertension: assessment of early and long term results. Ann Thorac Cardiovasc Surg. 2015;21(3):268-74. https://doi.org/10.5761/atcs.oa.14-00227
12. Melby SJ, Moon MR, Lindman BR, Bailey MS, Hill LL, Damiano Jr RJ. Impact of pulmonary hypertension on outcomes after aortic valve replacement for aortic valve stenosis. J Thorac Cardiovasc Surg. 2011;141(6):1424-30. https://doi.org/10.1016/j.jtcvs.2011.02.028
13. Ghoreishi M, Evans CF, DeFilippi CR, Hobbs G, Young CA, Griffith BP, et al. Pulmonary hypertension adversely affects short- and long-term survival after mitral valve operation for mitral regurgitation: implications for timing of surgery. J Thorac Cardiovasc Surg. 2011;142(6):1439-52. https://doi.org/10.1016/j.jtcvs.2011.08.030