Impact of right atrial pressure on fractional flow reserve calculation in the presence of a chronic total occlusion

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**Key words:** FFR, Right atrial pressure, Chronic total occlusion

**Abstract**

Background: The aim of this study was to assess the impact of right atrial pressure (Pra) on non-CTO vessels FFR measurements in patients with a chronic total occlusion.

Methods:Consecutive patients who underwent PCI for a CTO of the right coronary artery (RCA) were included. Prior to RCA recanalization, FFR and FFRmyo were measured in non-CTO vessels. FFR was calculated using the Pd/Pa equation during maximum hyperaemia and also accounting for right atrial pressure (Pd–Pra/Pa-Pra). Non-CTO vessels were characterised as major or minor donors based on angiographic assessment of provided collaterals.

Results:FFR and FFRmyo were measured in 68 arteries (34 LAD and 34 Cx) in 34 consecutive patients with successful RCA CTO PCI. Patients’ mean age was 62 ± 10 years old and 88% were male. Mean left ventricular ejection fraction was 51% ± 20. During maximum hyperaemia, mean Pra, Pa, and Pd were 4.1±3.8 mmHg, 82.6±12.2 mmHg, and 63.8±14.3 mmHg, respectively. In the major donor vessel, FFRmyo showed a difference of 0.007 to FFR (0.760 ± 0.113 vs. 0.767 ± 0.112, p=0.004). In the minor donor vessel the difference was0.004 (0.895 ± 0.067 vs. 0.899 ± 0.065, p < 0.001). There was a strong positive correlation between the FFR and FFRmyo in both the major and minor donor vessel groups (r=0.993, P<0.001 and r=0.996, P<0.001 respectively)

Conclusion:In the presence of a CTO, RA pressure adjustment of FFR in the non-CTO vessels leads to trivial numerical changes, which are statistically significant but clinically negligible.

**Introduction**

Fractional flow reserve is the current gold standard for invasive physiological assessment of intermediate coronary lesion severity in patients with stable coronary artery disease (1). It is defined as the ratio of maximal achievable blood flow in the stenotic coronary artery to the maximal achievable blood flow if the same artery was normal (2). In the original description of the FFR, the initial mathematical equation incorporated the right atrial pressure (Pra) into the computation as follows: FFRmyo = Pd-Pra/Pa-Pra (where Pd is the distal to the lesion pressure, Pa is the proximal arterial pressure and Pra is the venous or right atrial pressure) (2,3). In daily clinical practice the right atrial pressure (Pra) is considered to have minimal impact and is omitted from the equation, which has been simplified in its current form: FFR=Pd/Pa during hyperaemia (4). This is supported by a large retrospective study on a cohort of patients who underwent right and left heart catheterisation for clinical reasons (5).

Coronary chronic total occlusions (CTOs) are often encountered in patients with coronary artery disease undergoing coronary angiography (6). Although, historically, the frequency of CTO PCI has been low (7), recent progress in techniques and equipment has led to significantly improved procedural and clinical outcomes (8,9). Hence, interventional cardiologists more frequently tackle these complex lesions nowadays. CTOs are commonly found in the context of multi-vessel disease, making the use of FFR in this population important as it can delineate stenosis severity in the non-CTO vessels and guide clinical decision-making and subsequent management. There are a very limited number of studies that have specifically reported FFR measurements in the presence of a CTO in the non-CTO vessels. Indeed, whether the incorporation of Pra would significantly affect FFR and alter the clinical decisions has not previously been investigated.

The aim of this study was to assess the impact of right atrial pressure (Pra) on FFR measurements in the non-CTO vessels in patients with a chronic total occlusion.

**Material and Methods**

This was a prospective observational study, part of a research project on coronary CTO physiology (“The physiological impact of coronary chronic total occlusion percutaneous coronary intervention on coronary pressure-derived measurements and the influence of collateral circulation” / IMPACT-CTO study, NCT 02643940).

Study patients

Consecutive patients with symptomatic stable angina scheduled for elective RCA CTO PCI in a tertiary centre with a dedicated CTO programme were recruited from October 2015 to November 2016. All patients had an RCA total occlusion with duration ≥3 months, evidence of viability and / or ischaemia in the CTO territory as shown by non-invasive cardiac imaging and spontaneously visible collaterals from a contralateral donor artery. Patients with previous CABG, > 1 CTO and significant LMS disease were excluded. The study was approved by the local ethics committee (15/EE/0269) and all patients provided written informed consent prior to the procedure.

Fractional flow reserve measurements

The FFR and FFRmyo were measured and calculated for the non-CTO vessels (LAD and Cx) before attempting PCI to the CTO. Measurements were performed simultaneously in both vessels using 2 pressure wires (Philips Volcano Corporation, San Diego, California). Three hundred (300) mcg of intra-coronary nitro-glycerine was administered prior to each measurement. The pressure wire was normalised at the tip of the guide catheter and advanced to the distal vessel. Hyperaemia was achieved with intravenous adenosine infusion administered centrally through a femoral vein at a dose of 140 mcg/kg/min. Right atrial pressure (Pra) was measured with a 5-F pigtail catheter placed at the level of the right atrium via the femoral vein. The FFR was calculated as follows:

FFR=Pd/Pa,

where Pd is the mean arterial pressure at the distal vessel and Pa the mean aortic pressure at the tip of the guide catheter under maximum steady state hyperaemia.

The FFRmyo was calculated offline as:

FFRmyo= (Pd - Pra) / (Pa - Pra),

where Pra is the mean atrial pressure.

Once measurements were completed, the pressure guide wire was pulled back to the guide catheter and assessed for drift of the Pd/Pa recording. In the presence of drift (> ±0.02), measurements were repeated; otherwise the operator would proceed to CTO PCI.

Angiographic assessment of CTO and collateral circulation

J-CTO score (10) and donor vessel collateral contribution to the occluded artery using the Rentrop (11) and collateral connections (CC) grading systems (12) were assessed by two experienced CTO operators. For the purpose of the study non-CTO vessels were differentiated into major and minor collateral donors. The major collateral donor vessel was defined as the artery making the largest collateral contribution to the CTO. QCA analysis was performed in optimal projections using quantitative coronary angiography software (Philips Allura, The Netherlands).

Statistical analysis

All quantitative variables were tested for normal distribution according to the Kolmogorov-Smirnov test. Continuous variables are reported as mean and standard deviation values. Categorical variables are expressed as frequency and proportion. The paired t-test was used for the primary analysis to compare FFR with FFRmyo values. Scatter plots and Pearson’s correlation coefficients or Spearman’s correlation coefficients were used to assess the relationship between two variables as appropriate. The level of statistical significance was set at *p* = 0.05 with two tails. Statistical analysis was carried out using SPSS 20 software (SPSS Inc., Chicago, Illinois).

**Results**

Forty consecutive patients were recruited and 34 of them had successful CTO PCI. FFR and FFRmyo were measured in 68 coronary arteries. Baseline demographics and angiographic details are outlined in **Table 1**. Overall, the mean age was 62 ± 10 years and 88% of the patients were male. Average LVEF was 51% and the area of ischemia measured by CMR was 13.6 +/- 5%. The LAD was the predominant donor vessel in 88% of the cases with a mean maximum stenosis of 41 +/- 12.6%.

The baseline mean Pra was 4.6±3.8 mmHg. The hyperaemic mean Pra was 4.1±3.6 mmHg with normal distribution across a range of measurements (minimum: -2 mmHg and maximum: 15mmHg) (**Figure 1A)**. There was no statistically significant difference between the baseline and the hyperaemic Pra (P=0.09). During hyperaemia, the mean Pa was 82.6±12.2 mmHg, and the mean Pd 63.8±14.3 mmHg.

The mean FFR and FFRmyo in the major donor vessels were 0.767 and 0.760 (p=0.004) respectively, showing a mean difference of 0.007±0.013. In the minor donor vessels mean FFR was 0.899 and mean FFRmyo 0.895, (p<0.001) (mean difference 0.004±0.006) (**Figure 1B)**. Additionally, there was a strong positive correlation between the FFR and FFRmyo in both the major and minor donor vessel groups (r=0.993, P<0.001 and r=0.996, P<0.001 respectively) (**Figure 2A and 2B**).

For the major donor vessels the overall incidence of positive FFR (≤0.80) was 58.8% (20/34), which remained unchanged after the incorporation of Pra in the FFR computation with none of the cases crossing the dichotomous threshold of 0.80. For the minor donor vessels the overall incidence of positive FFR (≤0.80) was significantly lower, 5.9% (2/34), p<0.001 for the comparison with the major donor vessel positive FFR incidence. After the incorporation of Pra in the FFR calculation, only one additional patient was reclassified to a positive FFR≤0.80 (from 0.82 to 0.80).

Only FFR and FFRmyo of the major donor vessel depicted a positive correlation with the hyperaemic Pra, (r= 0.468, P=0.005 and r=0.399, P=0.019, respectively). The difference between FFR and FFRmyo in both major and minor donor vessels had a strong positive correlation with the hyperaemic Pra (r=0.593, P<0.001 and r=0.711, P<0.001, respectively)(**Figure 2C and 2D**). In view of these findings we divided the patients’ cohort in 4 groups based upon the Pra quartiles. We noticed that for both the major and the minor donor vessels there was a statistically significant increase in the difference between FFR and FFRmyo over the 4 groups: (-0.002±0.003 vs. 0.001±0.018 vs. 0.012±0.005 vs. 0.018±0.018, P=0.004 and -0.001±0.004 vs. 0.003±0.003 vs. 0.005±0.005 vs. 0.013±0.005, P<0.001, respectively)(**Figure 3)**.

**Discussion**

This is the first study that investigated the impact of right atrial pressure (Pra) in FFR measurements in the non-CTO vessels in patients with stable coronary artery disease and a chronic total occlusion. Incorporation of Pra in FFR calculations led to statistically significant difference of 0.007 and 0.004 in the major and minor collateral donor vessel respectively. However, these differences are trivial and do not have any clinical relevance. Consequently, there was an excellent correlation between the classical FFR and FFRmyo and only in one out of 68 vessels FFRmyo crossed the threshold of 0.80 (from 0.82 to 0.80).

Fractional flow reserve is currently the reference standard for physiological assessment of coronary artery stenoses in patients undergoing diagnostic coronary angiography. It has been well validated against non-invasive functional tests and has been shown to provide superior risk stratification and clinical outcomes compared to coronary angiography alone (13,14). Accordingly, the current revascularisation guidelines endorse its use for functional assessment of coronary lesions (1). During the initial experimental validation of FFR in animal models, Pra measured during right heart catheterisation was used for the calculation of FFR (2,3). Subsequently, as normal atrial pressure is very low compared with systemic and coronary pressures, it was removed from the FFR equation. FFR measurement was simplified and could easily be adapted without interrupting the catheterisation laboratory workflow. The landmark randomised trials that validated the use of FFR in guiding PCI (DEFER, FAME, FAME 2) used the simplified equation (13-15).

However, two small studies challenged this practice. Perera et al. studied 62 patients with stable coronary artery disease and single coronary artery stenoses of 50-75%. By ignoring Pra in the FFR equation and using the hyperaemic Pd/Pa, 14% of coronary lesions were misclassified as insignificant and the sensitivity of the FFR was reduced to 64%. The degree of error was positively correlated with the Pra levels, with higher incidence of misclassifications in patients with higher Pra, suggesting that Pra incorporation in the FFR calculation might be necessary, particularly in patients with significantly elevated values and those with an FFR in the grey zone (16). In another study of 42 patients with stable coronary artery disease as well as acute coronary syndromes, FFR corrected for Pra was significantly lower compared to the conventional FFR. Omitting Pra in the FFR calculation resulted in an overall 21% incidence of misclassified FFR results as negative. There was an inverse correlation between the severity of coronary artery stenosis and the Pra levels indicating that the effect of latter in the FFR calculation is more pronounced in the more severe coronary lesions. It is important to mention that in this study mean Pra was above the normal limits (9.1 mmHg) (17).

Trying to address these concerns, Toth et al. measured the impact of RA pressure on the difference between the simplified FFR and full formula FFRmyo in 1,675 stenoses from 1,235 patients with stable coronary artery disease and intermediate coronary artery stenosis (5). The mean Pra was 7 mmHg (max of 27 mmHg) in their cohort. The authors showed that the clinical impact of Pra incorporation in the FFR calculation is negligible and only extremely high values of Pra might result in rare occasions of FFR misclassification. When Pra was incorporated in the FFR equation, the FFR value went from >0.80 to an FFRmyo value of <0.80 only in a small proportion of patients (9%) and there were no cases where FFRmyo was <0.75. Given these results, the authors concluded that the impact of right atrial pressure on FFR measurement is negligible. These results are important and reassuring. However, this study was conducted in a specific cohort of patients requiring left and right heart catheterization for clinical reasons. The main clinical presentation was dyspnea and although this probably led to a significant number of patients with higher than normal Pra pressures, it also resulted to only half of the patients (52%) having ischaemic heart disease. The severity of coronary stenosis was mild to moderate (mean diameter of stenosis, 41+/- 18 %) and the incidence of CTOs was not reported.

In our study, we investigated the potential impact of Pra in the FFR assessment of the non-CTO vessels in a real-world cohort of patients with stable coronary artery disease and an RCA CTO. 40 consecutive patients scheduled for CTO PCI were recruited and 34 of them had a successful procedure (success rate 85%). Chronic total occlusions represent a common finding during diagnostic coronary angiograms and in the context of multi-vessel disease, accurate assessment of the severity of non-CTO vessel lesions is a critical step in the decision making process regarding the correct treatment and revascularisation plan (18,19). Our study showed that incorporating Pra in FFR calculations is not needed for these patients. This result is consistent with the findings of the largest study performed in this field by Toth et al. and supports the current recommendation for FFR measurements (4). In our cohort, mean hyperaemic Pra was 4.1 mmHg, with a distribution across a range of values (0 mmHg, minimum and 15 mmHg maximum) and the majority of the measurements being normal or low. This mean value is in the normal range for right atrial pressure, but it was considerably lower compared to the previous studies assessing the impact of Pra on FFR (9.1 mmHg in the study by Layland et al. and 7 mmHg in the study by Toth et al.). This difference reflects the different populations of the studies. Our cohort consisted exclusively by stable patients with normal LVEF presenting for an elective procedure. They had procedures of considerable duration as on top of the CTO PCI, they underwent a lengthy research protocol, so relative dehydration led to a number of low Pra values. There was a strong positive correlation between the FFR and FFRmyo, in both the major and the minor collateral donor vessels supporting the notion that the impact of Pra in the FFR assessment is negligible. Indeed, with respect to the major collateral donor vessel none of our patients had any significant FFR crossover through the dichotomy threshold of 0.80 and as far as the minor collateral donor vessel is concerned, only one additional patient was reclassified as FFR positive after incorporation of the Pra in the FFR (from 0.82 to 0.80 in a Cx artery). For such small differences, we have to keep in mind that there are close to the range of test–retest repeatability of FFR measurements (20). Furthermore, 0.80 is a binary cut off point, and decision making around this value should be made using clinical judgement as well as understanding of the technical issues related to FFR measurements (21,22). There was a strong positive correlation with the Pra value and the difference between FFR and FFRmyo (dFFR), with the dFFR increasing for higher Pra values (fig. 3). Based on that observation it can be extrapolated, that for very elevated right atrial pressures, the change in FFR corrected for Pra would be larger than the one observed in this study. Especially when combined with low aortic pressure like in cases of severe heart failure or shock, high Pra values could lead to a clinical significant difference (23).

Limitations

This study has a number of limitations. First of all, it was a single-centre observational study with a small number of patients. Furthermore, the study was limited only to patients with an RCA CTO. However, this reflects the daily clinical practice where the majority of CTOs planned for elective PCI involve the RCA (6). Furthermore, in the presence of intermediate disease in the non-CTO vessels, functional assessment of the LAD will guide predominately the choice between medical therapy, percutaneous or surgical revascularisation. The fact that the mean Pra was within the normal range probably results in underestimation of the effect of Pra in the FFR computation. Our cohort was a homogeneous unselected cohort of patients with stable coronary artery disease and normal LVEF, reflecting a real life scenario for patients having elective CTO PCI. However, in cases of very elevated Pra the impact on FFR value would be expected to be bigger. Nevertheless, the actual cases where the Pra is exceptionally high are not commonly observed in the daily elective catheterisation laboratory practice and are usually associated with significant underlying disorders such as severe systolic and /or diastolic LV dysfunction, valvular heart disease and pulmonary hypertension.

**Conclusions**

In patients with stable coronary artery and a chronic total occlusion, the incorporation of Pra results in statistically significant but clinically negligible reduction of the FFR in the non-CTO vessels. For the patients with normal Pra, this effect is trivial and does not affect lesions ischaemic classification.

**References**

1. Windecker S, Kolh P, Alfonso F, et al. 2014 ESC/EACTS Guidelines on myocardial revascularization: The Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS) Developed with the special contribution of the European Association of Percutaneous Cardiovascular Interventions (EAPCI). Eur Heart J.2014;35:2541-619.

2. Pijls NH, van Son JA, Kirkeeide RL, De Bruyne B, Gould KL. Experimental basis of determining maximum coronary, myocardial, and collateral blood flow by pressure measurements for assessing functional stenosis severity before and after percutaneous transluminal coronary angioplasty. Circulation. 1993;87:1354-67.

3. Pijls NH, Van Gelder B, Van der Voort P, et al. Fractional flow reserve. A useful index to evaluate the influence of an epicardial coronary stenosis on myocardial blood flow. Circulation. 1995;92:3183-93.

4. Toth GG, Johnson NP, Jeremias A, et al. Standardization of Fractional Flow Reserve Measurements. J Am Coll Cardiol. 2016;68:742-53.

5. Toth GG, De Bruyne B, Rusinaru D, et al. Impact of Right Atrial Pressure on Fractional Flow Reserve Measurements: Comparison of Fractional Flow Reserve and Myocardial Fractional Flow Reserve in 1,600 Coronary Stenoses. JACC Cardiovasc Interv. 2016;9:453-9.

* 6. Tsai TT, Stanislawski MA, Shunk KA, et al. Contemporary Incidence, Management, and Long-Term Outcomes of Percutaneous Coronary Interventions for Chronic Coronary Artery Total Occlusions: Insights From the VA CART Program. JACC Cardiovasc Interv. 2017;10:866-75.
* 7. Brilakis ES, Banerjee S, Karmpaliotis D, et al. Procedural outcomes of chronic total occlusion percutaneous coronary intervention: a report from the NCDR (National Cardiovascular Data Registry). JACC Cardiovasc Interv. 2015;8:245-53.

8. Maeremans J, Walsh S, Knaapen P, et al. The Hybrid Algorithm for Treating Chronic Total Occlusions in Europe: The RECHARGE Registry. J Am Coll Cardiol. 2016;68:1958-70.

9. Sapontis J, Salisbury AC, Yeh RW, et al. Early Procedural and Health Status Outcomes After Chronic Total Occlusion Angioplasty: A Report From the OPEN-CTO Registry (Outcomes, Patient Health Status, and Efficiency in Chronic Total Occlusion Hybrid Procedures). JACC Cardiovasc Interv. 2017;10:1523-34.

10. Morino Y, Abe M, Morimoto T, et al. Predicting successful guidewire crossing through chronic total occlusion of native coronary lesions within 30 minutes: the J-CTO (Multicenter CTO Registry in Japan) score as a difficulty grading and time assessment tool. JACC Cardiovasc Interv. 2011;4:213-21.

11. Rentrop KP, Thornton JC, Feit F, Van Buskirk M. Determinants and protective potential of coronary arterial collaterals as assessed by an angioplasty model. Am J Cardiol. 1988;61:677-84.

12. Werner GS, Ferrari M, Heinke S, et al. Angiographic assessment of collateral connections in comparison with invasively determined collateral function in chronic coronary occlusions. Circulation 2003;107:1972-7.

13. Bech GJ, De Bruyne B, Pijls NH, et al. Fractional flow reserve to determine the appropriateness of angioplasty in moderate coronary stenosis: a randomized trial. Circulation. 2001;103:2928-34.

14. Tonino PA, De Bruyne B, Pijls NH, et al. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention. N Engl J Med. 2009;360:213-24.

15. De Bruyne B, Pijls NH, Kalesan B, et al. Fractional flow reserve-guided PCI versus medical therapy in stable coronary disease. N Engl J Med. 2012;367:991-1001.

16. Perera D, Biggart S, Postema P, et al. Right atrial pressure: can it be ignored when calculating fractional flow reserve and collateral flow index? J Am Coll Cardiol. 2004;44:2089-91.

17. Layland J, Wilson AM, Whitbourn RJ, et al. Impact of right atrial pressure on decision-making using fractional flow reserve (FFR) in elective percutaneous intervention. Int J Cardiol. 2013;167:951-3.

18. Fefer P, Knudtson ML, Cheema AN, et al. Current perspectives on coronary chronic total occlusions: the Canadian Multicenter Chronic Total Occlusions Registry. J Am Coll Cardiol. 2012;59:991-7.

19. Jeroudi OM, Alomar ME, Michael TT, et al. Prevalence and management of coronary chronic total occlusions in a tertiary Veterans Affairs hospital. Catheter Cardiovasc Interv. 2014;84:637-43.

20. Johnson NP, Jeremias A, Zimmermann FM, et al. Continuum of Vasodilator Stress From Rest to Contrast Medium to Adenosine Hyperemia for Fractional Flow Reserve Assessment. JACC Cardiovasc Interv. 2016;9:757-67.

21. Wijns W, Pyxaras SA. Chasing numbers: the reinvention of clinical science. JACC Cardiovasc Interv. 2013;6:226-7.

22. Pijls NH, Tanaka N, Fearon WF. Functional assessment of coronary stenoses: can we live without it? Eur Heart J. 2013;34:1335-44.

23. Kern MJ. Validating Practicality: Impact of Right Atrial Pressure on Fractional Flow Reserve. JACC Cardiovasc Interv. 2016;9:460-2.

* **Tables**
* **Table 1: Baseline demographics, angiographic and procedural details**

|  |  |
| --- | --- |
|  | * **n (%) or mean ± SD**
 |
| * **Demographic** (n=34)
 |  |
| * Male
 | * 30 (88.2)
 |
| * Age (years)
 | * 61.76 ± 10.53
 |
| * Previous MI
 | * 21 (61.8)
 |
| * Previous PCI
 | * 14 (41.2)
 |
| * Hypertension
 | * 22 (64.7)
 |
| * Hypercholesterolaemia
 | * 24 (70.6)
 |
| * Diabetes mellitus
 | * 9 (26.5)
 |
| * Current smoker
 | * 7 (20.6)
 |
| * Angina Duration (months)
 | * 39.88 ± 65.58
 |
| * Estimated duration of CTO (weeks)
 | * 221.38 ± 397.30
 |
| * Angina CCS Class (1/2/3/4)
 | * 4(11.8) / 12(35.3) / 17(50.0) / 1(2.9)
 |
| * LVEF on CMR (%)
 | * 51.26 ± 19.61
 |
| * RVEF on CMR (%)
 | * 51.76 ± 23.37
 |
| * Ischaemia in RCA territory on CMR (%)
 | * 13.65 ± 5.00
 |
| * **Angiographic Characteristics**
 |  |
| * CTO Vessel (RCA)
 | * 34 (100)
 |
| * CTO length (mm)
* J-CTO Score (0/1/2/3/4)
 | * 34.59 ± 25.70
* 7(20.6) / 5(14.7) / 8(23.5) / 10(29.4) / 4(11.8)
 |
| * Predominant donor vessel (LAD / LCx)
 | * 30 (88) / 4 (12)
 |
| * Predominant donor vessel stenosis on QCA (%)
 | * 41.43 ± 12.59
 |
| * Minor donor vessel stenosis on QCA (%)
 | * 35.06 ± 13.72
 |
| * Overall Rentrop Classification grading
 |  |
| * (0/1/2/3)
 | * 0(0.0) / 0(0.0) / 2(5.9) / 32(94.1)
 |
| * Overall Collateral Connection Classification
* grading
 |  |
| * (0/1/2/3)
 | * 0 (0.0) / 3(8.8) / 22(64.7) / 9(26.5)
 |

* Table 1 legend:
* MI = myocardial infarction; PCI = percutaneous coronary intervention; CTO = chronic total occlusion; CCS = canadian cardiovascular society; LVEF = left ventricular ejection fraction; CMR= cardiac magnetic resonance imaging; RVEF = right ventricular ejection fraction; RCA = right coronary artery; LAD = left anterior descending artery; LCx = left circumflex artery; QCA = Quantitative coronary angiography.
* **Figure legends**
* **Figure 1.**
1. Distribution of the right atrial pressure within the patients’ cohort.
2. FFR and FFRmyo values in the major and minor donor vessel groups. The bars represent the mean FFR values. The error bars represent the 95% confidence intervals.

 Pra: right atrial pressure; FFR: fractional flow reserve; FFRmyo: fractional flow reserve after incorporating right atrial pressure.

* **Figure 2.**
1. Scatter plot diagram demonstrating the correlation between the FFR and FFRmyo in the major donor vessel group.
2. Scatter plot diagram demonstrating the correlation between the FFR and FFRmyo in the minor donor vessel group.
3. Scatter plot diagram demonstrating the correlation between the FFR difference after incorporating the Pra (FFR-FFRmyo difference) and the Pra in the major donor vessel group.
4. Scatter plot diagram demonstrating the correlation between the FFR difference after incorporating the Pra (FFR-FFRmyo difference) and the Pra in the minor donor vessel group.
* FFR: fractional flow reserve; FFRmyo: fractional flow reserve after incorporating right atrial pressure.
* **Figure 3.**
* Differences between FFR and FFRmyo across Pra quartiles. A statistically significant increase in the difference between the FFR before and after incorporating the Pra was observed across the Pra quartiles. However, even in the highest quartile this difference remained clinically trivial.
* Pra: right atrial pressure; FFR: fractional flow reserve; FFRmyo: fractional flow reserve after incorporating right atrial pressure.

**Figure 1.**



**Figure 2.**



**Figure 3.**

