View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by University of Birmingham Research Portal

UNIVERSITY OF BIRMINGHAM

University of Birmingham Research at Birmingham

Randomized controlled trial protocol to investigate the antiplatelet therapy effect on extracellular vesicles in acute myocardial infarction (AFFECT EV)

Gasecka, Aleksandra; Nieuwland, Rienk; Budnick, Monika; Dignat-George, Francoise; Eyileten, Ceren; Harrison, Paul; Huczek, Zenon; Kaplon-Cieslicka, Agnieszka; Lacroix, Romaric; Opolski, Grzegorz; Pluta, Kinga; van der Pol, Edwin; Postula, Marek; Leroyer, Aurelie; Siljander, Pia; Starke, Auguste; Filipiak, Krzysztof

DOI:
10.1080/09537104.2018.1557616

License:
None: All rights reserved

Document Version
Peer reviewed version

Citation for published version (Harvard):
Gasecka, A, Nieuwland, R, Budnick, M, Dignat-George, F, Eyileten, C, Harrison, P, Huczek, Z, Kaplon-Cieslicka, A, Lacroix, R, Opolski, G, Pluta, K, van der Pol, E, Postula, M, Leroyer, A, Siljander, P, Starke, A & Filipiak, K 2018, 'Randomized controlled trial protocol to investigate the antiplatelet therapy effect on extracellular vesicles in acute myocardial infarction (AFFECT EV)', *Platelets*. https://doi.org/10.1080/09537104.2018.1557616

Link to publication on Research at Birmingham portal

Publisher Rights Statement:
Checked for eligibility 04/12/2018

This is an Accepted Manuscript of an article published by Taylor & Francis in Platelets on 26/12/2018, available online: https://www.tandfonline.com/doi/full/10.1080/09537104.2018.1557616

General rights
Unless a licence is specified above, all rights (including copyright and moral rights) in this document are retained by the authors and/or the copyright holders. The express permission of the copyright holder must be obtained for any use of this material other than for purposes permitted by law.

• Users may freely distribute the URL that is used to identify this publication.
• Users may download and/or print one copy of the publication from the University of Birmingham research portal for the purpose of private study or non-commercial research.
• User may use extracts from the document in line with the concept of 'fair dealing' under the Copyright, Designs and Patents Act 1988 (?)
• Users may not further distribute the material nor use it for the purposes of commercial gain.

Where a licence is displayed above, please note the terms and conditions of the licence govern your use of this document.

When citing, please reference the published version.

Take down policy
While the University of Birmingham exercises care and attention in making items available there are rare occasions when an item has been uploaded in error or has been deemed to be commercially or otherwise sensitive.

If you believe that this is the case for this document, please contact UBIRA@lists.bham.ac.uk providing details and we will remove access to the work immediately and investigate.

Download date: 01. Mar. 2020

1 **Randomized controlled trial protocol to investigate the antiplatelet therapy effect on**
2 **extracellular vesicles in acute myocardial infarction (AFFECT EV)**

3 Aleksandra Gasecka[1,2], Rienk Nieuwland[2], Monika Budnik[1], Françoise Dignat-George[4],
4 Ceren Eyileten[5], Paul Harrison[6], Zenon Huczek[1], Agnieszka Kapłon-Cieślicka[1], Romaric
5 Lacroix[4], Grzegorz Opolski[1], Kinga Pluta[1], Edwin van der Pol[2,3], Marek Postuła[5], Aurélie
6 Leroyer[4], Pia Siljander[7,8], Auguste Sturk[2], Krzysztof J. Filipiak[1]

7 [1]1st Chair and Department of Cardiology, Medical University of Warsaw, Poland
8 [2]Vesicle Observation Centre, and Laboratory of Experimental Clinical Chemistry,
9 [3]Biomedical Engineering & Physics, Amsterdam UMC, University of Amsterdam
10 [4]Aix Marseille University, INSERM, VRCM, Marseille, France
11 [5]Department of Experimental and Clinical Pharmacology, Centre for Preclinical Research and
12 Technology, Warsaw, Poland
13 [6]Institute of Inflammation and Ageing, University of Birmingham, Birmingham, United
14 Kingdom
15 [7]Division of Biochemistry and Biotechnology, Department of Biosciences, [8]Division of
16 Pharmaceutical Biosciences, Faculty of Pharmacy, University of Helsinki, Helsinki, Finland
17
18 Corresponding author:
19 Aleksandra Gąsecka, MD
20 1st Chair and Department of Cardiology
21 Medical University of Warsaw
22 Central Teaching Hospital
23 Banacha 1a, 02-097 Warsaw, Poland
24 Phone: +48 518 343 599
25 E-mail: aleksandra.gasecka@wum.edu.pl

1 **Abstract**

2 Activated platelets contribute to thrombosis and inflammation by the release of extracellular
3 vesicles (EVs) exposing P-selectin, phosphatidylserine (PS) and fibrinogen. P2Y12 receptor
4 antagonists are routinely administered to inhibit platelet activation in patients after acute
5 myocardial infarction (AMI), being a combined anti-thrombotic and anti-inflammatory
6 therapy. The more potent P2Y12 antagonist ticagrelor improves cardiovascular outcome in
7 patients after AMI compared to the less potent clopidogrel, suggesting that greater inhibition
8 of platelet aggregation (IPA) is associated with better prognosis. The effect of ticagrelor and
9 clopidogrel on the release of EVs from platelets and other P2Y12-exposing cells is unknown.
10 This study compares the effects of ticagrelor and clopidogrel on (i) the concentrations of EVs
11 from activated platelets (primary end-point), (ii) the concentrations of EVs exposing
12 fibrinogen, exposing PS, from leukocytes and from endothelial cells (secondary end-points)
13 and (iii) the procoagulant activity of plasma EVs (tertiary end-points) in 60 consecutive AMI
14 patients. After the percutaneous coronary intervention, patients will be randomized to
15 antiplatelet therapy with ticagrelor (study group) or clopidogrel (control group). Blood will be
16 collected from patients at randomisation, 48 hours after randomisation, and 6 months
17 following the index hospitalization. In addition, 30 age- and gender-matched healthy
18 volunteers will be enrolled in the study to investigate the physiological concentrations and
19 procoagulant activity of EVs using recently standardized protocols and EV-dedicated flow
20 cytometry. Concentrations of EVs will be determined by flow cytometry. Procoagulant
21 activity of EVs will be determined by fibrin generation test. The compliance and response to
22 antiplatelet therapy will be assessed by impedance aggregometry. We expect that plasma from
23 patients treated with ticagrelor (i) contains lower concentrations of EVs from activated
24 platelets, exposing fibrinogen, exposing PS, from leukocytes and from endothelial cells, and
25 (ii) has lower procoagulant activity, when compared to patients treated with clopidogrel.

AFFECT EV may identify a new mechanism of action of ticagrelor, as well as create a basis for future studies to investigate whether lower EV concentrations are associated with improved clinical outcomes in patients treated with P2Y12 antagonists.

Keywords: extracellular vesicles, platelets, ADP receptors, P2Y12 antagonists, ticagrelor

Introduction

Activation and aggregation of platelets on a ruptured or erosed atherosclerotic plaque leads to acute myocardial infarction (AMI) [1]. During AMI, activated platelets release proinflammatory mediators and bind to leukocytes, leading to leukocyte activation [1]. In addition, activated platelets release fragments of their outer cell membrane, called platelet-derived extracellular vesicles (EVs) [2]. A transmission electron microscope image of EVs from human plasma is shown in Figure 1.

Platelet EVs are nanoparticles surrounded by a phospholipid membrane which contains platelet-derived proteins [3]. The presence of glycoprotein IIb/IIIa (CD41/CD61) enables to establish the cellular origin of EVs released from platelets or megakaryocytes among other EVs present in blood [4]. If EVs expose the glycoprotein IIb/IIIa along with P-selectin (CD62P) and/or phosphatidylserine (PS), or if EVs expose fibrinogen, such EVs are released from activated platelets and/ or platelet-rich thrombi [5,6].

Platelet EVs exposing P-selectin, PS and/ or fibrinogen are likely involved in inflammation and thrombosis [7-10], and potentially contribute to the development and progression of atherosclerosis [10-12]. P-selectin mediates binding of platelets and platelet EVs to monocytes via P-selectin glycoprotein ligand-1 on the monocyte, which leads to monocyte activation, cytokine release and exposure of tissue factor (TF) [7]. PS along with other negatively charged phospholipids binds clotting factors in the presence of calcium ions, thereby propagating thrombin generation [8]. Fibrinogen binds both to the CD11b/CD18

1 receptor (Mac-1) on monocytes, thereby activating monocytes, and to activated glycoprotein
2 IIb/IIIa, thereby enabling platelet crosslinking and aggregation [9].

3 Results of the Canakinumab Anti-inflammatory Thrombosis Outcomes (CANTOS)
4 study showed that inhibition of the interleukin-1β pathway decreases the rate of recurrent
5 cardiovascular events in patients after AMI, compared to placebo [13]. CANTOS proved that
6 atherosclerosis is an ongoing inflammatory disease, indicating the need for treatment
7 strategies that reduce inflammation and improve cardiovascular outcome. At present, patients
8 after AMI receive a multitude of drugs, of which the anti-inflammatory effects are not or
9 incompletely known. Drugs routinely administered after AMI include antagonists of the
10 P2Y12 receptor for adenosine diphosphate (ADP), such as ticagrelor and clopidogrel, which
11 prevent recurrent cardiovascular events in patients after AMI [14]. Ticagrelor inhibits platelet
12 activation more than clopidogrel, being a more potent antiplatelet drug [15]. Since activated
13 platelets contribute both to inflammation and thrombosis, P2Y12 receptor antagonists offer an
14 opportunity for a combined anti-inflammatory and anti-thrombotic strategy after AMI.

15 The P2Y12 receptor is exposed on platelets [16], leukocytes [17,18] and vascular
16 endothelial cells [19,20]. Binding of ticagrelor or clopidogrel to platelet P2Y12 receptors
17 increases the intracellular concentration of cyclic adenosine monophosphate, thereby making
18 platelets less sensitive to activation by other agonists [16]. If platelets are less sensitive to
19 activation, they are expected to expose and release less proinflammatory mediators, such as P-
20 selectin and CD40 ligand (CD40L), and to release less EVs. Because the more potent
21 antiplatelet drug ticagrelor improves the cardiovascular outcome of patients after AMI
22 compared to the less potent clopidogrel, greater inhibition of platelet aggregation (IPA) seems
23 associated with better prognosis [21]. However, both ticagrelor and clopidogrel decrease the
24 exposure of P-selectin, and concentrations of soluble P-selectin and CD40L to a similar
25 extent, both in patients with AMI and in healthy individuals administered endotoxin [22-25].

Reliable analysis of platelet P-selectin can only be performed in freshly collected whole blood, i.e. within 15 minutes following blood collection [26]. Soluble P-selectin and CD40L, in turn, can be released also from cells other than platelets [26,27]. Therefore, measurement of P-selectin exposure on platelets and soluble platelet-derived molecules do not reflect the extent of platelet activation *in vivo*.

Because platelet EVs are platelet-specific and can be analysed in biorepositories, platelet EVs are advantageous over other available biomarkers of platelet activation [28,29]. Both ticagrelor and clopidogrel inhibit the release of platelet EVs [30,31], but the effects of ticagrelor and clopidogrel on EVs have never been compared in a randomized clinical study. We hypothesize that plasma from patients treated with ticagrelor (i) contains lower concentrations of EVs from activated platelets, exposing fibrinogen, exposing PS, from leukocytes and endothelial cells, and (ii) has lower procoagulant activity, when compared to patients treated with clopidogrel. We aim to compare the effects of ticagrelor and clopidogrel on plasma concentrations of different EV subtypes and plasma EV procoagulant activity in patients with AMI.

Methods

Study design

This is a prospective, single-centre, randomised, investigator-blinded, parallel group design study conducted at the 1st Chair and Department of Cardiology, Medical University of Warsaw, Poland in collaboration with the Vesicle Observation Centre, and Laboratory of Experimental Clinical Chemistry, Amsterdam University Medical Centres, The Netherlands. The duration of this study is expected to be 12 months.

Selection of participants

The study inclusion and exclusion criteria are listed in Table 1. Patients will be enrolled by the principal investigator among those who were admitted to 1st Chair and Department of Cardiology, Medical University of Warsaw due to the first ST-segment elevation acute myocardial infarction (STEMI) or non-STEMI (NSTEMI), and then underwent percutaneous coronary intervention (PCI) with stent implantation. Since the majority of patients with STEMI is pre-treated with clopidogrel prior to hospital admission, initially all patients will be administered a loading dose of clopidogrel (600 mg) to obtain a homogenous patient group. Since the reported concentrations of EVs in plasma of healthy volunteers differ between studies [28], 30 age- and gender-matched healthy volunteers will be enrolled in the study to investigate the physiological concentrations and procoagulant activity of EVs using recently standardized protocols and EV-dedicated flow cytometry [29,32,33], confirming the results of previous studies [34-36]. The principal investigator will describe all study procedures and all patients and healthy volunteers will provide written informed consent.

Randomisation and blinding

Following written informed consent, patients who meet all inclusion criteria and do not meet any of the exclusion criteria will be included and randomised. Block randomisation with fixed block size of size 8 without stratification will be carried out using sealed envelope system in a 1:1 ratio either to replace clopidogrel with ticagrelor (study group) or to continue the treatment with clopidogrel (control group). Study drugs will be administered based on the randomisation list. Both randomisation and administration of the drugs will be conducted by an independent operator (K.P.), not involved in sample collection and analysis. During the clinical trial participants will be identified solely by an individual randomisation number. All collected samples will be coded with a unique number and analysed in one block by an operator blinded to patient- and treatment-related data (A.G).

Treatment arms

All drugs will be administered orally. Patients randomised to switch to ticagrelor will receive a loading dose of ticagrelor (180 mg), followed by a maintenance dose (90 mg twice daily) [14]. Patients randomised to clopidogrel will continue the treatment with a maintenance dose of clopidogrel (75 mg once daily) [14]. At hospital discharge, patients (i) will receive either ticagrelor or clopidogrel for 6 months of treatment and (ii) will be advised to contact the principal investigator in case of recurrent thrombotic event or bleeding. Patients who experience a recurrent thrombotic or bleeding event will be admitted to 1st Chair and Department of Cardiology for thorough examination, assessment and monitoring. In case of suspected or confirmed non-responsiveness to the initial P2Y12 antagonist, patients will switch to another P2Y12 antagonist. At 6 months, all patients will be invited for the follow-up visit. At the follow-up visit, compliance will be checked by counting of tablets, and ticagrelor will be recommended for the remaining 6 months of double antiplatelet therapy (altogether 12 months of treatment, as recommended by the guidelines of European Society of Cardiology) [14]. Patients who choose to switch to clopidogrel at the follow-up visit due to financial constraints or other reasons will be prescribed clopidogrel.

Trial schedule

The trial schedule is presented in Figure 2. Venous blood will be collected from fasting patients (i) 24 hours after administration of clopidogrel (randomisation), (ii) 48 hours following randomisation to ticagrelor or clopidogrel group (matching the length of the hospital stay of patients with AMI), and (iii) 6 months following the index hospitalization (follow-up visit). Venous blood will also once be collected from 30 gender- and age-matched fasting healthy volunteers.

Blood will be collected and processed according to the recently standardized protocol for collection, handling and storage of human plasma for analysis of EVs [29]. Briefly, blood

1 will be collected using a 19-gauge needle to 10 ml plastic tube containing citrate (final
2 concentration 0.109 mol/L). The tourniquet will be removed promptly after the venepuncture.
3 The first 2.5 mL of collected blood will be discarded to avoid pre-activation of platelets. To
4 remove cells, blood will be centrifuged twice using a Rotina 380 R centrifuge equipped with
5 a swing-out rotor and a radius of 155 mm (Hettich Zentrifugen, Tuttlingen, Germany). The
6 centrifugation parameters will be 2,500 g for 15 minutes at 20˚C, acceleration speed 1, no
7 brake. After the first centrifugation, plasma will be transferred to a new 5 ml plastic tube,
8 leaving ~1 cm plasma above the buffy layer. After the second centrifugation, cell- and
9 platelet-free plasma (PFP) will be collected and transferred carefully to a new 5 ml plastic
10 tube, leaving ~100 μL at the bottom of the old tube. PFP will be mixed with a pipet and 250
11 μl aliquots will be made in 1.5-ml tubes. PFP will be stored in -80˚C freezer until analysed.
12 Prior to the analysis, frozen samples will be transported on dry ice to the Vesicle Observation
13 Centre, Amsterdam University Medical Centres, The Netherlands. Since EV concentrations
14 are affected by numerous pre-analytical variables, such as diameter of a needle, type of tube
15 (plastic/ glass), type of system (free flow/ vacuum), use of tourniquet (released promptly/ kept
16 during the collection), blood will be collected and processed only by operators who
17 underwent an appropriate training with subsequent quality check of the samples in LEKC,
18 Amsterdam UMC (C.E., M.B.).
19 Analyses will compare (i) the concentrations of EVs from activated platelets, exposing
20 fibrinogen, exposing PS, from leukocytes and endothelial cells, and (ii) the procoagulant
21 activity of plasma EVs between patients treated with ticagrelor and clopidogrel at 48 hours
22 and at 6 months. In addition, IPA will be assessed in all patients at randomisation, 48 hours
23 and 6 months to check the compliance and the response to ASA and P2Y12 antagonists. Data
24 regarding demographic characteristics, co-morbidities and concomitant pharmacotherapy will

be collected, and thorough clinical examination will be conducted during the index hospitalization and at the follow-up visit.

Concomitant medications

If not administered prior to hospital admission, patients will receive a loading dose of aspirin (300 mg) prior to PCI. Unfractionated heparin will be administered during PCI in the dosage left at the discretion of the interventional cardiologist. At hospital discharge, all patients will receive treatment with ASA 75 mg once daily (as part of the prescribed double antiplatelet therapy) and atorvastatin at least 10 mg once daily.

Analytical methods

Concentration and composition of EVs

Concentrations of different EV subtypes, defined as a number of EVs (exceeding the detection limit) per ml plasma, will be determined by EV-dedicated flow cytometry (A60 Micro, Apogee Flow Systems, UK) according to the recent guidelines [32,33]. EVs released from different cells will be defined as following events: activated platelets: $CD61^{+}$/ P-selectin^{+}; fibrinogen-exposing EVs: $CD61^{+}$/fibrinogen^{+}; PS-exposing EVs: PS^{+}; leukocytes: $CD45^{+}$; endothelial cells: $CD31^{+}$ /$CD146^{+}$. Scatter detectors will be calibrated with Rosetta Calibration (Exometry, The Netherlands), fluorescence detectors will be calibrated with SPHERO PE Calibration kit (ECFP-F2-5K, Spherotech), Quantum FITC-5 MESF beads (555A, Bangs Laboratories) and Quantum APC MESF beads (823A, Bangs), and the flow rate will be calibrated with TruCount beads (BD Biosciences, Franklin Lakes, NJ, USA). To enable data comparison, detection limits of scatter and fluorescence detectors will be quantified in units of nm^2 and mean equivalent soluble fluorophore (MESF), respectively. Flow-SR will be applied to determine the size and refractive index of particles and improve specificity by enabling label-free differentiation between EVs and lipoprotein particles [37].

Procoagulant activity of EVs

1 The procoagulant activity of EVs will be determined as the ability of EVs in platelet-
2 free plasma to generate fibrin, as described previously [30]. Briefly, after pre-incubation for 5
3 min at 37°C, clotting will be initiated by addition of CaCl2. Fibrin formation over 1 hour will
4 be determined by measuring the optical density (λ = 405 nm) in duplicate on a
5 spectrophotometer at 37°C. Because TF is the key initiator of the coagulation [38], and
6 because plasma EVs in patients with AMI expose TF [39], the procoagulant activity of plasma
7 EVs will be evaluated in the absence and presence of antibody against human TF (coagulation
8 factor VII). Recombinant human TF will be used as a positive control, and saline will be used
9 as a negative control.

10 Inhibition of platelet aggregation

11 IPA in response to double antiplatelet therapy (acetylsalicylic acid and P2Y12
12 antagonist) will be assessed by impedance aggregometry (Multiplate Analyzer, Roche
13 Diagnostics) using the ASPI test (arachidonic acid, 0.5 mM) and the ADP high sensitivity test
14 (ADP, 6.5 µM with addition of prostaglandin E1, 9.4 nM), respectively [41].

15 *Endpoints*

16 Study end-points refer to two patient groups (ticagrelor vs clopidogrel). The primary
17 endpoint is the concentrations of EVs from activated platelets at 6 months. The secondary
18 endpoints are (i) the concentration of EVs from activated platelets at 48 hours, and (ii) the
19 concentrations of EVs exposing fibrinogen, exposing PS, from leukocytes and endothelial
20 cells at 48 hours and 6 months. The tertiary outcome is the procoagulant activity of the total
21 plasma EVs at 48 hours and 6 months. The study is not powered for mortality and other
22 adverse events.

23 *Sample size*

24 Because insufficient data are available to assess the impact of ticagrelor and
25 clopidogrel on the concentrations of platelet EVs and EVs from other types of cells in patients

with AMI, the standard deviation (SD) and mean difference between the two treatment arms was estimated based on the preliminary *in vitro* experiments, which we conducted during preparation for this study [30]. In our experiments, ticagrelor decreased ADP-induced platelet EVs release 3-fold, with the SD ± 1.0 value of the mean [30]. It was not feasible to investigate the effect of clopidogrel on EV release *in vitro* due to the instability of the clopidogrel active metabolite. However, data from the literature show that clopidogrel decreases the release of platelet EVs *ex vivo* by 2-fold, with SD ± 1.0 [31]. The required sample size was calculated by a two-sided t test at a significance level of 0.05 with the following assumptions: (i) SD in each group ± 1.0, (ii) mean difference between the groups = 1, (iii) nominal test power = 0.9. Based on this sample size estimation, a total of 46 patients (23 per group) should be enrolled in the trial. Since 5 to 30% of patients in clopidogrel group may have inadequate platelet inhibition [41], requiring to switch to a more potent P2Y12 receptor antagonists in case of recurrent thrombotic event, and since the overall rate of switching between P2Y12 antagonists reported in registries ranges from 5% to 50% [42,32], we assumed that up to 30% of patients may be potentially lost to follow-up. Based on this assumption, we estimated that 60 patients (30 per group) should be enrolled in the trial.

Statistical plan

A single statistical analysis will be performed at the end of the study using IBM SPSS Statistics 20. Since the differences between healthy volunteers and controls will be reported descriptively, no statistical matching of healthy volunteers and patients will be performed. Intention to treat (ITT) and per protocol populations will be defined. The ITT population will consist of all patients who were randomized and received at least one dose of the study drug, regardless of protocol violations. The per protocol population will consist of all patients who were randomized and treated completely in accordance with the study protocol. Categorical variables will be presented as number and percent; continuous variables will be presented as

1 mean and SD or median with inter-quartile range. Data will be displayed graphically for
2 visual examination. Shapiro-Wilk test will be used to test for non-Gaussian distribution of
3 continuous variables. No formal statistical testing will be performed on the differences
4 between the two treatment arms among patients with AMI at randomisation. Linear regression
5 with EV concentration at randomisation as an addition co-variate will be used to compare the
6 concentrations between the two treatment arms at 48 hours and 6 months. Student's two-sided
7 t-test or Mann–Whitney U test will be used to compare the EV procoagulant activity between
8 the two treatment arms at 48 hours and 6 months. No corrections for multiple testing will be
9 performed. Pearson or Spearman correlation coefficient will be used to analyse a correlation
10 between IPA and EV concentrations in both study groups, separately in patients responding
11 and not-responding to clopidogrel, according to the impedance aggregometry results. The
12 non-responsiveness to clopidogrel will be defined as platelet aggregation > 46 aggregation
13 units in response to 6.5 μM ADP [44]. A p-value below 0.05 will be considered significant.
14 Mortality and other adverse events as well as comparison of EV concentrations and EV
15 procoagulant activity between healthy volunteers and all AMI patients will be reported
16 descriptively.
17 *Legal considerations*
18 The study protocol was approved by the Bioethical Committee Approval of Medical
19 University of Warsaw (approval number: KB/112/2016), and registered in the ClinicalTrials
20 database (NCT02931045). Recording of adverse events will be conducted according to good
21 clinical practice, the ethical principles described in the Declaration of Helsinki, the
22 requirements of the European Medicines Agency, and local legal and regulatory requirements.
23 Data storage will be performed in accordance with local data protection laws. Competent
24 authorities and sponsor authorised persons may request access to trial documentation in case
25 of an inspection or audit. Direct access to these documents must be guaranteed by the

principal investigator. Documentation can be copied during inspection or audit in case the identity of the participant have been made unrecognisable.

Expected results

We expect lower concentrations of EVs from activated platelets, exposing fibrinogen, exposing PS, from leukocytes and endothelial cells, as well as lower procoagulant activity of plasma EVs in patients treated with ticagrelor, compared to clopidogrel. Consequently, we expect to identify a new mechanism of action of ticagrelor. If present, this mechanism would create a basis for future studies to investigate whether lower EV concentrations are associated with improved clinical outcomes in patients treated with P2Y12 antagonists.

We expect higher concentrations of all EV subtypes in patients with AMI at randomisation, compared to healthy volunteers, thereby confirming using the results of preceding studies [31-33] using recently standardized protocols and EV-dedicated flow cytometry [28-30].

Discussion

AFFECT EV is the first study which directly compares the effects of ticagrelor and clopidogrel on the concentrations and procoagulant activity of EVs in patients with AMI in a randomised and investigator-blinded way. The state-of-the art methods to collect and handle samples and to analyse PEVs will account for the reliability of results. The translational collaboration between the 1st Chair and Department of Cardiology, Medical University of Warsaw, Poland, and the Vesicle Observation Centre, Amsterdam University Medical Centres, The Netherlands will further ensure scientifically sound interpretation of data and optimize dissemination of results.

AFFECT EV is expected to establish whether EVs can be *affected* by drugs routinely used in patients after AMI, thereby identifying one of the potential novel mechanisms of action contributing to a combined anti-thrombotic/ anti-inflammatory benefit of the P2Y12 receptor antagonists. Regarding the exponentially growing interest in EVs during the last decade [30], determining the effect of the P2Y12 receptor antagonists on EVs may be the first step to explain the clinical benefits of long-term treatment with P2Y12 antagonists, and may provide a basis for future studies aimed to associate this effect with clinical outcomes.

Acknowledgements

A. Gasecka and K.J. Filipiak acknowledge AstraZeneca/ MedImmune for Externally Sponsored Scientific Research Grant in a form of ticagrelor for the study. E. van der Pol acknowledges funding from the Netherlands Organisation for Scientific Research - Domain Applied and Engineering Sciences (NWO-TTW), research program VENI 15924.

Declaration of Interest

E. van der Pol is a cofounder and shareholder of Exometry BV. All other authors report no declarations of interest.

Funding

The study is funded by Medical University of Warsaw (1WR\PM2\18). The sponsor is not involved in any procedure related with the protocol nor in the dissemination of the data. E. van der Pol is funded by the Netherlands Organisation for Scientific Research - Domain Applied and Engineering Sciences (NWO-TTW), research program VENI 15924.

1 **References**

2 1. Linden MD, Jackson DE. Platelets: pleiotropic roles in atherogenesis and
3 atherothrombosis. Int J Biochem Cell Biol. 2010;42:1762-1766.
4 2. van der Pol E, Böing AN, Harrison P, Sturk A, Nieuwland R. Classification, functions,
5 and clinical relevance of extracellular vesicles. Pharmacol Rev. 2012; 64: 676-705.
6 3. Aatonen MT, Ohman T, Nyman TA, Laitinen S, Grönholm M, Siljander PR. Isolation
7 and characterization of platelet-derived extracellular vesicles. J Extracell Vesicles.
8 2014; 3.
9 4. Rank A, Nieuwland R, Delker R, Köhler A, Toth B, Pihusch V, Wilkowski R, Pihusch
10 R. Cellular origin of platelet-derived microparticles in vivo. Thromb Res. 2010; 126:
11 e255–e259.
12 5. Brisson AR, Tan S, Linares R, Gounou C, Arraud N. Extracellular vesicles from
13 activated platelets: a semiquantitative cryo-electron microscopy and immuno-gold
14 labeling study. Platelets. 2017; 28: 263-271.
15 6. Merten M, Pakala R, Thiagarajan P, Benedict CR. Platelet microparticles promote
16 platelet interaction with subendothelial matrix in a glycoprotein IIb/IIIa-dependent
17 mechanism. Circulation. 1999; 99: 2577-2582.
18 7. Falati S, Liu Q, Gross P, Merrill-Skoloff G, Chou J, Vandendries E, Celi A, Croce K,
19 Furie BC, Furie B. Accumulation of tissue factor into developing thrombi in vivo is
20 dependent upon microparticle P-selectin glycoprotein ligand 1 and platelet P-selectin.
21 J Exp Med. 2003; 197: 158-1598.
22 8. Bevers EM, Williamson PL. Getting to the outer leaflet: physiology of
23 phosphatidylserine exposure at the plasma membrane. Physiol Rev. 2016; 96: 605-
24 645.

9. Davalos D, Akassoglou K. Fibrinogen as a key regulator of inflammation in disease. Semin Immunopathol. 2012; 34: 43-62.
10. Ridger VC, Boulanger CM1, Angelillo-Scherrer A, Badimon L, Blanc-Brude O, Bochaton-Piallat ML, Boilard E, Buzas EI, Caporali A, Dignat-George F, Evans PC, Lacroix R, Lutgens E, Ketelhuth DFJ, Nieuwland R, Toti F, Tunon J, Weber C, Hoefer IE. Microvesicles in vascular homeostasis and diseases. Position Paper of the European Society of Cardiology (ESC) Working Group on Atherosclerosis and Vascular Biology. Thromb Haemost. 2017; 117: 1296-1316.
11. Boulanger CM, Loyer X, Rautou PE, Amabile N. Extracellular vesicles in coronary artery disease. Nat Rev Cardiol. 2017; 14: 259-272.
12. Badimon L, Suades R, Fuentes E, Palomo I, Padró T. Role of platelet-derived microvesicles as crosstalk mediators in atherothrombosis and future pharmacology targets: a link between inflammation, atherosclerosis, and thrombosis. Front. Pharmacol. 2016; 7: 293.
13. Ridker PM, et al. Antiinflammatory Therapy with Canakinumab for Atherosclerotic Disease. N Engl J Med. 2017; 377: 1119-1131.
14. Ibanez B, James S, Agewall S, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). Eur Heart J. 2018; 39: 119-177.
15. Kubisa MJ, Jezewski MP, Gasecka A, Siller-Matula JM, Postuła M. Ticagrelor - toward more efficient platelet inhibition and beyond. Ther Clin Risk Manag. 2018; 14: 129-140.
16. Kim S, Kunapuli SP. P2Y12 receptor in platelet activation. Platelets. 2011; 22: 56-60.

1 17. Diehl P, Olivier C, Halscheid C, Helbing T, Bode C, Moser M. Clopidogrel affects
2 leukocyte dependent platelet aggregation by P2Y12 expressing leukocytes. Basic Res
3 Cardiol. 2010; 105: 379–387.
4 18. Wang L, Jacobsen SE, Bengtsson A, Erlinge D. P2 receptor mRNA expression
5 profiles in human lymphocytes, monocytes and CD34+ stem and progenitor cells.
6 2004; BMC Immunol 5: 16.
7 19. Simon J, Filippov AK, Göransson S, Wong YH, Frelin C, Michel AD, et al.
8 Characterization and channel coupling of the P2Y(12) nucleotide receptor of brain
9 capillary endothelial cells. J Biol Chem. 2002; 277: 31390–31400.
10 20. Shanker G, Kontos JL, Eckman DM, Wesley-Farrington D, Sane DC. Nicotine
11 upregulates the expression of P2Y12 on vascular cells and megakaryoblasts. J Thromb
12 Thrombolysis. 2006'; 22: 213–220.
13 21. Wallentin L, Becker RC, Budaj A, Cannon CP, Emanuelsson H, Held C, Horrow J,
14 Husted S, James S, Katus H, Mahaffey KW, Scirica BM, Skene A, Steg PG, Storey
15 RF, Harrington RA; PLATO Investigators, Freij A, Thorsén M. Ticagrelor versus
16 clopidogrel in patients with acute coronary syndromes. N Engl J Med. 2009; 361:
17 1045-1057.
18 22. Lowenstern A, Storey RF, Neely M, Sun JL, Angiolillo DJ, Cannon CP, Himmelmann
19 A, Huber K, James SK, Katus HA, Morais J, Siegbahn A, Steg PG, Wallentin L,
20 Becker RC; PLATO Investigators. Platelet-related biomarkers and their response to
21 inhibition with aspirin and P2Y12-receptor antagonists in patients with acute coronary
22 syndrome. J Thromb Thrombolysis. 2017; 44: 145-153.
23 23. Husted S, Storey RF, Harrington RA, Emanuelsson H, Cannon CP. Changes in
24 inflammatory biomarkers in patients treated with ticagrelor or clopidogrel. Clin
25 Cardiol. 2010; 33: 206-212.

24. Kiers D, van der Heijden WA, van Ede L, Gerretsen J, de Mast Q, van der Ven AJ, El Messaoudi S, Rongen GA, Gomes M, Kox M, Pickkers P, Riksen NP. A randomised trial on the effect of anti-platelet therapy on the systemic inflammatory response in human endotoxaemia. Thromb Haemost. 2017; 117: 1798-1807.
25. Thomas MR, et al. Platelet P2Y12 inhibitors reduce systemic inflammation and its prothrombotic effects in an experimental human model. Arterioscler Thromb Vasc Biol. 2015; 35: 2562–257.
26. Ferroni P, Pulcinelli FM, Lenti L, Gazzaniga PP. Is soluble P-selectin determination a more reliable marker of in vivo platelet activation than CD62P flow cytometric analysis? Thromb Haemost1999;81:472–473
27. Halldórsdóttir AM, Stoker J, Porche-Sorbet R, Eby CS. Soluble CD40 ligand measurement inaccuracies attributable to specimentype, processing time, and ELISA method. Clin Chem2005;51:1054–1057.
28. Gasecka A, et al. Platelet extracellular vesicles as biomarkers for arterial thrombosis. Platelets. 2017; 28: 228-234.
29. Yuana Y, Böing AN, Grootemaat AE, van der Pol E, Hau CM, Cizmar P, Buhr E, Sturk A, Nieuwland R. Handling and storage of human body fluids for analysis of extracellular vesicles. J Extracell Vesicles. 2015; 4: 29260.
30. Gasecka A, Nieuwland R, van der Pol E, Hajji N, Ćwiek A, Pluta K, Konwerski M, Filipiak KJ. P2Y12 antagonist ticagrelor inhibits the release of procoagulant extracellular vesicles from activated platelets: Preliminary results. Cardiol J. 2018; [ahead of print].
31. Behan MW, Fox SC, Heptinstall S, Storey RF. Inhibitory effects of P2Y12 receptor antagonists on TRAP-induced platelet aggregation, procoagulant activity,

microparticle formation and intracellular calcium responses in patients with acute coronary syndromes. Platelets. 2005; 16: 73-80.

32. Coumans FAW, Brisson AR, Buzas EI, Dignat-George F, Drees EEE, El-Andaloussi S, Emanueli C, Gasecka A, Hendrix A, Hill AF, Lacroix R, Lee Y, van Leeuwen TG, Mackman N, Mäger I, Nolan JP, van der Pol E, Pegtel DM, Sahoo S, Siljander PRM, Sturk G, de Wever O, Nieuwland R. Methodological Guidelines to Study Extracellular Vesicles. Circ Res. 2017; 120: 1632-1648.
33. van der Pol E, Böing AN, Gool EL, Nieuwland R. Recent developments in the nomenclature, presence, isolation, detection and clinical impact of extracellular vesicles. J Thromb Haemost. 2016; 14: 48-56.
34. van der Zee PM, Biró E, Ko Y, de Winter RJ, Hack CE, Sturk A, Nieuwland R. P-selectin- and CD63-exposing platelet microparticles reflect platelet activation in peripheral arterial disease and myocardial infarction. Clin Chem. 2006; 52(4):657-64.
35. Stępień E, Stankiewicz E, Zalewski J, Godlewski J, Zmudka K, Wybrańska I. Number of microparticles generated during acute myocardial infarction and stable angina correlates with platelet activation. Arch Med Res. 2012; 43: 31-35.
36. Giannopoulos G, Oudatzis G, Paterakis G, Synetos A, Tampaki E, Bouras G, Hahalis G, Alexopoulos D, Tousoulis D, Cleman MW, Stefanadis C, Deftereos S. Red blood cell and platelet microparticles in myocardial infarction patients treated with primary angioplasty. Int J Cardiol. 2014; 176: 145–150.
37. van der Pol E, de Rond L, Coumans FAW, Gool EL, Böing AN, Sturk A, Nieuwland R, van Leeuwen TG. Absolute sizing and label-free identification of extracellular vesicles by flow cytometry. Nanomedicine. 2018; 14 (3): 801-810.
38. Mackman N. The Role of Tissue Factor and Factor VIIa in Hemostasis. Anesth Analg. 2009; 108 (5): 1447-1452.

39. Chiva-Blanch G, Laake K, Myhre P, Bratseth V, Arnesen H, Solheim S, Badimon L, Seljeflot I. Platelet-, monocyte-derived and tissue factor-carrying circulating microparticles are related to acute myocardial infarction severity. PLoS One. 2017; 12(2) :e0172558.
40. Krüger JC, Meves SH, Kara K, Mügge A, Neubauer H. Monitoring ASA and P2Y12-specific platelet inhibition-comparison of conventional (single) and multiple electrode aggregometry. Scand J Clin Lab Invest. 2014; 74: 568-574.
41. Ray S. Clopidogrel resistance: The way forward. Indian Heart J. 2014; 66: 530–534.
42. Alexopoulos D, Xanthopoulou I, Deftereos S, Sitafidis G, Kanakakis I, Hamilos M, Angelidis C, Petousis S, Stakos D, Parissis H, Vavouranakis M, Davlouros P, Goudevenos J, Stefanadis C. In-hospital switching of oral P2Y12 inhibitor treatment in patients with acute coronary syndrome undergoing percutaneous coronary intervention: prevalence, predictors and short-term outcome. Am Heart J. 2014; 167: 68-76.e2.
43. Zettler ME, Peterson ED, McCoy LA, Effron MB, Anstrom KJ, Henry TD, Baker BA, Messenger JC, Cohen DJ, Wang TY; TRANSLATE-ACS Investigators. Switching of adenosine diphosphate receptor inhibitor after hospital discharge among myocardial infarction patients: Insights from the Treatment with Adenosine Diphosphate Receptor Inhibitors: Longitudinal Assessment of Treatment Patterns and Events after Acute Coronary Syndrome (TRANSLATE-ACS) observational study. Am Heart J. 2017; 183: 62-68.
44. Siller-Matula JM, Trenk D, Schrör K, Gawaz M, Kristensen SD, Storey RF, Huber K; European Platelet Academy. How to improve the concept of individualised antiplatelet therapy with P2Y12 receptor inhibitors - is an algorithm the answer? Thromb Haemost. 2015; 113: 37-52.

Tables and figures

Figure 1. Transmission electron microscopy image of extracellular vesicles in human plasma. Image courtesy Linda G. Rikkert, Vesicle Observation Centre, Academic Medical Centre of the University of Amsterdam.

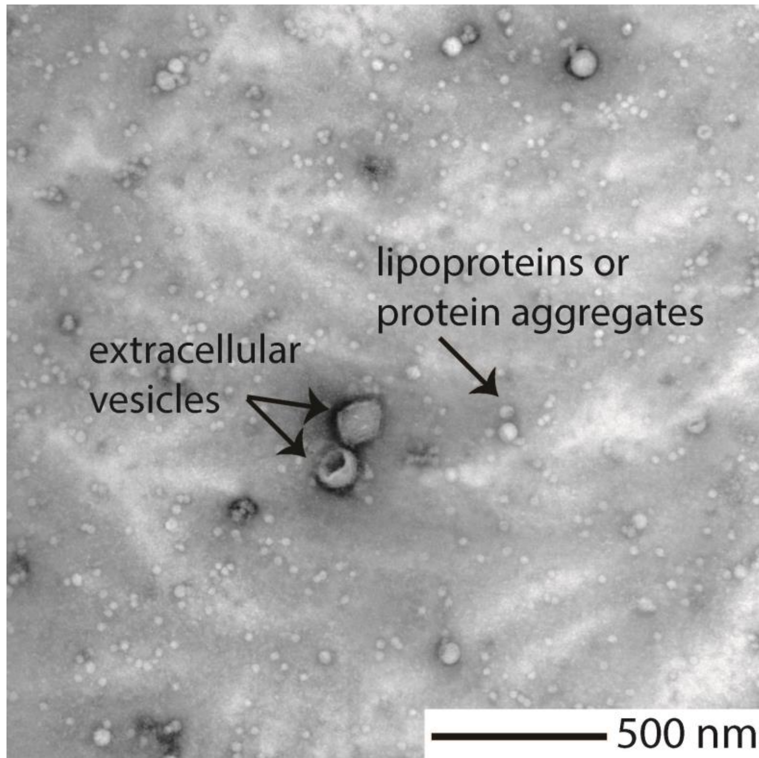
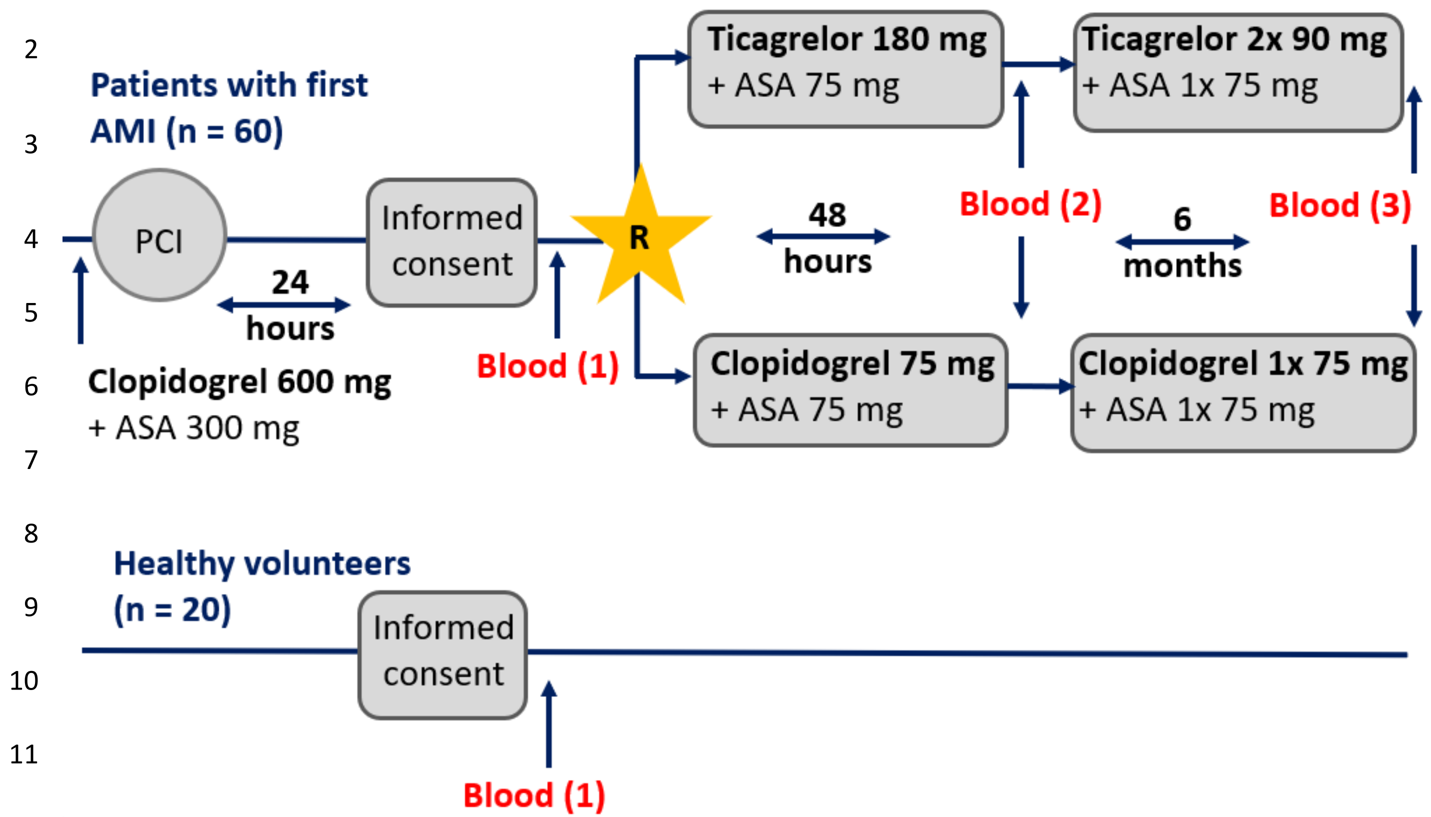


Figure 2. Trial schedule.



Abbreviations: AMI – acute myocardial infarction; ASA – acetylsalicylic acid; PCI – percutaneous coronary intervention; R – randomization.

1 Table 1. Eligibility criteria for the study

Inclusion criteria	Exclusion criteria
• Age > 18 years • Informed consent to • participate in the study • First ST-elevation myocardial infarction (STEMI) or non-STEMI (NSTEMI) • Percutaneous coronary intervention (PCI) with stent implantation • Administration of the loading dose of clopidogrel (600 mg) prior to PCI	• Known coagulopathy • Active pathological bleeding • Known history of bleeding disorder • Suspicion of intracranial haemorrhage • Need for oral anticoagulation therapy • Administration of GPIIb-IIIa antagonists • Cardiogenic schock • Severe chronic renal failure (eGFR < 30 mL/min) • Severe liver insufficiency • Infectious disease • Autoimmune disease • Neoplasm • Chronic dyspnea • Increased risk of bradycardia • Known pregnancy, breast-feeding, or intention to become pregnant during the study period • Study drug intolerance • Co-administration of ticagrelor or clopidogrel with strong CYP3A4 inhibitors • Participation in any previous study with ticagrelor or clopidogrel

2

3

4

5

6

7