A Pharmacodynamic Comparison of Prasugrel vs. High-Dose Clopidogrel in Patients with Type 2 Diabetes Mellitus and Coronary Artery Disease: Results of the Optimizing anti-Platelet Therapy In diabetes MellitUS (OPTIMUS)-3 Trial

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Accessibility
A pharmacodynamic comparison of prasugrel vs. high-dose clopidogrel in patients with type 2 diabetes mellitus and coronary artery disease: results of the Optimizing anti-Platelet Therapy In diabetes Mellitus (OPTIMUS)-3 Trial


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Aims

Patients with diabetes mellitus (DM) have increased platelet reactivity and reduced platelet response to clopidogrel compared with patients without DM. Prasugrel, a more potent antiplatelet agent, is associated with greater reductions in ischaemic events compared with clopidogrel, particularly in patients with DM. The aim of this study was to perform serial pharmacodynamic assessments of prasugrel with high-dose clopidogrel in patients with DM.

Methods and results

Optimizing anti-Platelet Therapy In diabetes Mellitus (OPTIMUS)-3 was a prospective, randomized, double-blind, crossover study in patients with type 2 DM and coronary artery disease (CAD). Patients (n = 35) were randomly assigned to either prasugrel 60 mg loading dose (LD)/10 mg maintenance dose (MD) or clopidogrel 600 mg LD/150 mg MD over two 1-week treatment periods separated by a 2-week washout period. Platelet function was assessed by VerifyNow® P2Y12 assay, light transmission aggregometry, and vasodilator-stimulated phosphoprotein phosphorylation at 0, 1, 4, and 24 h and 7 days. Greater platelet inhibition by VerifyNow® P2Y12 was achieved by prasugrel compared with clopidogrel at 4 h post-LD (least squares mean, 89.3 vs. 27.7%, P < 0.0001; primary endpoint). The difference in platelet inhibition between prasugrel and clopidogrel was significant from 1 h through 7 days (P < 0.0001). Similar results were obtained using all other platelet function measures. Prasugrel resulted in fewer poor responders at all time points irrespective of definition used.

Conclusion

In patients with type 2 DM and CAD, standard-dose prasugrel is associated with greater platelet inhibition and better response profiles during both the loading and maintenance periods when compared with double-dose clopidogrel. Clinical trial identifier: www.clinicaltrials.gov—NCT00642174

Keywords

Diabetes mellitus • Coronary disease • Platelets

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Introduction

Patients with diabetes mellitus (DM) are characterized by enhanced platelet reactivity and a reduced response to oral antipla-
tele medications used for the prevention of ischemic events.1–3 Platelets from patients with DM demonstrate upregulation of
several signalling pathways, which may explain the increased preva-
ience of low platelet inhibition following clopidogrel treatment and contribute to increased atherothrombotic risk in these patients
compared with those without DM.1,4 Therefore, greater platelet
P2Y12 receptor inhibition may provide more optimal platelet inhi-
bition in this high-risk patient population. In the Optimizing anti-
Platelet Therapy In diabetes MellitusUS (OPTIMUS)-1 Study, a high
proportion of patients had a suboptimal response to a standard
dose of clopidogrel. Although a high maintenance dose (MD) of
clopidogrel (150 mg per day) enhanced platelet inhibition in patients
with DM presenting with elevated platelet reactivity while on standard treatment regimens, a considerable proportion
of the population maintained persistently elevated platelet function
despite the more aggressive P2Y12 receptor blockade.5 These
results demonstrate the need for alternative platelet inhibition
strategies for this high-risk patient population.

Prasugrel is a thienopyridine that produced a greater reduction in
ischaemic events than clopidogrel but with increased risk of
bleeding in moderate-to-high-risk patients with acute coronary
syndrome undergoing percutaneous coronary interventions
(PCIs) in the Trial to Assess Improvement in Therapeutic Out-
comes by Optimizing Platelet Inhibition with Prasugrel-
Thrombolysis in Myocardial Infarction (TRITON-TIMI 38).6 In the
subgroup of patients with DM in TRITON, a 30% relative risk
reduction with prasugrel vs. clopidogrel in the primary composite
endpoint of cardiovascular death, non-fatal myocardial infarction,
or non-fatal stroke was demonstrated without an increased risk
of major bleeding.7 However, randomization was not stratified
by diabetic status in this clinical study and there was no significant
interaction between patients with and without diabetes. Addi-
tionally, two studies have examined, in non-randomized subgroup ana-
yses, the pharmacodynamic profiles of prasugrel and clopidogrel in
stable coronary artery disease (CAD) patients with DM.8,9 However, neither of these analyses was from a prospectively
defined trial in a well-characterized DM population.

In patients with DM, a prospective comparison of the pharmaco-
dynamic profiles of prasugrel with higher than approved loading dose
(LD) and MD of clopidogrel is largely unexplored in a prospectively
defined trial. Therefore, the aim of the present study was to compare
the pharmacodynamic activity of standard-dose prasugrel with
double-dose clopidogrel in patients with type 2 DM who have
CAD by means of multiple platelet function assays. We hypothesized
that prasugrel would achieve greater platelet inhibition compared
with double-dose clopidogrel in these patients.

Methods

Patient population and study design

OPTIMUS-3 was a prospective, randomized, double-blind, double-
dummy, active-controlled, two-period crossover study conducted
between April 2008 and January 2009 at four academic sites in the
USA. Patients with type 2 DM between 18 and 75 years of age
were treated with oral and/or parenteral hypoglycaemic therapy for at
least 1 month were enrolled. All patients had known CAD and were
taking aspirin (81–325 mg/day). Patients were ineligible to participate
if any of the following criteria was met: a defined need for thienopyr-
idine therapy (e.g. within 12 months of an acute coronary syndrome
event or placement of a drug eluting stent; or within 1 month of place-
ment of a bare metal stent); within 30 days of coronary artery bypass
graft surgery or PCI without a stent placed; planned coronary revascu-
larization; glycosylated haemoglobin (HbA1c) ≥10 mg/dL within 3
months; treatment with fibrin-specific fibrinolytic therapy <24 h or
non-fibrin-specific fibrinolytic therapy <48 h prior to randomization;
presence of active internal bleeding or history of bleeding diathesis
or clinical findings associated with an increased risk of bleeding;
history of ischaemic or haemorrhagic stroke, transient ischaemic
attack, intracranial neoplasm, arteriovenous malformation, or aneur-
ysm; body weight <60 kg; an international normalized ratio >1.5,
platelet count <100 000/mm³, or haemoglobin <10 g/dL within 1
week of study entry.

The trial was conducted in agreement with the Declaration of Hel-
sinki and the International Conference on Harmonisation Guidelines
for Good Clinical Practice. The protocol was approved by the local
Ethics Review Committee or institutional review board at each parti-
cipating site, and all patients gave written informed consent before
undergoing any study procedure or receiving any study treatment.

A clinical research organization (CRO) was contracted by the
sponsor to hold the data and perform the data analysis after data
lock and then deliver the database and the analysis results to the
sponsor. An independent expert was contracted to check the quality
of the blinded data prior to the data analysis by the CRO.

Patients who met all criteria for enrolment were randomized at the
first visit to double-blind treatment of either prasugrel 60 mg LD
orally followed by 10 mg/day MD for 7 days or clopidogrel 600 mg LD
orally [75 mg tablets Plavix® (clopidogrel bisulfate; Bristol–Myers
Squibb/sanofi-aventis, Bridgewater, NJ, USA)] followed by 150 mg/day
MD for 7 days (Figure 1A). The randomization ratio was 1:1 between
the two treatments within each site. Assignment to treatment was deter-
mined by a computer-generated random sequence using an interactive
voice response system. Prasugrel was administered as the hydrochloride
salt in 10 mg tablets (Eli Lilly and Company, Indianapolis, IN, USA).
Patients were administered an equal number of identical tablets for
either the LDs (six prasugrel 10 mg tablets and eight placebo tablets
or eight clopidogrel 75 mg tablets and six placebo tablets) or MDs
(one prasugrel 10 mg tablet and two placebo tablets or two clopidogrel
75 mg tablets and one placebo tablet). Patients continued taking their
pre-study dosage of aspirin throughout the study. Platelet function
studies were performed at 0 (baseline), 1, 4, and 24 h, and 7 days (24 h
post last MD) after LD. After completion of the first 1-week treatment
period, patients discontinued the study drug, and platelet function
studies were repeated 1 and 2 weeks later, with the 2-week measure
serving as the baseline (0 h) for the second treatment period. After
the 2-week washout period, patients received the other study drug
regimen for 1 week, during which assessment of platelet function mir-
rrored the first period. Final platelet function studies were performed 1
week after discontinuation of therapy.

Sample collection and platelet function
assays

Blood for platelet function analyses was collected from an antecubital
vein at pre-defined time points into citrated tubes (Figure 1). Platelet
function assays included VerifyNow® P2Y12 (Accumetrics, Inc., San Diego, CA, USA), light transmission aggregometry (LTA), and vasodilator-stimulated phosphoprotein phosphorylation (VASP-P) expressed as the platelet reactivity index (PRI). The VerifyNow® P2Y12 assay is a rapid whole-blood point-of-care device and was utilized according to the instructions of the manufacturer as described previously.10,11 Light transmission aggregometry was performed according to standard protocols.2–5 Maximum platelet aggregation (MPA) was induced by 5 and 20 μM ADP and IPA% (IPA, inhibition of platelet aggregation) was calculated as (baseline aggregation response – post-dose aggregation response)/baseline aggregation response × 100. Vasodilator-stimulated phosphoprotein phosphorylation was assessed as recommended by the manufacturer5 using quantitative flow cytometry and commercially available labelled monoclonal antibodies (Biocytex, Inc., Marseille, France) at a central laboratory at the University of Massachusetts.

**Study endpoints**

The primary endpoint of this study was IPA measured by the VerifyNow® P2Y12 assay 4 h after the administration of the study drug LD. This time point was selected because the peak (≥95%) effect of prasugrel 60 mg occurs by 2 h post-LD and is sustained past 4 h, whereas the peak effect of a clopidogrel 600 mg LD has been measured at ≤4 h in several studies.12,13 Secondary measures included: IPA by VerifyNow® P2Y12 at all other time points; VerifyNow® P2Y12 PRI, LTA (MPA and IPA), and VASP-P PRI at all time points; and evaluation of the incidence of adverse events such as thrombosis and haemorrhage. In addition, a responder-type analysis was conducted in which a poor response to thienopyridine treatment was defined as: VerifyNow® P2Y12 PRI >235;20 μM ADP LTA MPA >50%;20 μM ADP LTA IPA ≤20%;15 or VASP-P PRI >50%.16 Finally, the possibility of ‘rebound’ platelet activation was evaluated in an analysis of the pharmacodynamic effect of prasugrel 6–8 days after treatment discontinuation for each study period. Rebound was considered to have occurred if, after the cessation of the study drug, a ≥20% increase in platelet reactivity above the 0 h value was obtained at the start of each treatment period. A cut-off value of 20% was chosen because it is outside the range of assay variability.

**Statistical analysis**

A sample size of 30 patients was required to provide at least 90% power to detect a 17.5% difference in VerifyNow® P2Y12 IPA (primary endpoint) between treatment groups with a standard deviation of 20% at a two-tailed significance level of 0.05. This difference was based on the response to MD therapy with prasugrel compared with clopidogrel in a previous study available at the time of the OPTIMUS-3 design.17 All statistical comparisons of platelet function between prasugrel and clopidogrel for the primary endpoint and secondary endpoints with continuous variables were conducted using a linear mixed-effect model with treatment group, sequence, and treatment-group-by-sequence (i.e. period) as fixed effects and patient as a random effect. Confidence intervals (CI) and all tests of statistical significance for treatment comparisons were evaluated at a two-tailed significance level of 0.05 using SAS version 9.1. Results are reported as the least-squares mean with 95% CI. Sensitivity analysis on the primary endpoint was conducted after adjusting baseline IPA values assessed by VerifyNow® P2Y12 in the mixed-effect model. Categorical variables were analysed using Fisher’s exact tests.

All analyses of platelet function were conducted on the pharmacodynamic population, which was defined as all randomized subjects who received at least one dose of study drug and had blood draws for IPA.
assessed by VerifyNow® P2Y12 4 h after the administration of the LD. Safety analyses were conducted on the safety population, which included all patients exposed to at least one dose of the study drug. Safety was assessed by evaluating vital signs, all reports of bleeding, and all reported adverse events including thrombotic cardiovascular events, death, myocardial infarction, and stroke. Bleeding was classified as major, minor, or insignificant according to the Thrombolysis In Myocardial Infarction (TIMI) criteria.5

Results

Forty-three patients were screened and 35 were randomly assigned to either prasugrel (n = 18) or clopidogrel (n = 17) for the first treatment period (Figure 1B). Of these 35 patients, 34 completed both treatment periods and served as their own control. One patient who was initially assigned to the clopidogrel group in the first treatment period was found to have an exclusion criterion (HbA1c ≥ 10 mg/dL) and did not cross over to prasugrel. Baseline characteristics are described in Table 1.

Table 1  Baseline characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N = 35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), mean ± SD</td>
<td>61.3 ± 8.8</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>24 (68.6)</td>
</tr>
<tr>
<td>Race, n (%)</td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic white</td>
<td>15 (42.9)</td>
</tr>
<tr>
<td>Non-Hispanic black</td>
<td>7 (20.0)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>8 (22.9)</td>
</tr>
<tr>
<td>Other</td>
<td>5 (14.3)</td>
</tr>
<tr>
<td>Body mass index (kg/m²), mean ± SD</td>
<td>33.1 ± 8.2</td>
</tr>
<tr>
<td>Cardiovascular history, n (%)</td>
<td></td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>5 (14.3)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>33 (94.3)</td>
</tr>
<tr>
<td>Hypercholesterolaemia</td>
<td>33 (94.3)</td>
</tr>
<tr>
<td>Prior myocardial infarction</td>
<td>13 (37.1)</td>
</tr>
<tr>
<td>Prior PCI</td>
<td>20 (57.1)</td>
</tr>
<tr>
<td>Prior coronary artery bypass graft</td>
<td>8 (22.9)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>7 (20.0)</td>
</tr>
<tr>
<td>Obesity (body mass index ≥ 30)</td>
<td>17 (48.6)</td>
</tr>
<tr>
<td>Duration of CAD (years), mean ± SD</td>
<td>3.1 ± 3.3</td>
</tr>
<tr>
<td>Duration of type 2 DM (years), mean ± SD</td>
<td>8.5 ± 6.6</td>
</tr>
<tr>
<td>Antihyperglycaemic medication, n (%)</td>
<td></td>
</tr>
<tr>
<td>Insulin</td>
<td>7 (20.0)</td>
</tr>
<tr>
<td>Non-insulin</td>
<td>28 (80.0)</td>
</tr>
<tr>
<td>Aspirin dose, n (%)</td>
<td></td>
</tr>
<tr>
<td>81 mg/day</td>
<td>22 (62.9)</td>
</tr>
<tr>
<td>162 mg/day</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>325 mg/day</td>
<td>12 (34.3)</td>
</tr>
</tbody>
</table>

CAD, coronary artery disease; DM, diabetes mellitus; MI, myocardial infarction; N, number of patients; n, number in group; PCI, percutaneous intervention; SD, standard deviation.

VerifyNow® P2Y12 assay

At 4 h post-LD (primary endpoint), patients treated with prasugrel had significantly greater IPA compared with clopidogrel [89.3% (95% CI = 83.0–95.6) vs. 27.7% (95% CI = 21.5–33.9), P < 0.0001] (Figure 2A). Following ~1 week of MD therapy, the IPA was still significantly greater with daily prasugrel 10 mg compared with daily clopidogrel 150 mg [61.8% (95% CI = 55.7–67.9) vs. 44.2% (38.1–50.3), P < 0.0001]. The difference between prasugrel- and clopidogrel-treated patients was significant at all time points from 1 h post-LD through 7 days (24 h after the last MD). The difference between prasugrel- and clopidogrel-treated patients was also significant at all time points from 1 h post-LD through 7 days as measured by VerifyNow® P2Y12 PRU (Figure 2B). When measured at 1 week following discontinuation of study drug, platelet function for prasugrel- and clopidogrel-treated patients returned to near baseline (Figure 2A and B). The results were consistent irrespective of the use of insulin for glycaemic control (data not shown).

Light transmission aggregation

Figure 3A shows MPA to 20 µM ADP using LTA. Maximum platelet aggregation values at 0 h for patients in both treatment groups were similar. At 4 h post-LD, patients treated with prasugrel had significantly lower MPA compared with patients treated with...
clopidogrel [22.4% (95% CI = 17.0–27.8) vs. 57.5% (52.2–62.8), P < 0.0001]. Following ∼1 week of MD therapy, MPA was still significantly lower with prasugrel compared with clopidogrel [38.3% (95% CI = 33.0–43.6) vs. 50.7% (95% CI = 45.4–56.0), P < 0.0001]. The differences between prasugrel- and clopidogrel-treated patients were significant at all time points from 1 h post-LD through 7 days. Similar findings were observed using 5 μM ADP (Figure 3D).

Vasodilator-stimulated phosphoprotein
Baseline VASP PRI values for prasugrel- and clopidogrel-treated patients were similar [83.5% (95% CI = 78.8–88.3) vs. 80.6% (95% CI = 75.9–85.3), P = 0.37] (Figure 4). At 4 h post-LD, patients treated with prasugrel had significantly lower platelet reactivity by VASP PRI than patients treated with clopidogrel [14.5% (95% CI = 7.7–21.4) vs. 67.5% (95% CI = 60.8–74.2), P < 0.0001]. Following ∼1 week of MD therapy, VASP PRI was still significantly lower with prasugrel 10 mg daily compared with clopidogrel 150 mg daily [27.4% (95% CI = 20.8–34.0) vs. 42.3% (95% CI = 35.7–48.9), P = 0.0012]. The differences between prasugrel- and clopidogrel-treated patients was significant at all time points from 1 h post-LD through 7 days.

Response profiles
Figure 5 shows individual patient VerifyNow® P2Y12 PRU values at baseline (0 h) and 4 h post-LD during the clopidogrel-to-prasugrel crossover sequence (Figure 5A) and the prasugrel-to-clopidogrel crossover sequence (Figure 5B). After the prasugrel 60 mg LD, PRU was generally lower than that achieved after the clopidogrel 600 mg LD, regardless of whether prasugrel was administered in the first or second treatment period. Figure 5 also illustrates less variability in response to prasugrel compared with clopidogrel. Three patients treated with clopidogrel achieved response rates comparable with those treated with prasugrel.

Figure 6 presents the results of the poor responder analysis at 4 and 24 h post-LD and at 7 days. Regardless of the definition used,
the poor responder rate was considerably higher with clopidogrel compared with prasugrel (all P-values < 0.05). At 4 h post-LD, the rate of poor responders ranged from 0 to 3.1% for prasugrel and from 35.3 to 82.9% for clopidogrel. At 24 h post-LD, the rate of prasugrel poor responders was 0% regardless of definition compared with 51.5–78.8% for clopidogrel. At 7 days, the poor responder rate ranged from 2.9 to 21.2% for prasugrel and from 23.5 to 52.9% for clopidogrel.

Rebound platelet activation

One patient on prasugrel and one patient on clopidogrel met rebound criteria by MPA but not by the other assays. Similarly, one prasugrel patient met rebound criteria by VerifyNow® P2Y12 PRU; one patient on prasugrel and two patients on clopidogrel met rebound criteria according to PRI using VASP-P; and none of these patients met rebound criteria using the other assays. No patient meeting rebound criteria on clopidogrel or prasugrel met criteria with the alternative drug.

Safety

Major or minor bleeding by TIMI criteria did not occur with either treatment regimen. Two TIMI minimal bleeding events that occurred within 24 h of the last MD were observed in clopidogrel-treated patients. One prasugrel-treated patient experienced a vessel puncture site bleed. None of these episodes required intervention to control bleeding. No deaths or other serious adverse events occurred during the study. The incidence of adverse events in the prasugrel group was 14.7% (5/34), and 25.7% (9/35) in the clopidogrel group. The types of adverse events in the prasugrel and clopidogrel groups were similar (Table 2). No patients discontinued due to an adverse event.

Discussion

The results of the OPTIMUS-3 study confirm the hypothesis that treatment with prasugrel 60 mg LD/10 mg MD is associated with greater platelet inhibition than double-dose clopidogrel 600 mg LD/150 mg MD in a prospectively defined study in patients with type 2 DM and CAD. This study enrolled a well-characterized population of patients with DM, unlike previous studies. Platelet...
inhibition was corroborated by multiple platelet function assessments using different methodologies, including point-of-care testing, LTA, and flow cytometry, which encompassed a range of specificities for P2Y12-mediated platelet activation. This higher level of platelet inhibition in prasugrel-treated patients was evident at the first measurement (1 h post-LD) and continued over 24 h. Although the level of platelet inhibition after 1 week of prasugrel 10 mg MD was lower than the prasugrel LD, as the need for very high levels of platelet inhibition is probably not required in the absence of a procedure, the level of inhibition associated with the prasugrel 10 mg MD was significantly higher than with clopidogrel 150 mg MD. This study also provides additional information on clopidogrel’s poor response in patients with DM, examines potential rebound after 7 days of drug withdrawal, and provides adverse event data in the study population.

Numerous studies have demonstrated the clinical benefit associated with platelet P2Y12 receptor inhibition with clopidogrel, particularly in high-risk patients. However, patients with DM continue to have a higher risk of recurrent ischaemic events, including stent thrombosis, compared with patients without DM despite the use of clopidogrel. This may be attributed, at least in part, to the greater prevalence of suboptimal P2Y12 inhibition achieved with recommended regimens of clopidogrel that has been associated with a higher risk of atherothrombotic complications.

Table 2 Summary of adverse events in the safety population of the OPTIMUS-3 Study

<table>
<thead>
<tr>
<th>Adverse event</th>
<th>Prasugrel 60 mg LD/10 mg MD (n = 34), n (%)</th>
<th>Clopidogrel 600 mg LD/150 mg MD (n = 35), n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients with at least one event</td>
<td>5 (14.7)</td>
<td>9 (25.7)</td>
</tr>
<tr>
<td>Number of events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haematocrit decreaseda</td>
<td>1 (2.9)</td>
<td>0</td>
</tr>
<tr>
<td>Haemoglobin decreaseda</td>
<td>1 (2.9)</td>
<td>0</td>
</tr>
<tr>
<td>Headache</td>
<td>1 (2.9)</td>
<td>2 (5.7)</td>
</tr>
<tr>
<td>Pain in extremity</td>
<td>1 (2.9)</td>
<td>0</td>
</tr>
<tr>
<td>Upper respiratory tract infection</td>
<td>1 (2.9)</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Urinary tract infection</td>
<td>1 (2.9)</td>
<td>0</td>
</tr>
<tr>
<td>Vessel puncture site haemorrhage</td>
<td>1 (2.9)</td>
<td>0</td>
</tr>
<tr>
<td>Contusion</td>
<td>0</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Diarrhoea</td>
<td>0</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Electrolyte imbalance</td>
<td>0</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Epistaxis</td>
<td>0</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Haemorrhage</td>
<td>0</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Nausea</td>
<td>0</td>
<td>1 (2.9)</td>
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<tr>
<td>Respiratory tract congestion</td>
<td>0</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Rhinorrhoea</td>
<td>0</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Sinusitis</td>
<td>0</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Vomiting</td>
<td>0</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Wart excision</td>
<td>0</td>
<td>1 (2.9)</td>
</tr>
</tbody>
</table>

*aInvestigator defined.*
observations suggest the need for more effective P2Y$_{12}$ inhibition, particularly in high-risk patients such as those with DM.

The OPTIMUS-1 study demonstrated that a high-clopidogrel MD was associated with greater platelet inhibitory effects compared with standard dosing in patients with DM and CAD who presented with elevated platelet reactivity while on standard dual antiplatelet therapy. However, inadequate platelet inhibition persisted in 60% of patients. In the PRINCIPLE-TIMI 44 Trial, the rate of response to prasugrel 60 mg LD/10 mg MD was significantly greater than double-dose clopidogrel in the overall patient population, as well as in patients with DM. The rate of poor responders in patients with DM at 24 h post-LD was ~40%. The OPTIMUS-2 study showed that adjunctive treatment with cilostazol ('triple therapy') enhances measures of platelet P2Y$_{12}$ inhibition in patients with DM and CAD to a greater extent than standard dual antiplatelet therapy with aspirin and clopidogrel. However, cilostazol is poorly tolerated and has an elevated prevalence of side effects that limit treatment compliance. Results from a subgroup of 19 patients with DM were presented by Erlinge et al. in a study examining the pharmacodynamic poor responder rate with high dose clopidogrel compared with prasugrel. There was a higher rate of poor responders as measured by LTA and VASP in the patients receiving clopidogrel 600 mg LD/75 mg MD compared with prasugrel 60 mg LD/10 mg MD for 28 days. These previous investigations suggested the need to explore better tolerated treatment strategies, which provide more effective P2Y$_{12}$ blockade, as was assessed in the present study. The results from the OPTIMUS-3 randomized trial in patients with DM confirmed earlier pharmacodynamic observations from subgroup analyses that the rate of response to prasugrel was greater than the response to clopidogrel despite the use of the double the approved clopidogrel dose. Additionally, both prasugrel and clopidogrel were well tolerated in this population with DM.

Clinical outcome data demonstrating an increase in recurrent ischaemic events following withdrawal of thienopyridine therapy suggest the potential for rebound in platelet reactivity. Although limited by the short duration of the current study, no consistent evidence of a rebound effect was measured at either 1 week following discontinuation of study drug or at 2 weeks when the second baseline (post crossover) was compared with the first. If rebound did exist, one would expect to find it in the early period when new, fully functional platelets would be the majority of platelets in circulation. This was an exploratory analysis and not specifically designed to examine rebound; therefore, results of our study should be interpreted with caution but are consistent with those reported by Sibbing et al., who found no evidence of rebound platelet activity on clopidogrel withdrawal in a prospectively defined study. This suggests that the previously reported increase in ischaemic events observed following thienopyridine withdrawal may be the result of treatment cessation rather than rebound platelet reactivity.

**Study limitations**

The aim of this study was to compare the antiplatelet effects of prasugrel with double-dose clopidogrel in patients with DM; therefore, comparisons with patients without DM cannot be made. Although adequately powered for the pharmacodynamic endpoints, this study was conducted in a relatively small number of patients, thus precluding an evaluation of clinical endpoints. Additionally, the short duration of the trial did not allow for meaningful assessment of bleeding events associated with antiplatelet therapy and also limited conclusions regarding platelet function and rebound following drug withdrawal to the time frame of the study. Finally, patients included in the study were not indicated for prasugrel or clopidogrel in order to allow a washout phase without putting patients at risk. It should be underscored that in the USA and Europe, prasugrel is indicated for ACS patients undergoing PCI, a population of patients not included in this study.

**Conclusions**

Compared with double-dose clopidogrel (600 mg LD/150 mg MD), standard-dose prasugrel (60 mg LD/10 mg MD) resulted in greater platelet inhibition in aspirin-treated patients with type 2 DM and CAD as assessed by multiple pharmacodynamic measures in this prospective, randomized, double-blind, crossover study. Prasugrel also resulted in a better response profile with lower rates of poor responders after both the LD and MD periods, irrespective of platelet function assay or definition used. These findings may explain the clinical benefit observed with prasugrel in patients with DM.

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Appendix

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