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Factors affecting short- and long-term survival of patients with acute coronary syndrome treated invasively using intravascular ultrasound and fractional flow reserve: Analysis of data from the Polish Registry of Acute Coronary Syndromes 2017–2020

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Factors affecting short- and long-term survival of patients with acute coronary syndrome treated invasively using intravascular ultrasound and fractional flow reserve: Analysis of data from the Polish Registry of Acute Coronary Syndromes 2017–2020

Short title: Use of IVUS and FFR – analysis of data from PL-ACS

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WHAT'S NEW?

The authors present current trends in the use of intravascular ultrasound (IVUS) and fractional flow reserve (FFR) in the treatment of acute coronary syndromes based on the Polish Register of Acute Coronary Syndromes. The frequency of their use is increasing, they are safe at the same time. However, although they reduce in-hospital mortality, they do not affect 30-day and annual survival.

ABSTRACT

Background: Intravascular ultrasound (IVUS) and fractional flow reserve (FFR) are invasive procedures increasingly used in acute coronary syndrome (ACS).

Aims: The aim of this study was to evaluate the prevalence of IVUS and FFR use in patients

with ACS in Poland and to assess the safety of these procedures, as well as their impact on short- and long-term survival.

Methods and results: The retrospective study included 103849 patients enrolled in the PL-ACS registry in 2017-2020. IVUS was performed in 1,727 patients, FFR in 1,537 patients, both procedures in 37 patients. The frequency of performing FFR in ACS over the years increased from 1.3% to 1.8% ($p < 0.0001$) and IVUS from 1.7% to 2.3% ($p < 0.0001$). In the FFR and/or IVUS group, a similar incidence of stroke, reinfarction, target vessel revascularization and major bleeding was observed, while in-hospital mortality was lower (0% for IVUS + FFR vs. 0.9% for FFR vs. 2.3% for IVUS vs. 3.7 for no procedure; $p < 0.0001$). FFR and IVUS did not affect the 30-day and one-year prognosis.

Conclusion: In the consequent years, the number of FFR and IVUS procedures performed in patients with ACS in Poland increased. There was lower in-hospital mortality in the FFR and/or IVUS group in ACS, no differences in the incidence of stroke, reinfarction, target vessel revascularization and major bleeding were observed. Performing FFR and IVUS in ACS does not significantly affect 30-day or one-year mortality.

Key words: acute coronary syndrome, coronary artery disease, fractional flow reserve, intravascular ultrasound

INTRODUCTION

In recent years, cardiovascular diseases have become a major cause of death in developed countries [1]. To gain a better understanding of the nature of the disease and to optimize diagnosis and therapy in sudden cardiac events, many countries have established large medical registries for data collection. In Poland, the reference registry collecting data on sudden cardiac events is the Polish Registry of Acute Coronary Syndromes (PL-ACS) [2]. Analysis of registry data provides information on many factors associated with the prognosis of acute coronary syndrome (ACS) [3, 4]. One of the less well-known and studied factors is the use of intravascular ultrasound (IVUS) and fractional flow reserve (FFR) in the diagnosis of ACS [5]. An intravascular probe was used to evaluate coronary artery lesions for the first time in 1980 [6]. Since then, use of this technique has become widespread. This method allows real-time assessment of the vessel lumen and morphology and volume of the atherosclerotic plaque, as well as optimization of stent deployment [7]. IVUS is also used in diagnostically ambiguous clinical cases such as suspected intramural hematoma or double vessel lumen [8].

FFR is an index that determines the degree of coronary stenosis, defined as the ratio of maximal blood flow in the zone of stenosis to normal maximal flow [9]. The main indication for use of this technique in diagnosis is the examination of patients with multivessel disease or moderate-degree stenosis (40–90%) if no ischemia is found on non-invasive testing [10]. Based on numerous clinical studies, the acceptable threshold value considered to be hemodynamically significant is 0.80 [11, 12]. In patients with stable coronary artery disease and an FFR of 0.80 or lower, percutaneous coronary intervention (PCI) with drug-eluting stent implantation was shown to result in reduced incidence of the primary endpoint of death, non-fatal myocardial infarction, and urgent revascularization at 2 years, compared with conservative treatment [13]. Both IVUS and FFR are therefore good invasive diagnostic tools to evaluate ambiguous coronary lesions and guide appropriate management [10].

The aim of this study was to evaluate the prevalence of IVUS and FFR use in patients with ACS in Poland and to assess the safety of these procedures, as well as their impact on short- and long-term survival.

METHODS

Data for 103849 patients included in the PL-ACS between 2017 and 2020 were analyzed. During that period, the FFR procedure was used in 1727 patients and IVUS was used in 1537 patients. We assessed the prevalence of IVUS and FFR use in individual centers in Poland based on the number of procedures reported. We compared the frequency of IVUS and FFR procedures performed in consecutive years. We analyzed the frequency of complications in groups undergoing IVUS and FFR as well as in patients who did not undergo either of these procedures. Factors associated with the achievement of 30-day survival and 1-year survival were determined. The 30-day and 1-year survival rates were compared between patients who underwent IVUS and/or FFR and those who underwent neither of these procedures.

Follow-up data for all-cause mortality was obtained from the National Health Fund database. Follow-up time was censored at 365 days or at the end of follow-up time, on the 24th December 2021 (whichever came first).

Statistical analysis

Categorical variables are shown as numbers of patients and percentages. Continuous variables were not distributed normally, which was verified by means of the Shapiro Wilk test, and are

therefore presented as median and interquartile range. Comparisons of categorical and continuous variables across groups were performed using Chi-squared and Kruskal–Wallis tests. Cumulative survival in the groups of patients stratified by the use of IVUS or FFR was presented using Kaplan-Meier curves and compared by log-rank test. Univariate logistic regression analysis was used to identify variables associated with 30-day mortality and univariate Cox regression analysis was used to identify variables associated 1-year mortality. Variables that were significantly associated with the outcome in the univariate models were included in multivariable analysis. Statistical significance was defined as $p<0.05$ (two-tailed). Statistica version 13.3 (TIBCO Software, CA, USA) and MedCalc® Statistical Software version 20.115 (MedCalc Software Ltd, Ostend, Belgium) were used for computational analyses.

RESULTS

Among the 103849 patients with ACS included in the study, 1727 patients underwent IVUS, 1537 underwent FFR, and 37 had both procedures. Patients' follow-up was presented in Figure 1. Flowchart percentages for deaths and survival refer to the number of patients with available follow-up data. Survival data was not available for only 25 patients without IVUS / FFR and one patient in the IVUS group. Multiple clinical and procedural factors were analyzed. Descriptive characteristics of the study groups are shown in Table 1. In 2017 - 2020, an increase in the frequency of FFR procedures from 113 (1.3%) to 441 (1.8%) and IVUS from 89 (1.0%) to 557 (2.3%) was observed. In 2020, an increase in 30-day (1489; 6.2%) and 1-year (3292; 13.6%) mortality was observed. Additional information on the laboratory and clinical parameters are shown on Table 2. Annual trends in the number of procedures performed are shown in Figure 2.

The lead center performed FFR in 14.71% of patients with ACS, while IVUS in the lead center was performed in 37.33% of patients with ACS. Tables S1 and S2 show the centers in Poland that most frequently performed FFR and IVUS in patients with ACS.

A significant reduction in in-hospital mortality was observed in the group treated with FFR and/or IVUS, other complications occurred with a similar frequency. A comparison of the number of complications depending on the procedures performed (IVUS, FFR or both) is presented in Table 3.

More often FFR was performed in left anterior descending artery (LAD), diagonal branch (Dg), and circumference branch (Cx), while IVUS was related to left main coronary artery (LM) and

v branch (OM). Differences in the use of these procedures depending on ACS presentation and coronary artery typology are shown in Table 4.

The long-term follow-up of median 365 days (Q1-Q3 365-365; mean 335 days) was available for 99.98%. Performing FFR was significantly associated with 30-day and 1-year survival, but only in univariate analysis. Multivariable regression analysis showed no association between FFR or IVUS and 30-day mortality. Logistic regression analysis revealed multiple factors significantly associated with 30-day survival in patients with ST-segment elevation myocardial infarction (STEMI) and non-ST-segment elevation myocardial infarction (NSTEMI) (Tables S3 - S5). Factors associated with 1-year survival are shown in Tables S6 - S8.

To compare the survival of patients with STEMI, NSTEMI and unstable angina undergoing FFR and IVUS, Kaplan-Meier curves assessing 1-year survival were plotted (Figure 3 A - C). Survival probability was higher in patient with STEMI undergoing FFR.

DISCUSSION

The PL-ACS collects numerous data on the treatment and diagnosis of ACS in Poland. The volume and quality of information collected is so comprehensive that it can successfully compete with similar large European registries, such as the MINAP registry in the UK and the RIKS-HIA registry in Sweden [12, 14]. In addition to traditional coronary angiography, many complementary diagnostic methods are now available for the diagnosis of ACS. IVUS and FFR have become common complementary methods in current diagnostics.

Reports from European cardiological societies show that both diagnostic methods are highly prevalent and available in Europe. In an analysis of 118706 PCI cases in Portugal, Guerreiro et al. found that IVUS was used in 2266 (1.9%). Moreover, they found increasing use of the method over time: from 0.1% in 2003 to 2.4% in 2006 [15]. Similar data showing increasing use of invasive diagnostic tests over time were found in a large Spanish registry [16]. Other papers have compared IVUS to other modern methods complementary to invasive diagnostics, such as optical coherence tomography [17]. Analysis of data from other large national registries, such as PRIME-FFR (Insights from the POST-IT [Portuguese Study on the Evaluation of FFR-Guided Treatment of Coronary Disease] and R3F [French FFR Registry] Integrated Multicenter Registries - Implementation of FFR [Fractional Flow Reserve] in Routine Practice), shows that the frequency of FFR procedures has also been increasing in Europe in recent years [18]. In our study, based on the analysis of PL-ACS data, we found increasing use of this method over time and high involvement of centers performing the

procedures.

Use of FFR as a complementary diagnostic method for coronary vascular testing in ACS does not seem very promising to date. Patients with ACS and postponed revascularization based on FFR have poorer clinical outcomes than even with those with stable angina [19 - 21]. In the FAMOUS-NSTEMI study, Layland et al. analyzed FFR-guided (n = 176) and angiography-guided (n = 174) groups and showed a significantly lower survival rate in the FFR group [22]. Similarly, in an analysis of the randomized FAME (Fractional flow reserve versus Angiography or Multivessel Evaluation) study, Sels et al. compared FFR-guided PCI in multivessel disease in 1005 patients with either stable or unstable angina. At 2-year follow-up, the two groups did not differ in the rate of major adverse cardiovascular events (MACE) [23]. Similarly, in pooled data from the R3F and POST-IT prospective registry studies, van Belle et al. did not find statistically significant differences between the FFR and conventional groups in a total of 1983 patients at 1-year follow-up [18]. Lee et al. analyzed combined data for 1596 patients from the Korean 4 centers Registry and 3-vessel FFR FRIENDS study from 2003 to 2014. They compared the prognosis of deferred non-culprit lesions in patients with ACS with those in patients with stable coronary artery disease based on FFR and did not identify a statistically significant difference in terms of MACE [20].

In our analysis of 1537 Polish patients with ACS who qualified for FFR over 4 years, we found that performing FFR in both STEMI and NSTEMI is associated with a reduced risk of in-hospital death, but is not associated with the incidence of stroke, reinfarction, target vessel revascularization, or major bleeding.

Many studies, including randomized trials, have confirmed the significant utility of the introduced extended invasive diagnostics. One of the first and largest randomized trials was the ULTIMATE trial by Zhang et al., which demonstrated a reduction in the incidence of vessel patency abnormalities 12 months after IVUS-guided PCI, compared to an angiography-based PCI strategy [24]. By contrast, in a study of 543 patients randomly assigned to IVUS-guided (n = 269) or angiography-guided (n = 274) PCI, Kim et al. did not find the IVUS strategy to be superior in terms of the primary endpoint including MACE after 1 year [25]. In a study of 2127 patients who qualified for IVUS-guided PCI and 8235 patients who qualified for PCI directly, Khurshid et al. did not find an advantage of IVUS over direct PCI after 12 months [26].

In the above analyses, the most important issue is the effect of extended invasive diagnostics on 30-day mortality and 1-year mortality. As a result of our analyses, we confirm that performing FFR is associated with a reduction in 30-day mortality but not with 1-year mortality. Analyzing the available literature, we found that the results of previous studies are divergent. A large meta-analysis by Liou et

al., including 5457 patients with coronary artery disease, found a higher long-term mortality rate using FFR in patients with ACS than in patients with stable angina [27]. In the FUTURE trial, Rioufol et al. randomly assigned 927 patients with stable multivessel coronary artery disease to either a traditional strategy or one based on prior FFR. The study was terminated early and no advantage of the FFR strategy over the traditional strategy was demonstrated [28]. The latest AISN PTK report also confirmed an increase in the incidence of FFR and IVUS use during PCI compared to 2020 [29]. The authors did not analyze the time of day at which the procedures were performed, but previous studies have shown a similar number of perioperative complications in STEMI patients treated during on- and off-hours. However, higher perioperative mortality was observed during off-hours [30]. The authors did not demonstrate the effect of FFR and IVUS on improving 1-year survival in patients with ACS, while recent publications have shown that the comprehensive care program called The KOS-Infarction significantly improved 1-year survival in patients after myucardial infarction [31].

Intravascular echocardiography and FFR assessment are currently the standard of care for functional assessment in patients with multivessel coronary artery disease or moderate-degree stenosis (40 – 90%) in the absence of evidence of ischemia on non-invasive testing. However, the efficacy of this method compared to the traditional strategy for ACS diagnosis cannot be definitively confirmed. The involvement of catheterization laboratories, increasing prevalence of the method, planned randomized trials, and large registry analyses will soon provide many answers to the questions raised.

CONCLUSIONS

1. In the years 2017–2020 in Poland, the number of FFR and IVUS procedures performed in Acute Coronary Syndromes increased significantly.
2. In the group of patients with ACS who underwent FFR and/or IVUS, significantly lower in-hospital mortality was observed, while no differences in the incidence of stroke, re-myocardial infarction, revascularization of the target vessel or serious bleeding were observed.
3. In a multivariable analysis, IVUS or FFR during coronary angioplasty in patients with acute coronary syndrome was not associated with a better distant prognosis (12 months).

Article information

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Sanofi, Astra Zeneca and Orion Pharma. Marek Gierlotka is a member of the Advisory Board of Novartis, Sanofi and Astra Zeneca. Michał Hawranek received lectures honoraria from Abbott and Novartis.

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REFERENCES

1. GBD 2017 Causes of Death Collaborators. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2018; 392(10159): 1736–1788, doi: 10.1016/S0140-6736(18)32203-7, indexed in Pubmed: 30496103.
2. Polish Registry of Acute Coronary Syndromes. Available online: https://pl-acs.sccs.pl/. [Accessed at January 12, 2022].
3. Piątek Ł, Janion-Sadowska A, Piątek K, et al. The progress in outcomes of the management of patients with non-ST-segment elevation myocardial infarction between 2005 and 2014 in Poland. A propensity score matching analysis from the PL-ACS registry. Postepy Kardiol Interwencyjnej. 2020; 16(1): 41–48, doi: 10.5114/aic.2020.93911, indexed in Pubmed: 32368235.
4. Siudak Z, Ochała A, Lesiak M, et al. Temporal trends and patterns in percutaneous treatment of coronary artery disease in Poland in the years 2005-2011. Kardiol Pol. 2015; 73(7): 485–492, doi: 10.5603/KP.a2015.0037, indexed in Pubmed: 25733178.
5. Collet JP, Thiele H, Barbato E, et al. Questions and answers on workup diagnosis and risk stratification: a companion document of the 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. Eur Heart J. 2021; 42(14): 1379–1386, doi: 10.1093/eurheartj/ehaa602, indexed in Pubmed: 32860030.

6. Yock PG, Linker DT, Angelsen BA. Two-dimensional intravascular ultrasound: technical development and initial clinical experience. J Am Soc Echocardiogr. 1989; 2(4): 296–304, doi: 10.1016/s0894-7317(89)80090-2, indexed in Pubmed: 2697308.
7. Johnson TW, Räber L, di Mario C, et al. Clinical use of intracoronary imaging. Part 2: acute coronary syndromes, ambiguous coronary angiography findings, and guiding interventional decision-making: an expert consensus document of the European Association of Percutaneous Cardiovascular Interventions. Eur Heart J. 2019; 40(31): 2566–2584, doi: 10.1093/eurheartj/ehz332, indexed in Pubmed: 31112213.
8. Alfonso F, Paulo M, Gonzalo N, et al. Diagnosis of spontaneous coronary artery dissection by optical coherence tomography. J Am Coll Cardiol. 2012; 59(12): 1073–1079, doi: 10.1016/j.jacc.2011.08.082, indexed in Pubmed: 22421300.
9. Pijls NHJ, Fearon WF, Tonino PAL, et al. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention. N Engl J Med. 2009; 360(3): 213–224, doi: 10.1056/NEJMoa0807611, indexed in Pubmed: 19144937.
10. Neumann FJ, Sousa-Uva M, Ahlsson A, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. Eur Heart J. 2019; 40(2): 87–165, doi: 10.1093/eurheartj/ehy394, indexed in Pubmed: 30165437.
11. Berry C, McClure JD, Oldroyd KG. Meta-Analysis of Death and Myocardial Infarction in the DEFINE-FLAIR and iFR-SWEDEHEART Trials. Circulation. 2017; 136(24): 2389–2391, doi: 10.1161/CIRCULATIONAHA.117.030430, indexed in Pubmed: 28972006.
12. Harnek J, Nilsson J, Friberg O, et al. The Swedish Web-system for enhancement and development of evidence-based care in heart disease evaluated according to recommended therapies (SWEDEHEART). Heart. 2010; 96(20): 1617–1621, doi: 10.1136/hrt.2010.198804, indexed in Pubmed: 20801780.
13. Fearon WF, Nishi T, De Bruyne B, et al. Clinical Outcomes and Cost-Effectiveness of Fractional Flow Reserve-Guided Percutaneous Coronary Intervention in Patients With Stable Coronary Artery Disease: Three-Year Follow-Up of the FAME 2 Trial (Fractional Flow Reserve Versus Angiography for Multivessel Evaluation). Circulation. 2018; 137(5): 480–487, doi: 10.1161/CIRCULATIONAHA.117.031907, indexed in Pubmed: 29097450.
14. Herrett E, Smeeth L, Walker L, et al. The Myocardial Ischaemia National Audit Project (MINAP). Heart. 2010; 96(16): 1264–1267, doi: 10.1136/hrt.2009.192328, indexed in Pubmed: 20659944.

15. Azevedo Guerreiro R, Fernandes R, Campante Teles R, et al. Fifteen years of coronary intravascular ultrasound in percutaneous coronary intervention in Portugal. Rev Port Cardiol (Engl Ed). 2019; 38(11): 779–785, doi: 10.1016/j.repc.2019.02.007, indexed in Pubmed: 32057522.
16. Cid Álvarez AB, Rodríguez Leor O, Moreno R, et al. Spanish Cardiac Catheterization and Coronary Intervention Registry. 27th Official Report of the Spanish Society of Cardiology Working Group on Cardiac Catheterization and Interventional Cardiology (1990-2017). Rev Esp Cardiol (Engl Ed). 2018; 71(12): 1036–1046, doi: 10.1016/j.rec.2018.09.009, indexed in Pubmed: 30297279.
17. Matthews SD, Frishman WH. A Review of the Clinical Utility of Intravascular Ultrasound and Optical Coherence Tomography in the Assessment and Treatment of Coronary Artery Disease. Cardiol Rev. 2017; 25(2): 68–76, doi: 10.1097/CRD.0000000000000128, indexed in Pubmed: 28099219.
18. Van Belle E, Baptista SB, Raposo L, et al. Impact of Routine Fractional Flow Reserve on Management Decision and 1-Year Clinical Outcome of Patients With Acute Coronary Syndromes: PRIME-FFR (Insights From the POST-IT [Portuguese Study on the Evaluation of FFR-Guided Treatment of Coronary Disease] and R3F [French FFR Registry] Integrated Multicenter Registries - Implementation of FFR [Fractional Flow Reserve] in Routine Practice). Circ Cardiovasc Interv. 2017; 10(6), doi: 10.1161/CIRCINTERVENTIONS.116.004296, indexed in Pubmed: 28615234.
19. Hakeem A, Edupuganti MM, Almomani A, et al. Long-term prognosis of deferred acute coronary syndrome lesions based on nonischemic fractional flow reserve. J Am Coll Cardiol. 2016; 68(11): 1181–1191, doi: 10.1016/j.jacc.2016.06.035, indexed in Pubmed: 27609680.
20. Lee JM, Choi KiH, Koo BK, et al. Prognosis of deferred non-culprit lesions according to fractional flow reserve in patients with acute coronary syndrome. EuroIntervention. 2017; 13(9): e1112–e1119, doi: 10.4244/EIJ-D-17-00110, indexed in Pubmed: 28691907.
21. Masrani Mehta S, Depta JP, Novak E, et al. Association of Lower Fractional Flow Reserve Values With Higher Risk of Adverse Cardiac Events for Lesions Deferred Revascularization Among Patients With Acute Coronary Syndrome. J Am Heart Assoc. 2015; 4(8): e002172, doi: 10.1161/JAHA.115.002172, indexed in Pubmed: 26289346.
22. Layland J, Oldroyd KG, Curzen N, et al. Fractional flow reserve vs. angiography in guiding management to optimize outcomes in non-ST-segment elevation myocardial

infarction: the British Heart Foundation FAMOUS-NSTEMI randomized trial. Eur Heart J. 2015; 36(2): 100–111, doi: 10.1093/eurheartj/ehu338, indexed in Pubmed: 25179764.

23. Sels JWEM, Tonino PAL, Siebert U, et al. Fractional flow reserve in unstable angina and non-ST-segment elevation myocardial infarction experience from the FAME (Fractional flow reserve versus Angiography for Multivessel Evaluation) study. JACC Cardiovasc Interv. 2011; 4(11): 1183–1189, doi: 10.1016/j.jcin.2011.08.008, indexed in Pubmed: 22115657.
24. Gao XF, Ge Z, Kong XQ, et al. Intravascular ultrasound versus angiography-guided drug-eluting stent implantation: the ULTIMATE trial. J Am Coll Cardiol. 2018; 72(24): 3126–3137, doi: 10.1016/j.jacc.2018.09.013, indexed in Pubmed: 30261237.
25. Kim JS, Kang TS, Mintz GS, et al. Randomized comparison of clinical outcomes between intravascular ultrasound and angiography-guided drug-eluting stent implantation for long coronary artery stenoses. JACC Cardiovasc Interv. 2013; 6(4): 369–376, doi: 10.1016/j.jcin.2012.11.009, indexed in Pubmed: 23523455.
26. Ahmed K, Jeong MHo, Chakraborty R, et al. Role of intravascular ultrasound in patients with acute myocardial infarction undergoing percutaneous coronary intervention. Am J Cardiol. 2011; 108(1): 8–14, doi: 10.1016/j.amjcard.2011.02.339, indexed in Pubmed: 21529735.
27. Liou KP, Ooi SYM, Hoole SP, et al. Fractional flow reserve in acute coronary syndrome: a meta-analysis and systematic review. Open Heart. 2019; 6(1): e000934, doi: 10.1136/openhrt-2018-000934, indexed in Pubmed: 30774965.
28. Rioufol G, Dérimay F, Roubille F, et al. Fractional flow reserve to guide treatment of patients with multivessel coronary artery disease. J Am Coll Cardiol. 2021; 78(19): 1875–1885, doi: 10.1016/j.jacc.2021.08.061, indexed in Pubmed: 34736563.
29. Siudak Z, Bartuś S, Hawranek M, et al. Interventional cardiology in Poland in 2021. Annual summary report of the Association of Cardiovascular Interventions of the Polish Cardiac Society (AISN PTK) and Jagiellonian University Medical College. Postepy Kardiol Interwencyjnej. 2022; 18(2): 87–89, doi: 10.5114/aic.2022.118523, indexed in Pubmed: 36051825.
30. Tokarek T, Dziewierz A, Plens K, et al. Percutaneous coronary intervention during on- and off-hours in patients with ST-segment elevation myocardial infarction. Hellenic J Cardiol. 2021; 62(3): 212–218, doi: 10.1016/j.hjc.2021.01.011, indexed in Pubmed: 33540055.

31. Kubielas G, Diakowska D, Uchmanowicz I. Survival analysis of patients with acute coronary syndrome receiving comprehensive coordinated care after myocardial infarction (KOS-Zawał). Kardiol Pol. 2022; 80(3): 415–321, doi: 10.33963/KP.a2022.0035, indexed in Pubmed: 35129204.

Table 1. Descriptive characteristics of patients included in the PL-ACS in 2017–2020

Variables	Total (n = 103 849)	2017 (n = 8756)	2018 (n = 35 180)	2019 (n = 35 718)	2020 (n = 24 195)	*P*-value
Sex (male), n (%)	67 553 (65.1)	5555 (63.5)	22827 (64.9)	23298 (65.2)	15873 (65.6)	0.003
Age, years, median (IQR)	67.6 (60.6–75.1)	67.9 (61.0–76.1)	67.5 (60.6–75.3)	67.6 (60.6–75.1)	67.7 (60.6–74.5)	0.01
BMI, kg/m^2, median (IQR)	27.8 (25.1–31.2)	27.7 (25.0–31.0)	27.8 (25.0–31.2)	27.8 (25.0–31.2)	27.9 (25.3–31.2)	<0.001
Acute coronary syndrome						<0.001
STEMI, n (%)	31 128 (30.3)	2479 (29.0)	10423 (29.9)	10668 (30.2)	7558 (31.7)	
NSTEMI, n (%)	52 397 (51.1)	4090 (47.8)	17342 (49.8)	18510 (52.4)	12455 (52.2)	
UA, n (%)	19 045 (18.6)	1979 (23.2)	7064 (20.3)	6170 (17.5)	3832 (16.1)	
Killip classification						<0.001
I, n (%)	86 101 (84.3)	7364 (86.5)	29523 (85.1)	29506 (84.1)	19708 (82.9)	
II, n (%)	11 591 (11.4)	792 (9.3)	3773 (10.9)	4110 (11.7)	2916 (12.3)	
III, n (%)	2 139 (2.1)	166 (2.0)	659 (1.9)	744 (2.1)	570 (2.4)	
IV, n (%)	2 252 (2.2)	188 (2.2)	740 (2.1)	739 (2.1)	585 (2.5)	
CA before	2 536 (2.5)	228 (2.7)	837 (2.4)	824 (2.4)	647 (2.7)	0.02

admission, n (%)						
Previous MI, n (%)	23 211 (23.9)	2090 (25.5)	8029 (24.1)	7802 (23.5)	5290 (23.8)	0.001
Previous PCI, n (%)	22 762 (23.5)	2021 (24.7)	7846 (23.5)	7689 (23.1)	5206 (23.4)	0.03
Previous CABG, n (%)	5 264 (5.4)	545 (6.6)	1834 (5.5)	1676 (5.0)	1209 (5.4)	<0.001
Previous stroke, n (%)	5 238 (5.4)	487 (6.0)	1776 (5.4)	1777 (5.4)	1198 (5.4)	0.16
PAD, n (%)	6 267 (6.6)	554 (6.9)	2138 (6.5)	2204 (6.7)	1371 (6.3)	0.09
CKD, n (%)	7 696 (8.0)	775 (9.5)	2628 (7.9)	2611 (7.9)	1682 (7.6)	<0.001
COPD, n (%)	4 928 (5.1)	458 (5.7)	1739 (5.3)	1679 (5.1)	1052 (4.8)	0.01
Diabetes, n (%)	26 970 (28.0)	2371 (29.3)	9263 (28.0)	9252 (27.9)	6084 (27.5)	0.03
EF, %, median (IQR)	50 (40–55)	50 (41–55)	50 (42–55)	50 (40–55)	50 (40–55)	<0.001
LM disease, n (%)	6 501 (6.3)	547 (6.3)	2254 (6.4)	2217 (6.3)	1483 (6.2)	0.54
Multivessel disease						0.003
2VD, n (%)	20 575 (19.9)	1612 (18.5)	6984 (19.9)	7116 (20.1)	4863 (20.2)	
3VD, n (%)	8 738 (8.5)	806 (9.2)	2908 (8.3)	3035 (8.6)	1989 (8.3)	
Vascular access						<0.001
Radial, n (%)	86 290 (83.9)	6518 (75.9)	28439 (81.4)	30358 (85.9)	20975 (87.3)	
Femoral, n (%)	15 500 (15.1)	2000 (23.3)	6161 (17.6)	4606 (13.0)	2733 (11.4)	
Other, n (%)	1 057 (1.0)	66 (0.8)	319 (0.9)	366 (1.0)	306 (1.3)	
PCI, n (%)	81 017 (78.6)	6494 (75.5)	27348 (78.2)	27827 (78.4)	19348 (80.3)	<0.001
CABG, n (%)	4 158 (4.1)	441 (5.2)	1508 (4.4)	1340 (3.8)	869 (3.6)	<0.001

30-day mortality rate, n (%)	5231 (5.0)	403 (4.6)	1628 (4.6)	1711 (4.8)	1489 (6.2)	<0.001
1-year mortality rate, n (%)	11775 (11.3)	965 (11.0)	3661 (10.4)	3857 (10.8)	3292 (13.6)	<0.001
FFR, n (%)	1 537 (1.5)	113 (1.3)	394 (1.1)	589 (1.6)	441 (1.8)	<0.001
IVUS, n (%)	1 727 (1.7)	89 (1.0)	427 (1.2)	654 (1.8)	557 (2.3)	<0.001

Categorical data are presented as number of patients (%). Continuous variables are shown as median (interquartile range [IQR])

Abbreviations: 1VD, one vessel disease; 2VD, two vessels disease; 3VD, three vessels disease; BMI, body mass index; CA, cardiac arrest; CABG, coronary artery bypass grafting; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; EF, ejection fraction; FFR, fractional flow reserve; IVUS, intravascular ultrasonography; LM, left main coronary artery; MI, myocardial infarction; NSTEMI, non-ST-segment elevation myocardial infarction; PAD, peripheral artery disease; PCI, percutaneous coronary intervention; STEMI, ST-segment elevation myocardial infarction; UA, unstable angina

Table 2. Additional information on the laboratory findings, in-hospital treatment and smoking status in the groups of patients stratified by the use of IVUS and FFR and initial presentation

STEMI				
	FFR	**IVUS**	**None**	***P*–value**
Smoking status				<0.001
Current, %	52.85	38.66	41.49	
Former, %	17.62	20.73	24.83	
In-hospital treatment				
Clopidogrel, %	35.55	34.21	46.33	<0.001
Prasugrel, %	1.42	4.33	1.30	<0.001
Ticagrelor, %	53.30	54.05	39.66	<0.001
Aspirin, %	94.34	96.00	93.04	0.04
GP IIb/IIIa inhibitors, %	27.96	42.34	27.01	<0.001

Laboratory results				
LDL-C, mmol/l, median (IQR)	3.27 (2.40–4.01)	3.21 (2.43–3.96)	3.10 (2.30–3.93)	0.50
Total cholesterol, mmol/l, median (IQR)	5.00 (4.20–5.95)	4.94 (4.09–5.59)	4.90 (4.01–5.79)	0.48
Creatinine, μmol/l, median (IQR)	79.5 (67.0–92.5)	79.0 (69.0–93.0)	81.0 (69.0–98.0)	0.16
Hemoglobin, mmol/l, median (IQR)	8.44 (7.97–9.19)	8.69 (8.07–9.43)	8.8 (8.1–9.5)	0.06
Hematocrit, %, median (IQR)	40.0 (38.0–43.0)	41.00 (38.0–45.0)	41.0 (38.0–44.0)	0.03
NSTEMI				
	FFR	**IVUS**	**None**	**P–value**
Smoking status				<0.001
Current, %	34.57	31.26	27.47	
Former, %	23.30	25.40	32.49	
In-hospital treatment				
Clopidogrel, %	53.94	52.64	56.89	<0.001
Prasugrel, %	1.72	2.19	1.23	0.01
Ticagrelor, %	28.31	32.85	21.43	<0.001
Aspirin, %	93.86	94.65	92.94	0.07
GP IIb/IIIa inhibitors, %	9.97	17.49	7.46	<0.001
Laboratory results				
LDL-C, mmol/l, median (IQR)	2.77 (1.99–3.78)	2.65 (1.86–3.57)	2.70 (1.91–3.60)	0.37
Total cholesterol, mmol/l, median (IQR)	4.61 (3.60–5.65)	4.32 (3.44–5.33)	4.50 (3.57–5.48)	0.04
Creatinine, μmol/l, median (IQR)	83.5 (72.0–99.0)	85.0 (71.0–105.0)	85.0 (71.0–106.0)	0.47
Hemoglobin, mmol/l, median (IQR)	8.75 (7.94–9.40)	8.69 (7.82–9.31)	8.7 (7.9–9.3)	0.19

Hematocrit, %, median (IQR)	41.0 (38.0–44.0)	41.0 (37.0–44.0)	41.0 (37.0–44.0)	0.95
Unstable angina				
	FFR	**IVUS**	**None**	**P–value**
Smoking status				0.03
Current, %	24.42	15.90	21.27	
Former, %	33.99	31.28	36.28	
In-hospital treatment				
Clopidogrel, %	54.64	49.34	53.39	0.41
Prasugrel, %	2.12	3.93	0.75	<0.01
Ticagrelor, %	15.92	29.26	11.45	<0.01
Aspirin, %	91.51	95.20	92.28	0.22
GP IIb/IIIa inhibitors, %	1.33	3.06	1.48	0.14
Laboratory results				
LDL-C, mmol/l, median (IQR)	2.30 (1.64–3.00)	2.27 (1.57–3.31)	2.36 (1.71–3.23)	0.57
Total cholesterol, mmol/l, median (IQR)	4.14 (3.35–5.02)	3.96 (3.25–5.12)	4.22 (3.44–5.20)	0.49
Creatinine, µmol/l, median (IQR)	82.0 (70.0–95.0)	82.0 (71.0–100.0)	82.0 (70.0–97.0)	0.64
Hemoglobin, mmol/l, median (IQR)	8.75 (8.07–9.34)	8.69 (7.76–9.18)	8.8 (8.1–9.3)	0.12
Hematocrit, %, median (IQR)	41.0 (38.5–44.0)	41.00 (37.0–43.0)	42.0 (39.0–44.0)	0.01

Categorical data are presented as number of patients (%). Continuous variables are shown as median (interquartile range [IQR])

Abbreviations: GP IIb/IIIa inhibitors, glycoprotein IIb/IIIa inhibitors; LDL-C, low density lipoprotein cholesterol; other — see Table 1

Table 3. Comparison of complication rates depending on procedures performed.

Variables	IVUS + FFR (n = 37)	FFR (n = 1500)	IVUS (n = 1690)	None (n = 100 620)	*P*-value
Stroke	0 (0.0)	4 (0.3)	1 (0.1)	206 (0.2)	0.57
ReMI	0 (0.0)	4 (0.3)	6 (0.4)	267 (0.3)	0.88
TVR	0 (0.0)	2 (0.1)	7 (0.4)	327 (0.3)	0.5
Major bleeding	1 (2.7)	11 (0.8)	27 (1.7)	1159 (1.2)	0.09
In-hospital mortality	0 (0.0)	14 (0.9)	39 (2.3)	3714 (3.7)	< 0.001

Data are presented as number of patients (%)

Abbreviations: ReMI, myocardial reinfarction; TVR, target vessel revascularization; other — see Table 1

Table 4. Comparison of the use of FFR and IVUS depending on the clinical presentation of ACS and coronary artery anatomy

	FFR (n = 1537)	IVUS (n = 1727)	*P*-value
STEMI	220 (14.5)	442 (26.2)	<0.001
NSTEMI	914 (60.2)	1009 (59.7)	
UA	384 (25.3)	238 (14.1)	
LM	67 (4.4)	556 (32.2)	<0.001
LAD	1196 (77.8)	979 (56.7)	<0.001
Dg	75 (4.9)	49 (2.8)	0.002
IM	15 (1.0)	17 (1.0)	0.98
Cx	278 (18.1)	252 (14.6)	0.01
OM	47 (2.7)	74 (4.8)	0.002
RCA	239 (15.5)	249 (14.4)	0.36
By-pass	2 (0.1)	7 (0.4)	0.13

Data are presented as number of patients (%)

Abbreviations: ACS, acute coronary syndrome; Cx, circumference branch; Dg, diagonal branch; IM, intermediate branch; LAD, left anterior descending artery; OM, obtious marginalis branch; RCA, right coronary artery; other — see Table 1

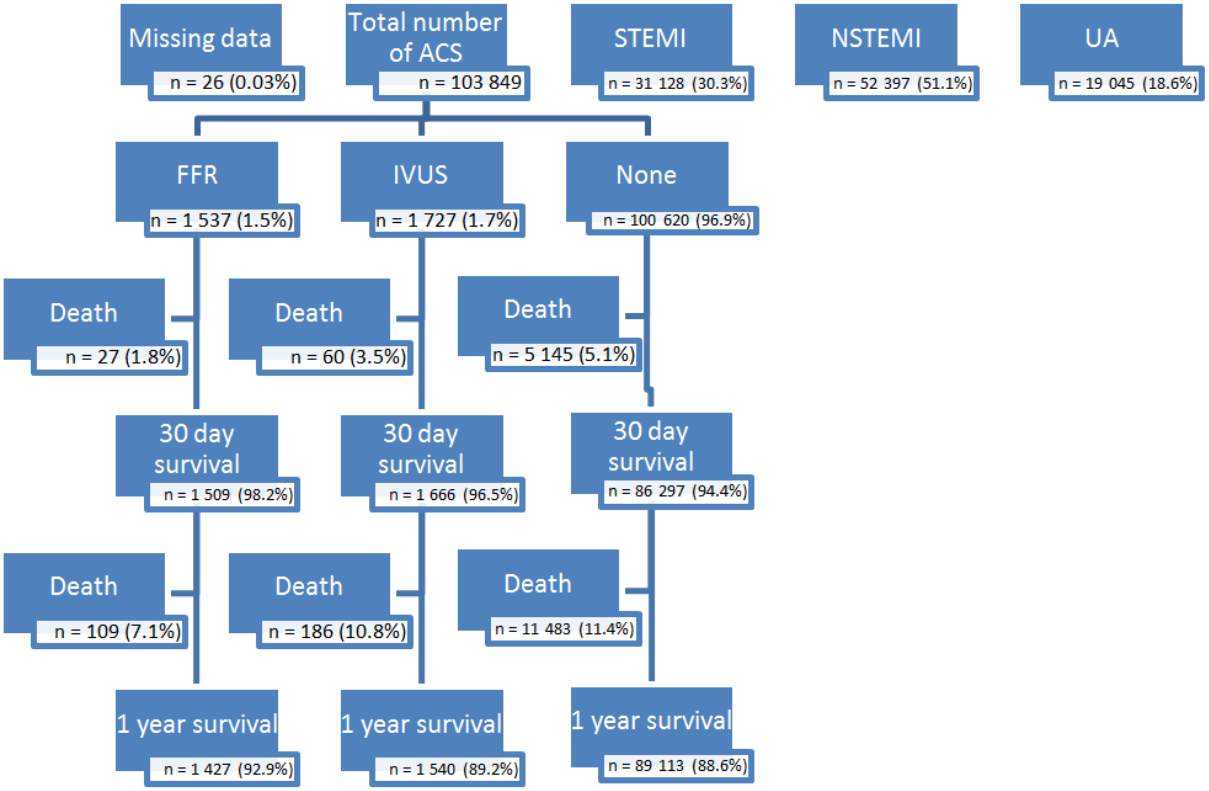


Figure 1. Prognosis of patients included in the PL-ACS register in 2017–2020

Abbreviations: ACS, acute coronary syndrome; FFR, fractional flow reserve; IVUS, intravascular ultrasonography; NSTEMI, non-ST-segment elevation myocardial infarction; STEMI, ST-segment elevation myocardial infarction; UA, unstable angina

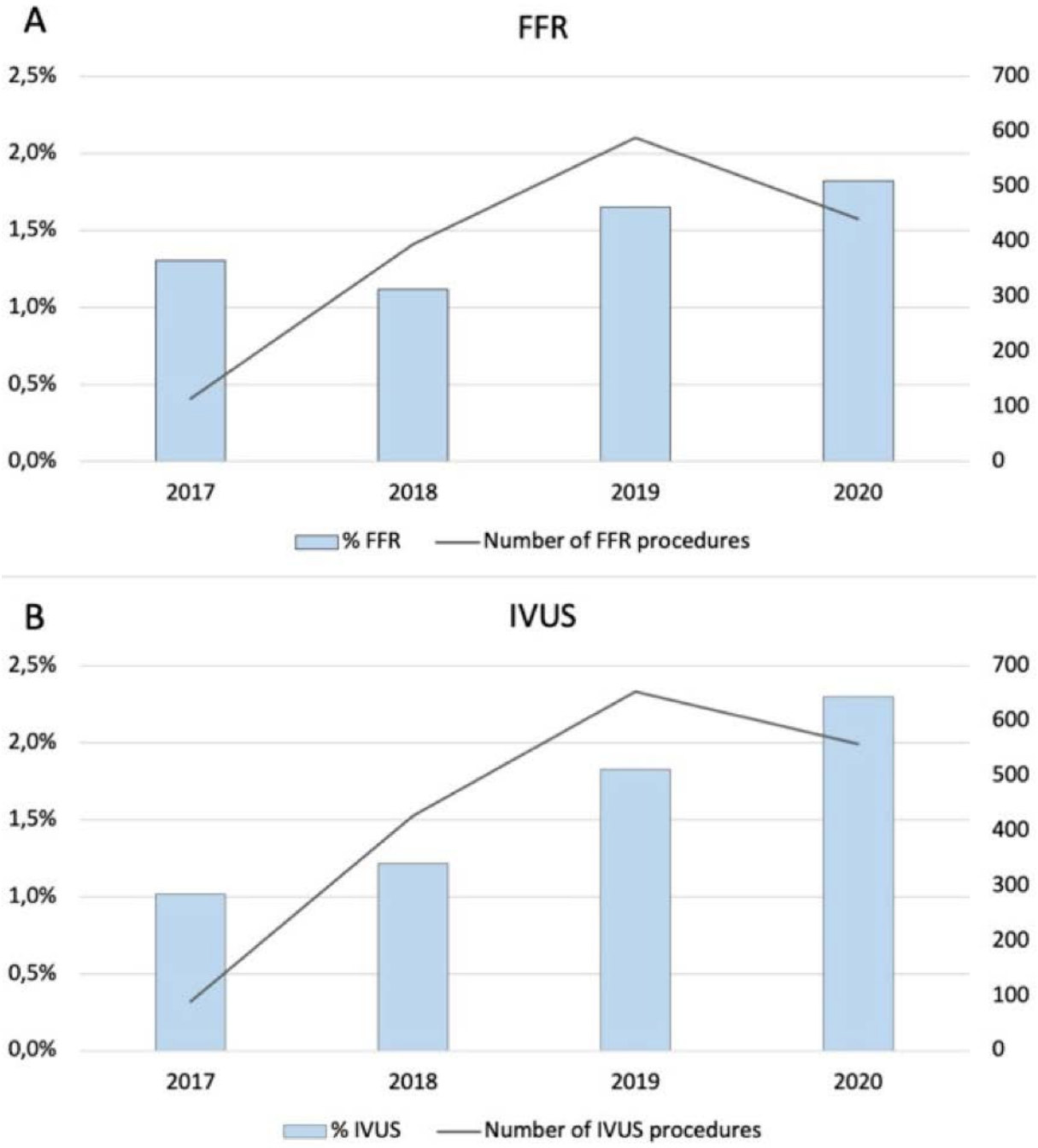
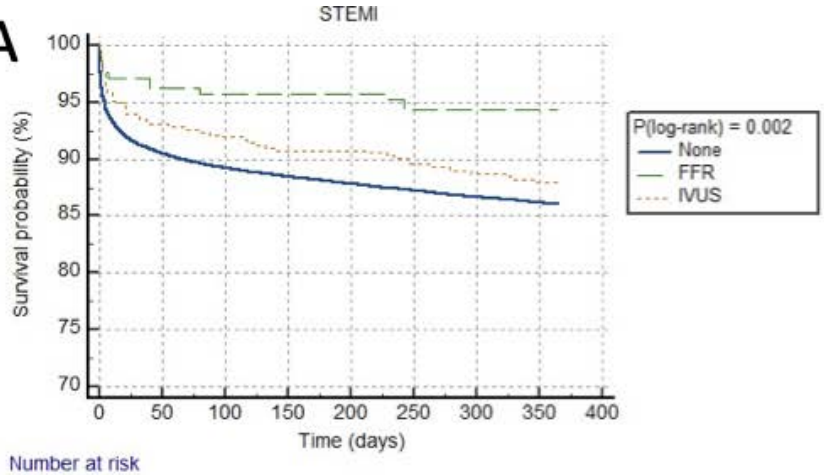


Figure 2. Number and frequency of FFR (A) and IVUS (B) procedures performed in ACS patients, in consecutive years of the PL-ACS registry (*P* <0.001)

Abbreviations: see Figure 1

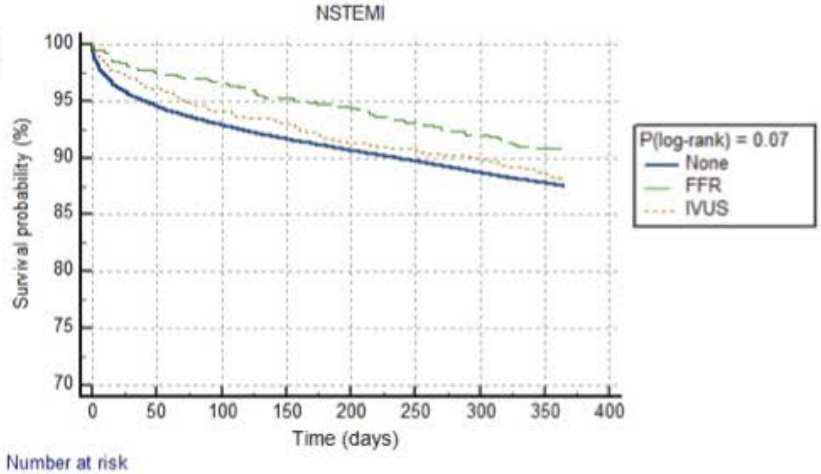
A



Number at risk

Group: None	29741	27556	27176	26940	26752	26571	26398	26244
Group: FFR	211	204	203	203	203	200	200	200
Group: IVUS	430	403	398	393	393	388	384	381

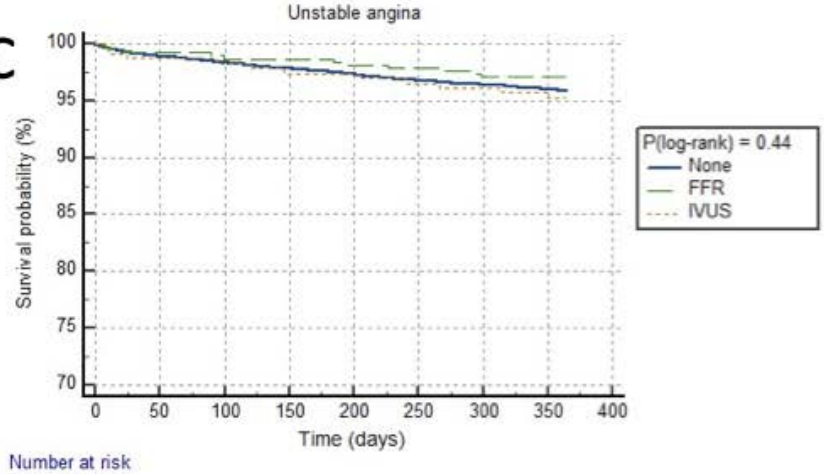
B



Number at risk

Group: None	50163	47711	46881	46262	45751	45287	44764	44313
Group: FFR	889	868	861	847	840	829	819	809
Group: IVUS	984	948	929	918	901	895	888	874

C



Number at risk

Group: None	18413	18229	18121	18027	17932	17834	17766	17687
Group: FFR	377	374	372	372	370	369	366	366
Group: IVUS	231	228	227	225	225	223	222	220

Figure 3. Probability of survival patients with STEMI (**A**), NSTEMI (**B**) and unstable angina (**C**)

Abbreviations: see Figure 1 and Table 1

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