

The ODYSSEY OUTCOMES Trial: Topline Results

Alirocumab in Patients After Acute Coronary Syndrome

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On behalf of the ODYSSEY OUTCOMES Investigators and Committees

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Disclosures

- The trial was funded by **Sanofi** and **Regeneron Pharmaceuticals**
- **Ph. Gabriel Steg** discloses the following relationships:
 - Research grants from Bayer, Merck, Sanofi, and Servier
 - Speaking or consulting fees from Amarin, Amgen, AstraZeneca, Bayer/Janssen, Boehringer Ingelheim, Bristol-Myers Squibb, Lilly, Merck, Novartis, Novo-Nordisk, Pfizer, Regeneron Pharmaceuticals, Sanofi, and Servier
- **Gregory G. Schwartz** discloses research support to his institution

Residual Risk After Acute Coronary Syndrome

- Remains high despite evidence-based preventive therapies
- Is related, in part, to levels of low-density lipoprotein cholesterol (LDL-C)
- Is reduced when LDL-C is lowered by
 - Statin therapy, compared with placebo¹
 - High-intensity, compared with moderate-intensity statin therapy²
 - Ezetimibe, compared with placebo, added to statin³

1. Schwartz GG, et al. JAMA 2001;285:1711-8. 2. Cannon CP, et al. NEJM 2004;350:1495-504.
3. Cannon CP, et al. NEJM 2015;372:2387-97.

Alirocumab

- A fully human monoclonal antibody against PCSK9
- Produces substantial and sustained reductions in LDL-C and other atherogenic lipoproteins¹
- Has been safe and well-tolerated in studies to date²

PCSK9, proprotein convertase subtilisin/kexin type 9

1. Robinson JG, et al. NEJM 2015;372:1489-99. 2. Robinson JG, et al. JACC 2017;69:471-82.

Study Hypothesis

Alirocumab, versus placebo, reduces cardiovascular (CV) morbidity and mortality after recent acute coronary syndrome (ACS) in patients with elevated levels of atherogenic lipoproteins despite intensive or maximum-tolerated statin therapy

Main Inclusion Criteria

- **Age** ≥ 40 years
- **ACS**
 - 1 to 12 months prior to randomization
 - Acute myocardial infarction (MI) or unstable angina
- **High-intensity statin therapy***
 - Atorvastatin 40 to 80 mg daily **or**
 - Rosuvastatin 20 to 40 mg daily **or**
 - Maximum tolerated dose of one of these agents for ≥ 2 weeks
- **Inadequate control of lipids**
 - LDL-C ≥ 70 mg/dL (1.8 mmol/L) **or**
 - Non-HDL-C ≥ 100 mg/dL (2.6 mmol/L) **or**
 - Apolipoprotein B ≥ 80 mg/dL

*Patients not on statins were authorized to participate if tolerability issues were present and documented
Schwartz GG, et al. Am Heart J 2014;168:682-689.e1.

Key Exclusion Criteria

- Uncontrolled hypertension
- NYHA class III or IV heart failure;
LVEF <25% if measured
- History of hemorrhagic stroke
- Fasting triglycerides >400 mg/dL
(4.52 mmol/L)
- Use of fibrates other than fenofibrate or fenofibric acid
- Recurrent ACS within 2 weeks prior to randomization visit
- Coronary revascularization performed within 2 weeks prior to randomization visit, or planned after randomization
- Liver transaminases >3 × ULN;
hepatitis B or C infection
- Creatine kinase >3 × ULN
- eGFR <30 mL/min/1.73 m²
- Positive pregnancy test

Primary Efficacy Outcome

Time of first occurrence of:

- **Coronary heart disease (CHD) death, or**
- **Non-fatal MI, or**
- **Fatal or non-fatal ischemic stroke, or**
- **Unstable angina requiring hospitalization***

All outcomes adjudicated by the Clinical Events Committee, under the auspices of the Duke Clinical Research Institute (DCRI). Members were unaware of treatment assignment and lipid levels

*Required all of the following:

1. Hospital admission >23 h for MI symptoms, ↑ tempo in prior 48 hours and/or ≥20 min of chest discomfort at rest
2. New ECG findings consistent with ischemia or infarction
3. Angiographically significant obstructive coronary disease

Major Secondary Efficacy Endpoints

Tested in the following hierarchical sequence:

- **CHD event:** CHD death, non-fatal MI, unstable angina requiring hospitalization, or ischemia-driven coronary revascularization*
- **Major CHD event:** CHD death or non-fatal MI
- **CV event:** CV death, non-fatal CHD event, or non-fatal ischemic stroke
- **All-cause death, non-fatal MI, non-fatal ischemic stroke**
- **CHD death**
- **CV death**
- **All-cause death**

*Revascularization performed because of recurrent ACS, new or progressive symptoms of myocardial ischemia or new or progressive abnormalities on functional testing, except revascularization due to restenosis at a prior coronary intervention site.

Other Secondary and Safety Endpoints

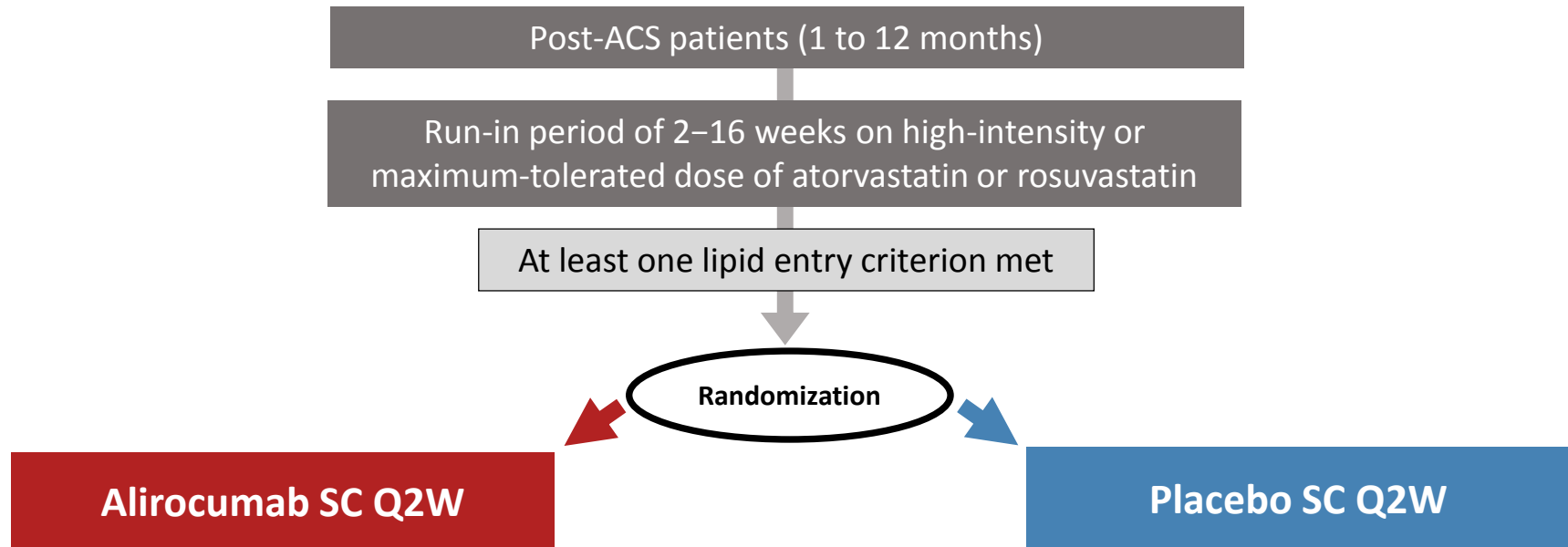
Other secondary endpoints

- Components of the primary endpoint considered individually:
 - CHD death
 - Non-fatal MI
 - Fatal and non-fatal ischemic stroke
 - Unstable angina requiring hospitalization
- Ischemia-driven coronary revascularization
- Congestive heart failure requiring hospitalization

Safety endpoints

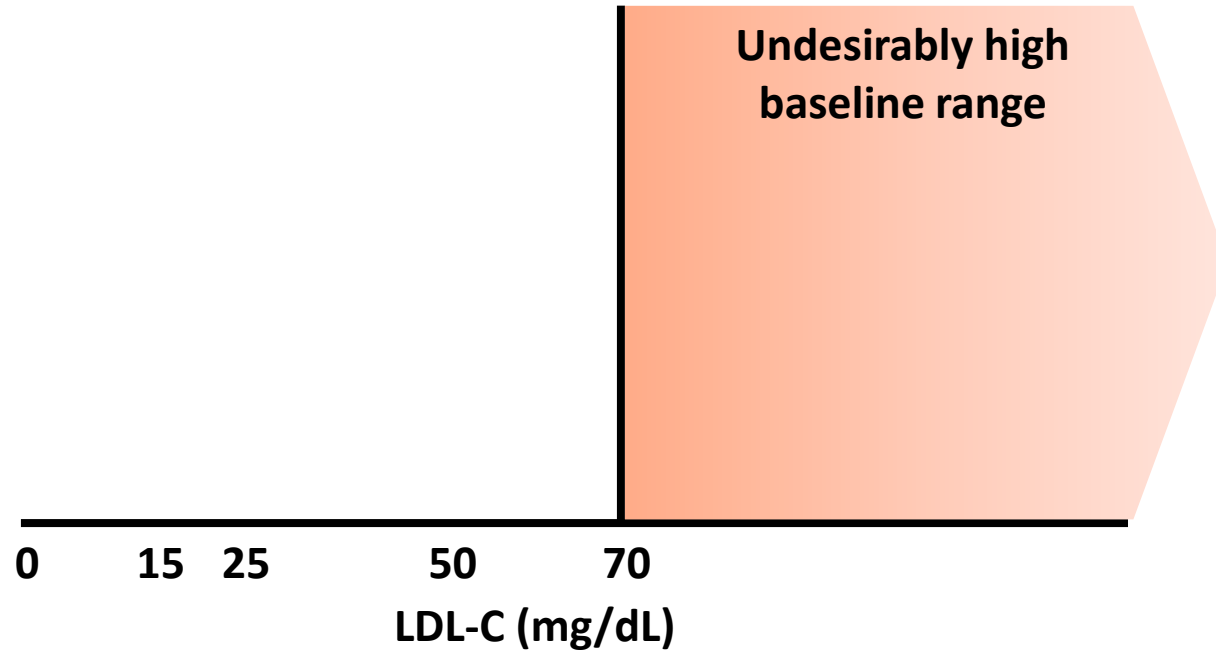
- Adverse events
- Laboratory assessments

Treatment Assignment

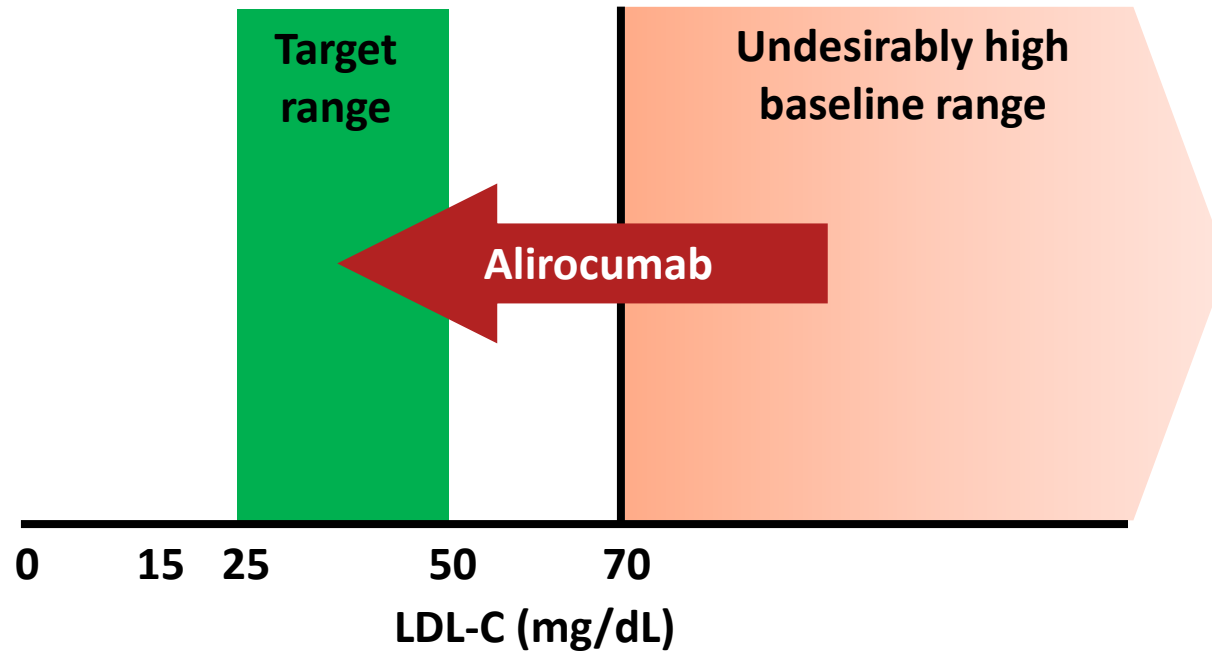


Patient and investigators remained blinded to treatment and lipid levels for the entire duration of the study

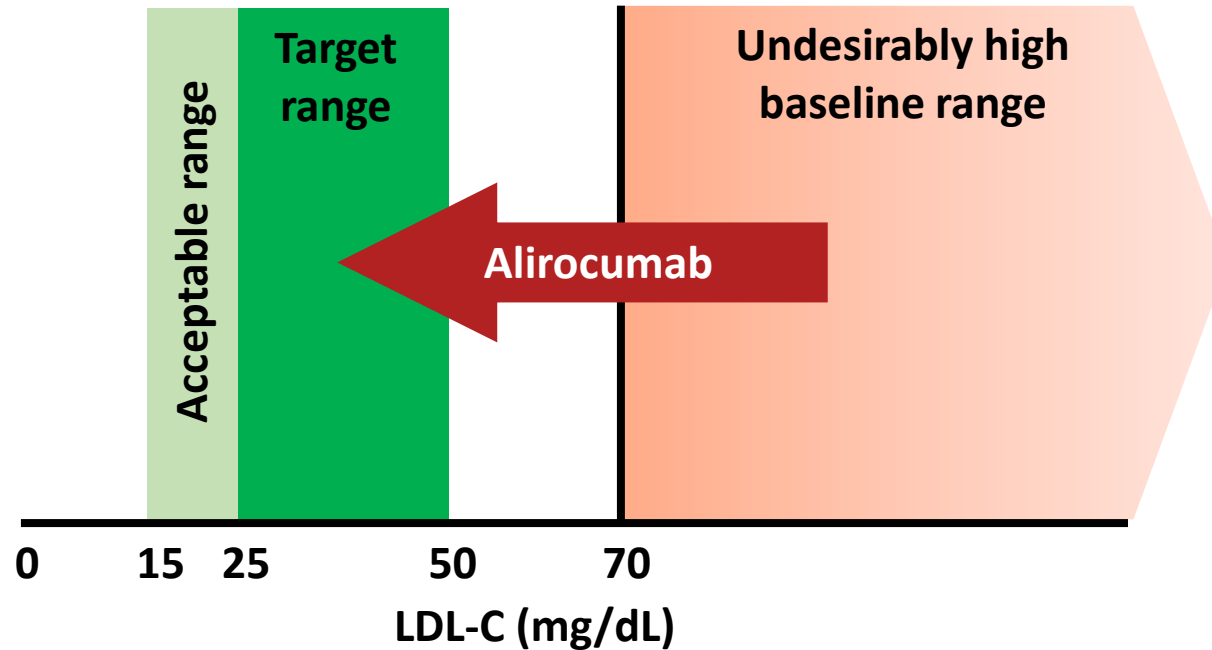
A Target Range for LDL-C



A Target Range for LDL-C

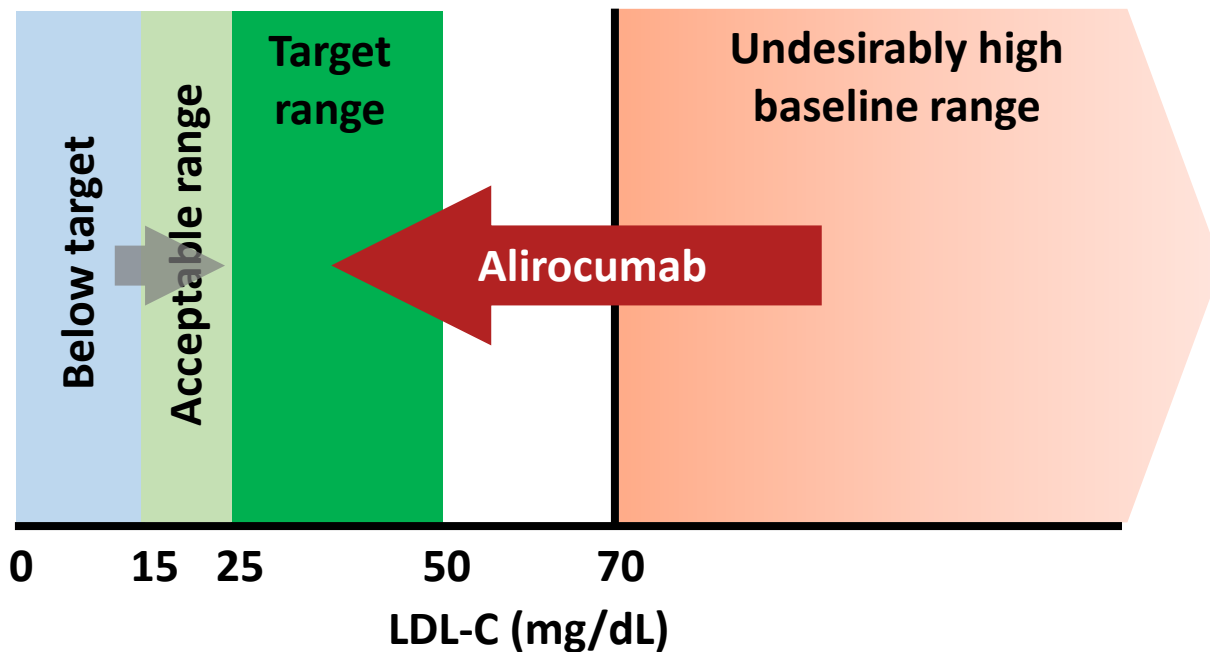


A Target Range for LDL-C



A Target Range for LDL-C

We attempted to maximize the number of patients in the target range and minimize the number below target by blindly titrating alirocumab (75 or 150 mg SC Q2W) or blindly switching to placebo.



Statistical Considerations

- All analyses conducted by independent academic statistical team at State University of New York (SUNY) Downstate School of Public Health, in parallel with the sponsor
- Efficacy analysis by intention-to-treat (ITT)

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- All analyses conducted by independent academic statistical team at State University of New York (SUNY) Downstate School of Public Health, in parallel with the sponsor
- Efficacy analysis by intention-to-treat (ITT)
- Assumptions
 - Cumulative incidence of primary endpoint in placebo group 11.4% at 48 months
 - Baseline LDL-C 90 mg/dL; reduction to 45 mg/dL with alirocumab
 - **15% expected hazard reduction for primary endpoint**
 - Loss to follow-up at 24 months: 1%
 - Log-rank test with 1-sided 2.5% significance level
 - Continuation of the trial until **1613** patients with a primary endpoint (for 90% power) **AND** all surviving patients followed for **≥2 years** (for adequate safety assessments), **whichever came later***

* Except for patients enrolled in China (enrollment started on May 5, 2016)

ODYSSEY OUTCOMES: 18,924 patients randomized at 1315 sites in 57 countries, Nov 2, 2012 – Nov 11, 2017

Canada/USA

Canada	361
US	2511

Western Europe

Austria	58
Belgium	197
Denmark	352
Finland	116
France	185
Germany	509
Greece	70
Italy	275
Netherlands	686
Norway	97
Portugal	174
Spain	826
Sweden	250
Switzerland	88
UK	292

Central/Eastern Europe

Bosnia–Herzegovina	156	Macedonia	132
Bulgaria	333	Poland	926
Croatia	70	Romania	145
Czech Republic	381	Russian Federation	1109
Estonia	216	Serbia	255
Georgia	131	Slovakia	340
Hungary	224	Slovenia	36
Latvia	80	Turkey	78
Lithuania	188	Ukraine	639

Asia

China	614
Hong Kong	17
India	521
Japan	204
Korea	94
Malaysia	110
Philippines	116
Singapore	49
Sri Lanka	314
Taiwan	93
Thailand	161

Latin America

Argentina	592
Brazil	928
Chile	132
Colombia	354
Guatemala	25
Mexico	349
Peru	208

We thank the patients,
their families, all
investigators and
coordinators involved in
this study, and DCRI

Rest of World

Australia	216
Israel	582
New Zealand	257
South Africa	505

ODYSSEY OUTCOMES National Leaders

Argentina R. Diaz	Finland M.S. Nieminen	Lithuania A. Laucevicus	Slovakia J. Murin
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Monitoring of safety in patients with low LDL-C values

K. Alexander, C. Meloni, R.S. Rosenson, E.J.G. Sijbrands

ODYSSEY OUTCOMES Trial Organization

Academic and Contract Research Organizations

Brazilian Clinical Research Institute, São Paulo, Brazil R. Lopes, F. Egydio, A. Kawakami, J. Oliveira

Canadian VIGOUR Centre, University of Alberta, Toronto, Canada S.G. Goodman, J. Wozniak

Covance, Marlow, Buckinghamshire, UK A. Matthews, C. Ratky, J. Valiris

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Estudios Clínicos Latino America, Rosario, Santa Fe, Argentina R. Diaz, A. Pascual, C. Rovito

French Alliance for Cardiovascular Trials, Paris, France N. Danchin, M. Bezault, E. Drouet, T. Simon

Green Lane Coordinating Centre, Kingsland, Auckland, New Zealand H.D. White, C. Alsweiler

Leuven Klinisch Coördinatiecentrum, Leuven, Belgium P. Sinnaeve, A. Luyten

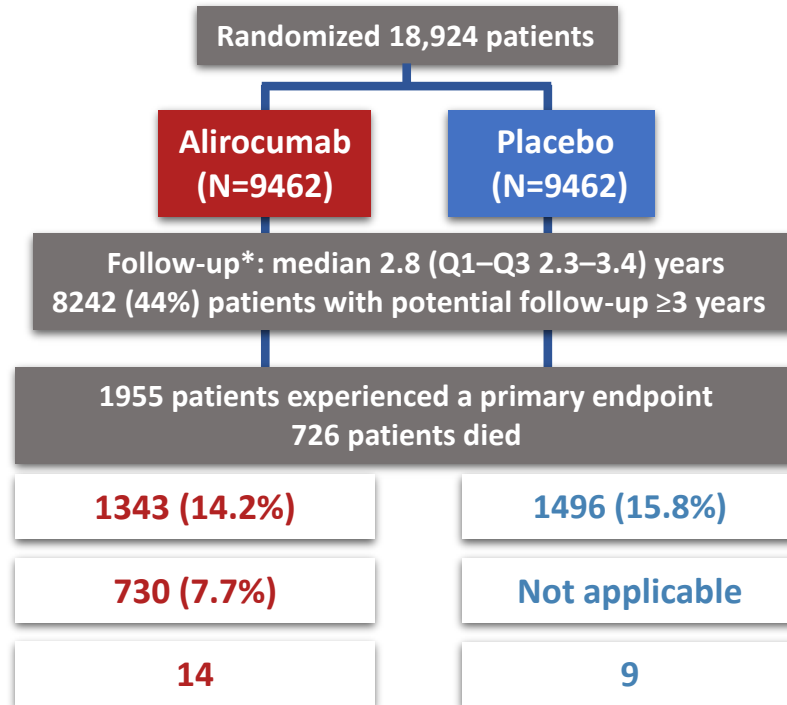
South Australian Health & Medical Research Institute P. Aylward, J. Butters, L. Griffith, M. Shaw

Uppsala Kliniska Forskningscentrum, Uppsala, Sweden E. Hagstrom, L. Grunberg

Independent Statistical Team

SUNY Downstate School of Public Health M. Szarek, S. Islam

Patient Disposition



- Premature treatment discontinuation
- Blinded switch to placebo (2 consecutive LDL-C values <15 mg/dL)
- Patients lost to follow-up (vital status)

*Ascertainment was complete for 99.1% and 99.8% of potential patient-years of follow-up for the primary endpoint and all-cause death, respectively

Baseline Demographics

Characteristic	Alirocumab (N=9462)	Placebo (N=9462)
Age, years, median (Q1–Q3)	58 (52–65)	58 (52–65)
Female, n (%)	2390 (25.3)	2372 (25.1)
Medical history, n (%)		
Hypertension	6205 (65.6)	6044 (63.9)
Diabetes mellitus	2693 (28.5)	2751 (29.1)
Current tobacco smoker	2282 (24.1)	2278 (24.1)
Prior MI	1790 (18.9)	1843 (19.5)

Baseline Index Events

Characteristic	Alirocumab (N=9462)	Placebo (N=9462)
Time from index ACS to randomization, months, median (Q1–Q3)	2.6 (1.7–4.4)	2.6 (1.7–4.3)
ACS type, n (%)		
NSTEMI	4574 (48.4)	4601 (48.7)
STEMI	3301 (35.0)	3235 (34.2)
Unstable angina	1568 (16.6)	1614 (17.1)
Revascularization for index ACS, n (%)	6798 (71.8)	6878 (72.7)

Baseline Lipid Characteristics

Characteristic, mg/dL, median (Q1–Q3)	Alirocumab (N=9462)	Placebo (N=9462)
LDL-C	87 (73–104)	87 (73–104)
Non-HDL-C	115 (99–136)	115 (99–137)
Apolipoprotein B	79 (69–93)	80 (69–93)
HDL-C	43 (37–50)	42 (36–50)
Triglycerides	129 (94–181)	129 (95–183)
Lipoprotein(a)	21 (7–59)	22 (7–60)

92.5% of patients qualified on the basis of LDL-C $\geq$ 70 mg/dL

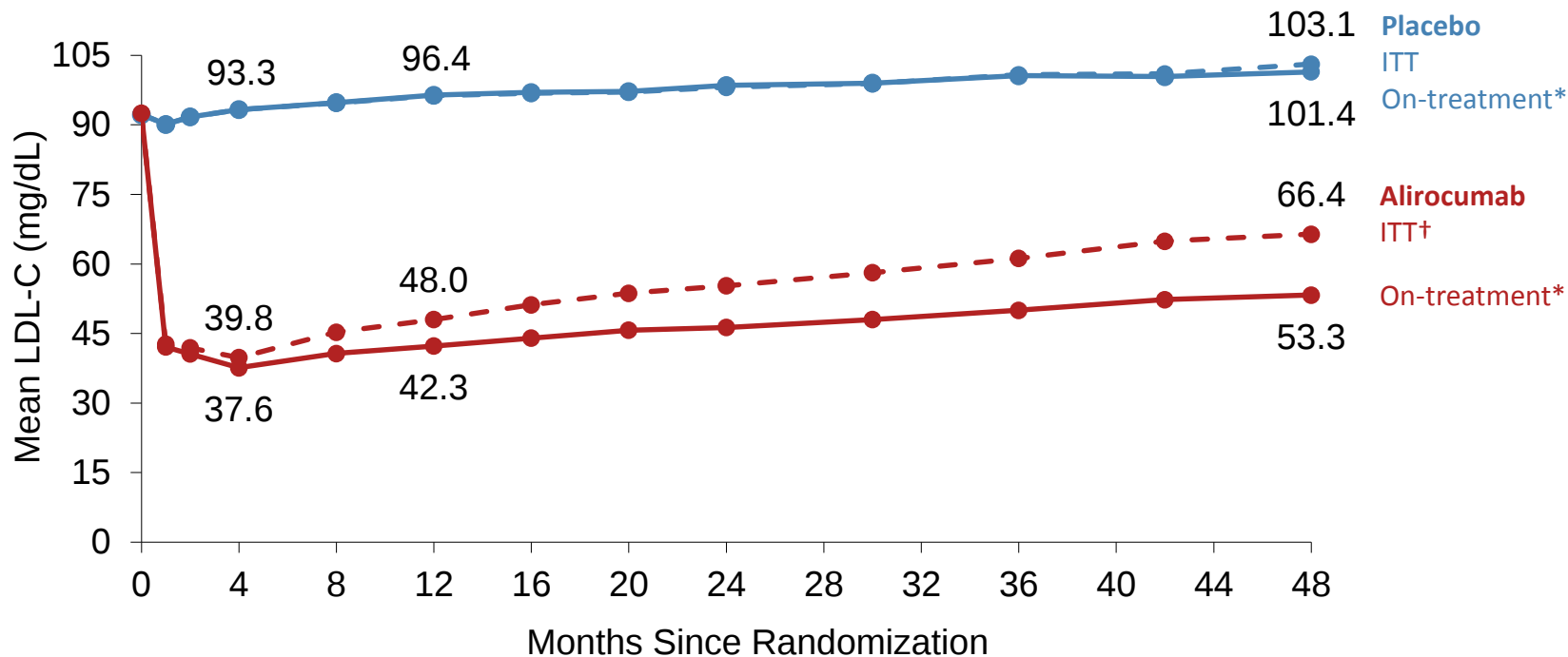
Baseline Lipid-Lowering Therapy

Therapy, n (%)	Alirocumab (N=9462)	Placebo (N=9462)
High-dose atorvastatin/rosuvastatin	8380 (88.6)	8431 (89.1)
Low-/moderate-dose atorvastatin/rosuvastatin	830 (8.8)	777 (8.2)
Other statin	19 (0.2)	27 (0.3)
Ezetimibe, with or without statin	269 (2.8)	285 (3.0)
No lipid-lowering therapy	87 (0.9)	91 (1.0)

Guideline-Recommended Post-ACS Medications

Medication, n (%)	Alirocumab (N=9462)	Placebo (N=9462)
Aspirin	9050 (95.6)	9036 (95.5)
P2Y ₁₂ antagonist	8296 (87.7)	8245 (87.1)
ACE-I/ARB	7356 (77.7)	7360 (77.8)
Beta-blocker	7998 (84.5)	7992 (84.5)

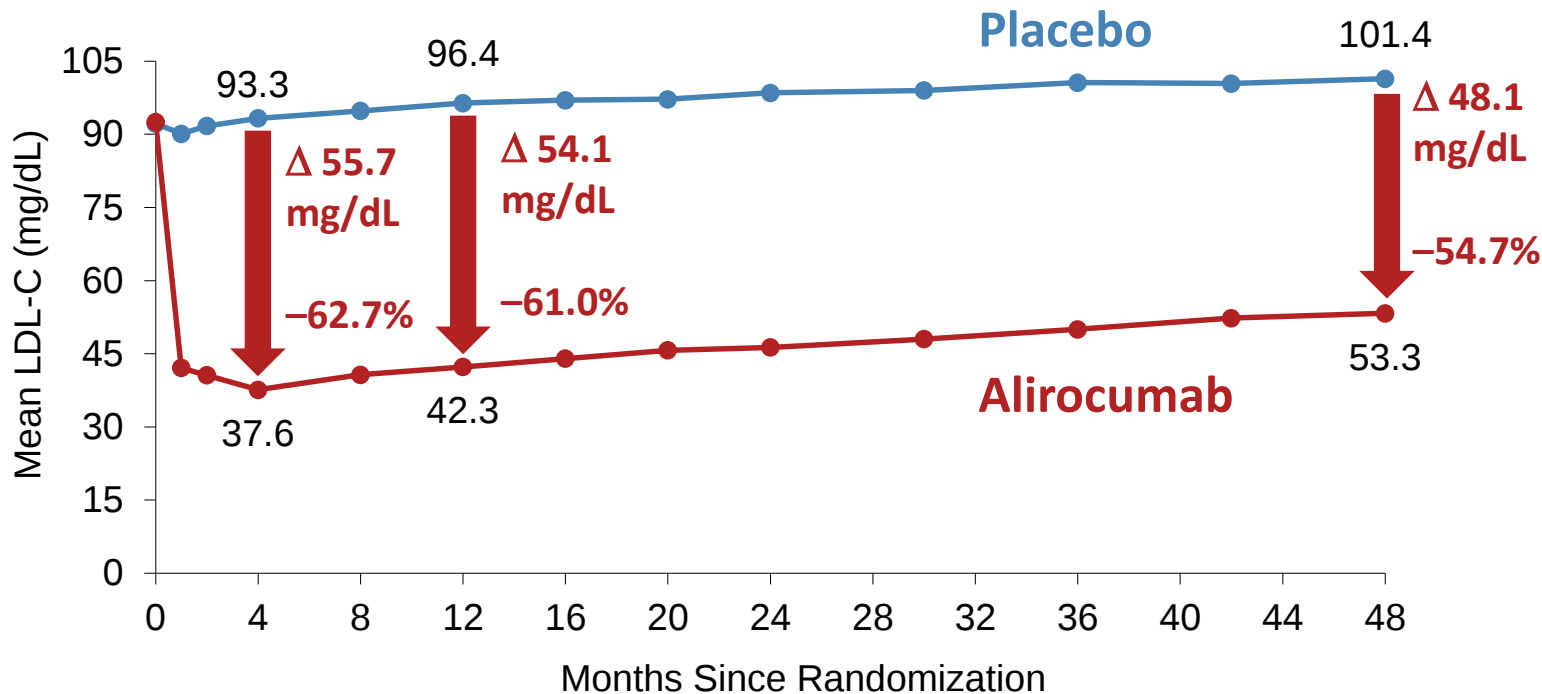
LDL-C: ITT and On-Treatment Analyses



*Excludes LDL-C values after premature treatment discontinuation or blinded switch to placebo

†All LDL-C values, including those after premature treatment discontinuation, blinded down titration, or blinded switch to placebo

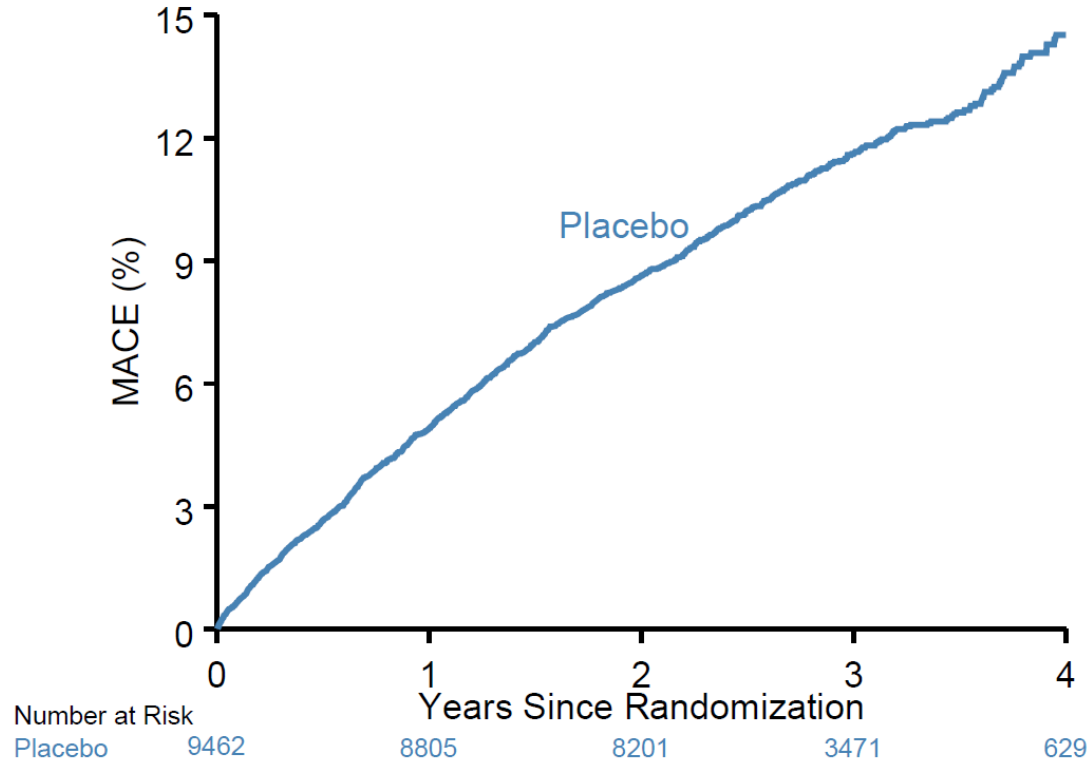
LDL-C: On-Treatment Analysis



Excludes LDL-C values after premature treatment discontinuation or blinded switch to placebo
Approximately 75% of months of active treatment were at the 75 mg dose

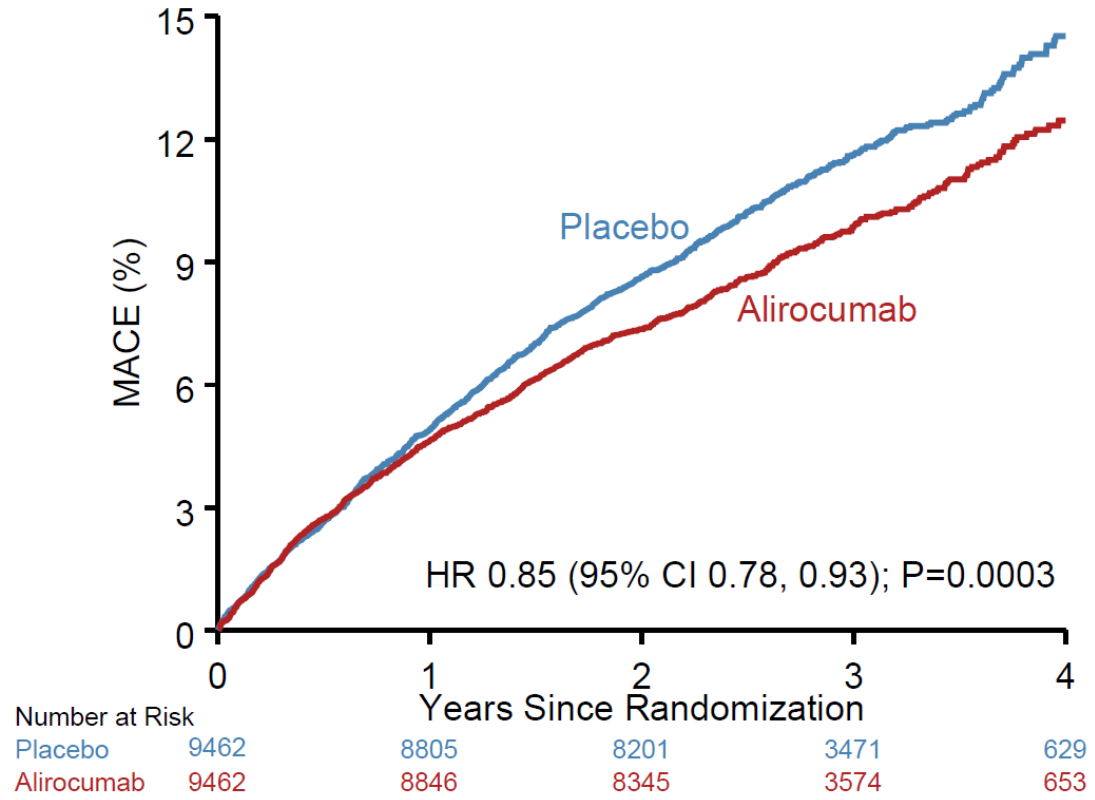
Primary Efficacy Endpoint: MACE

MACE: CHD death,
non-fatal MI,
ischemic stroke, or
unstable angina requiring
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Primary Efficacy Endpoint: MACE

MACE: CHD death, non-fatal MI, ischemic stroke, or unstable angina requiring hospitalization



ARR* 1.6%

*Based on cumulative incidence

Primary Efficacy and Components

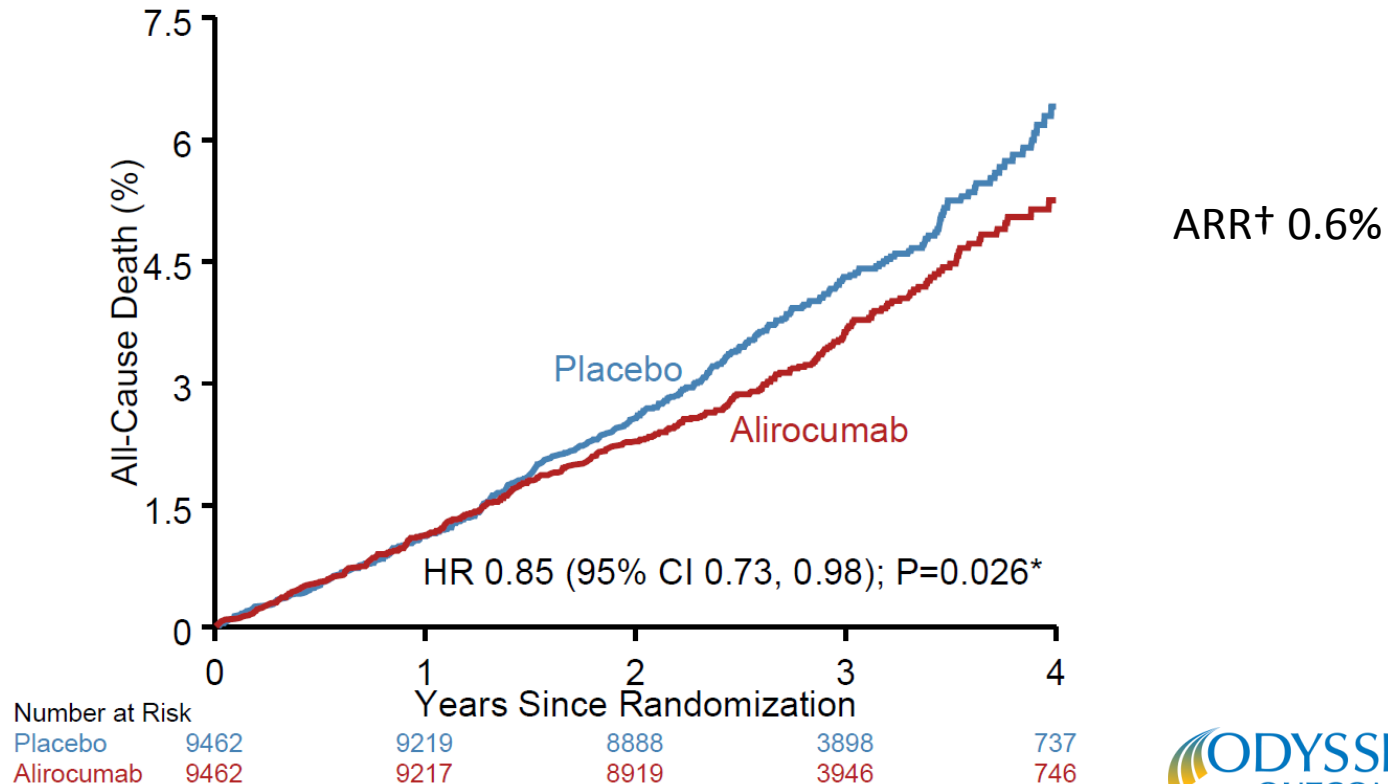
Endpoint, n (%)	Alirocumab (N=9462)	Placebo (N=9462)	HR (95% CI)	Log-rank P-value
MACE	903 (9.5)	1052 (11.1)	0.85 (0.78, 0.93)	0.0003
CHD death	205 (2.2)	222 (2.3)	0.92 (0.76, 1.11)	0.38
Non-fatal MI	626 (6.6)	722 (7.6)	0.86 (0.77, 0.96)	0.006
Ischemic stroke	111 (1.2)	152 (1.6)	0.73 (0.57, 0.93)	0.01
Unstable angina	37 (0.4)	60 (0.6)	0.61 (0.41, 0.92)	0.02

Main Secondary Efficacy Endpoints: Hierarchical Testing

Endpoint, n (%)	Alirocumab (N=9462)	Placebo (N=9462)	HR (95% CI)	Log-rank P-value
CHD event	1199 (12.7)	1349 (14.3)	0.88 (0.81, 0.95)	0.001
Major CHD event	793 (8.4)	899 (9.5)	0.88 (0.80, 0.96)	0.006
CV event	1301 (13.7)	1474 (15.6)	0.87 (0.81, 0.94)	0.0003
Death, MI, ischemic stroke	973 (10.3)	1126 (11.9)	0.86 (0.79, 0.93)	0.0003
CHD death	205 (2.2)	222 (2.3)	0.92 (0.76, 1.11)	0.38
CV death	240 (2.5)	271 (2.9)	0.88 (0.74, 1.05)	0.15
All-cause death	334 (3.5)	392 (4.1)	0.85 (0.73, 0.98)	0.026*

*Nominal P-value

All-Cause Death



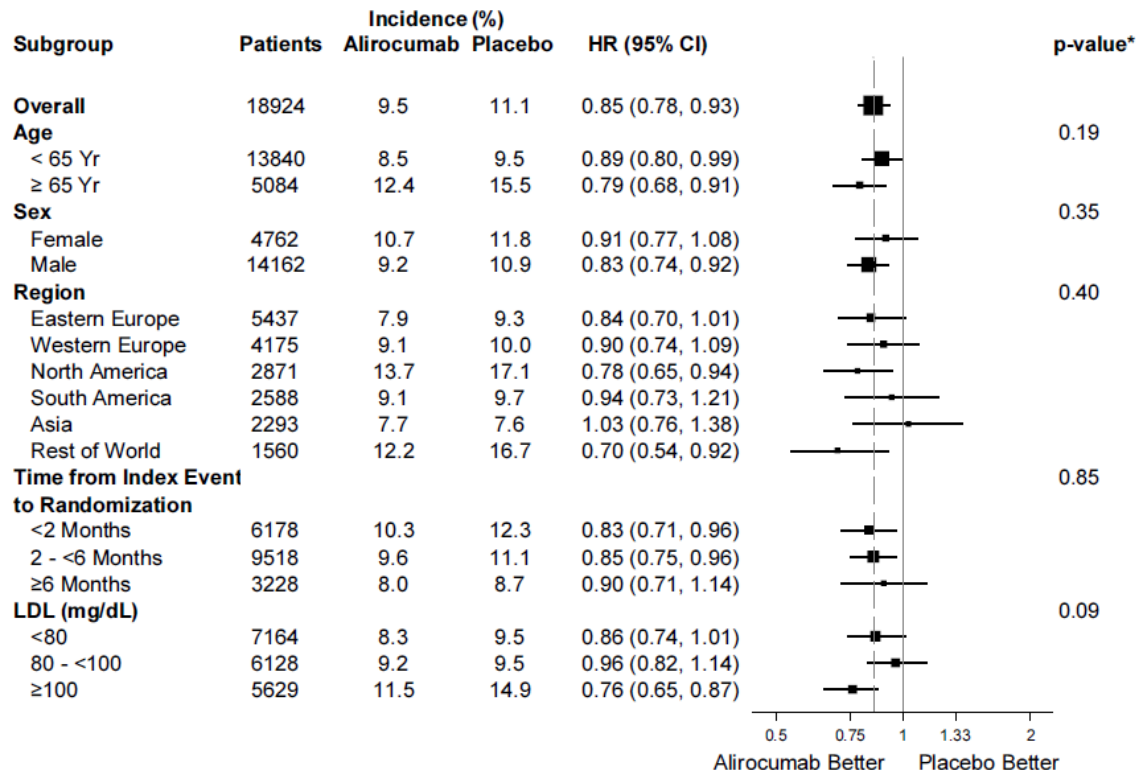
*Nominal P-value

†Based on cumulative incidence

Other Efficacy Endpoints

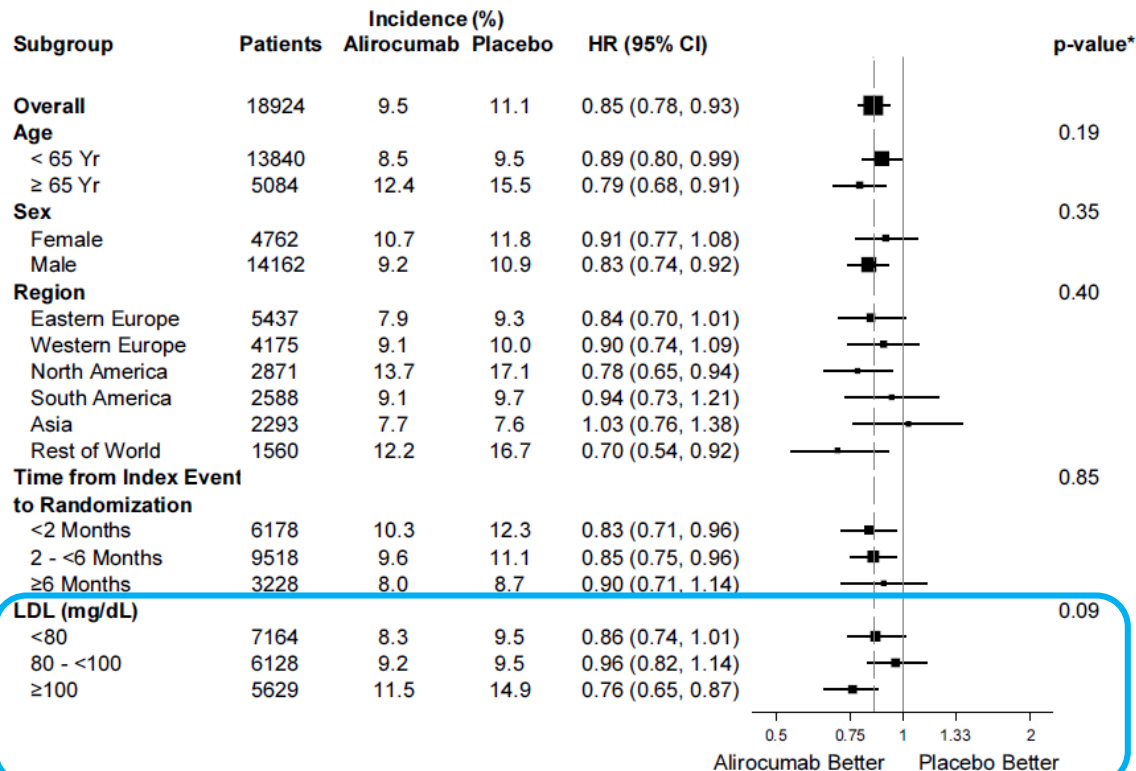
Endpoint n (%)	Alirocumab (N=9462)	Placebo (N=9462)	HR (95% CI)	Log-rank P-value
Ischemia-driven coronary revascularization	731 (7.7)	828 (8.8)	0.88 (0.79, 0.97)	0.009
Hospitalization for CHF	176 (1.9)	179 (1.9)	0.98 (0.79, 1.20)	0.84

Primary Efficacy in Main Prespecified Subgroups



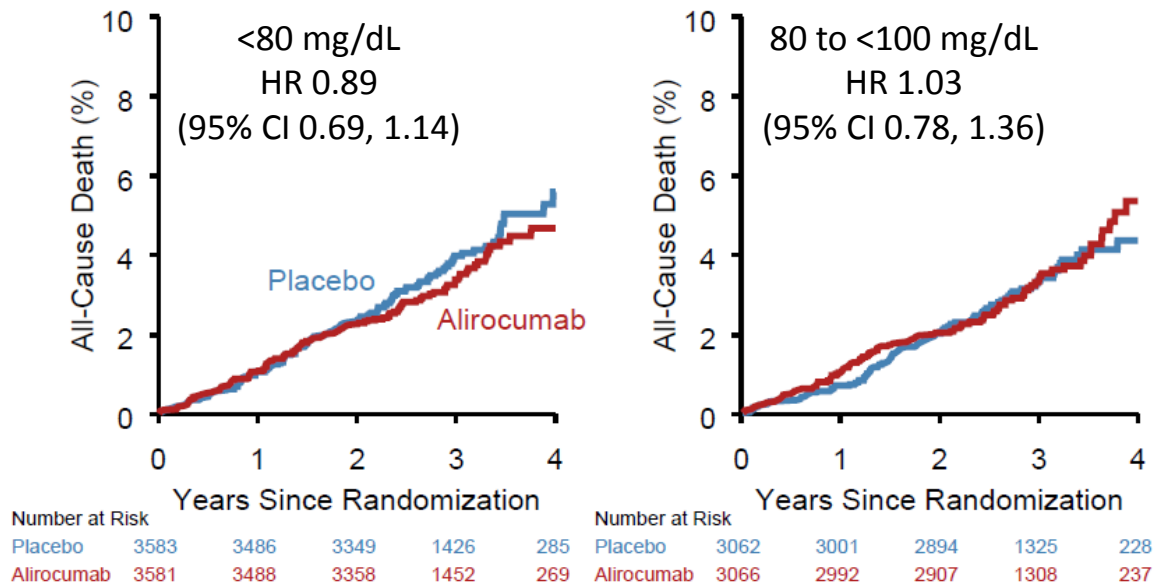
*P-values for interaction

Primary Efficacy in Main Prespecified Subgroups



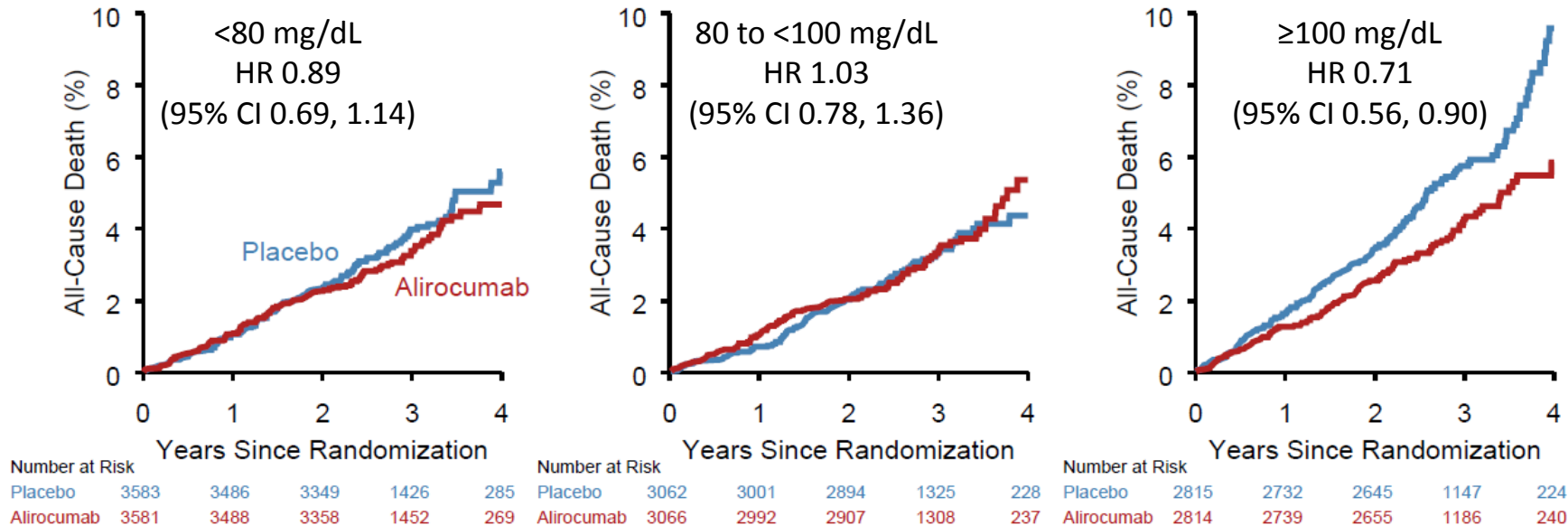
*P-values for interaction

Post Hoc Analysis: All-Cause Death by *Prespecified* Baseline LDL-C Subgroups



Post Hoc Analysis: All-Cause Death by *Prespecified* Baseline LDL-C Subgroups

ARR* 1.7% $P_{\text{interaction}}=0.12$



*Based on cumulative incidence

Efficacy: Subgroup with Baseline LDL-C ≥ 100 mg/dL (Median Baseline LDL-C 118 mg/dL)

Endpoint, n (%)	Alirocumab (N=2814)	Placebo (N=2815)	Absolute risk reduction (%)	HR (95% CI)
MACE	324 (11.5)	420 (14.9)	3.4	0.76 (0.65, 0.87)
CHD death	69 (2.5)	96 (3.4)	1.0	0.72 (0.53, 0.98)
CV death	81 (2.9)	117 (4.2)	1.3	0.69 (0.52, 0.92)
All-cause death	114 (4.1)	161 (5.7)	1.7	0.71 (0.56, 0.90)

Safety (1)

Treatment-emergent adverse events, n (%)	Alirocumab (N=9451)	Placebo (N=9443)
Any	7165 (75.8)	7282 (77.1)
Serious	2202 (23.3)	2350 (24.9)

Laboratory value	Alirocumab	Placebo
ALT >3 × ULN, n/N (%)	212/9369 (2.3)	228/9341 (2.4)
Creatine kinase >10 × ULN, n/N (%)	46/9369 (0.5)	48/9338 (0.5)

Safety (2)

Event	Alirocumab (N=9451)	Placebo (N=9443)
Diabetes worsening or diabetic complications: <i>pts w/DM at baseline</i> , n/N (%)	506/2688 (18.8)	583/2747 (21.2)
New onset diabetes; <i>pts w/o DM at baseline</i> , n/N (%)	648/6763 (9.6)	676/6696 (10.1)
General allergic reaction, n (%)	748 (7.9)	736 (7.8)
Hepatic disorder, n (%)	500 (5.3)	534 (5.7)
Local injection site reaction, n (%)*	360 (3.8)	203 (2.1)
Neurocognitive disorder, n (%)	143 (1.5)	167 (1.8)
Cataracts, n (%)	120 (1.3)	134 (1.4)
Hemorrhagic stroke, n (%)	9 (<0.1)	16 (0.2)

*HR vs. placebo 1.82 (95% CI 1.54, 2.17)

Conclusions

Compared with placebo in patients with recent ACS, alirocumab 75 or 150 mg Q2W targeting LDL-C levels 25–50 mg/dL, and allowing levels as low as 15 mg/dL:

1. Reduced MACE, MI, and ischemic stroke
2. Was associated with a lower rate of all-cause death
3. Was safe and well-tolerated over the duration of the trial

Clinical Implications

- In this nearly 19,000-patient placebo-controlled trial, including many patients treated for ≥ 3 years, there was no safety signal with alirocumab other than injection site reactions

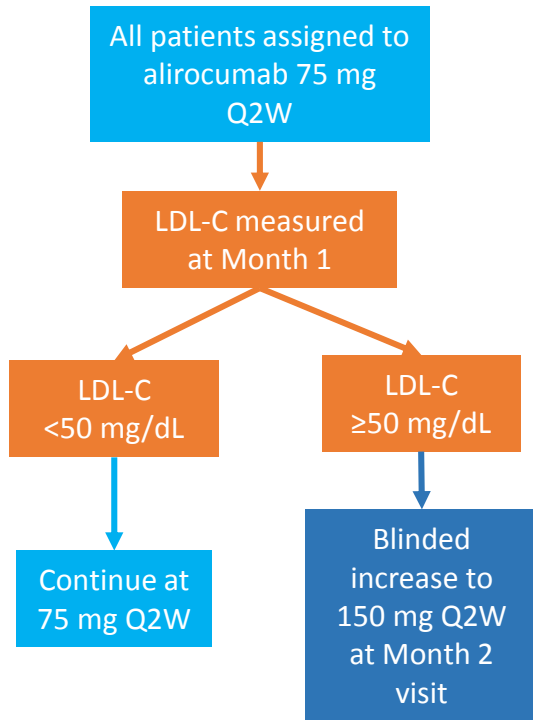
Clinical Implications

- In this nearly 19,000-patient placebo-controlled trial, including many patients treated for ≥ 3 years, there was no safety signal with alirocumab other than injection site reactions
- Among patients with ACS and baseline LDL-C ≥ 100 mg/dL, alirocumab reduced MACE by 24% (ARR 3.4%) and all-cause death by 29% (ARR 1.7%) compared with placebo
 - These are the patients who may benefit most from treatment

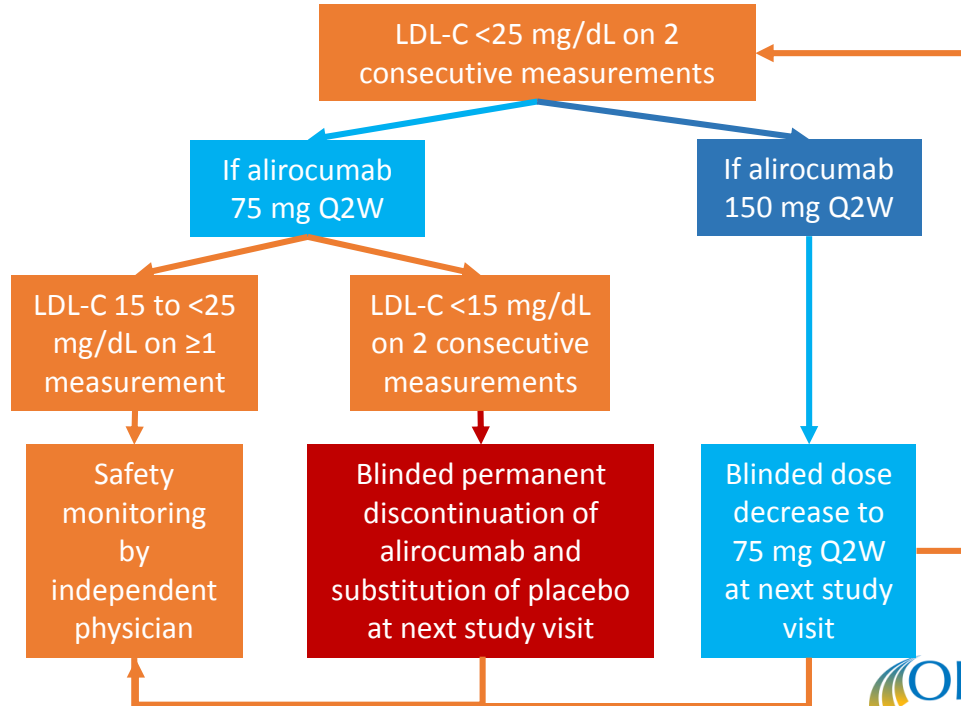
Backup

Blinded Alirocumab Dose Adjustments

Up-titration of alirocumab for LDL-C ≥ 50 mg/dL



Down-titration of alirocumab and/or safety monitoring for LDL-C <25 mg/dL



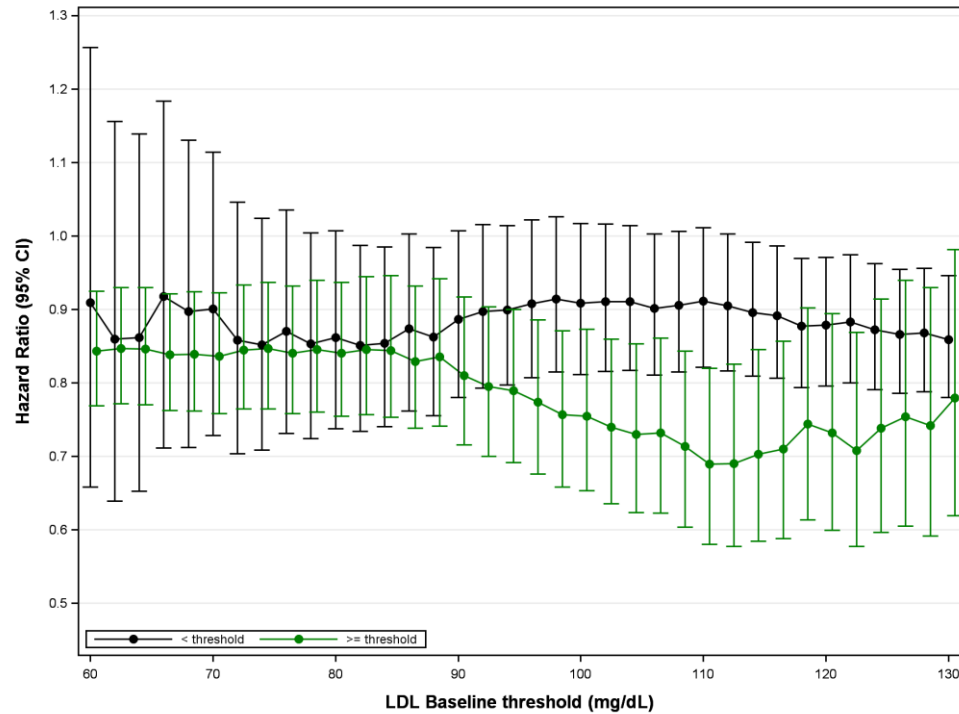
	FOURIER	ODYSSEY OUTCOMES
Population	Stable ASCVD	Recent ACS
Qualifying LDL-C, mg/dL	≥70	≥70
Primary endpoint	<u>5-point MACE:</u> CV death, MI, CVA, UA, coronary revasc.	<u>4-point MACE:</u> CHD death, MI, CVA, UA
Follow up	26 months	34 months
Age (median, years)	63	58
ACS <1 year	20%	100%
High-intensity statin	69%	89%
No statin	0.2%	2.5%

Outcomes relative risk reduction	FOURIER	ODYSSEY OUTCOMES
Primary endpoint	15%	15%
MI	27%	14%
Stroke	21%	27%
Unstable angina	1%	39%
CV death	+5% increase (NS)	12% (NS)
All cause death	+4% increase (NS)	15% (p=0.026*)

Main Outcomes

Overall cohort						
Endpoint, n (%)	Alirocumab (N=9462)	Placebo (N=9462)	ARR	NNT	HR (95% CI)	Log-rank P-value
MACE	903 (9.5)	1052 (11.1)	1.6%	64	0.85 (0.78, 0.93)	0.0003
All-cause death	334 (3.5)	392 (4.1)	0.6%	163	0.85 (0.73, 0.98)	0.026*
Patients with baseline LDL-C $\geq$ 100 mg/dL						
Endpoint, n (%)	Alirocumab (N=2814)	Placebo (N=2815)	ARR	NNT	HR (95% CI)	
MACE	324 (11.5)	420 (14.9)	3.4%	29	0.76 (0.65–0.87)	
All-cause death	114 (4.1)	161 (5.7)	1.7%	60	0.71 (0.56–0.90)	

Time to First Occurrence of MACE (Primary Endpoint) Per CEC, According to Baseline LDL-C (ITT Population)

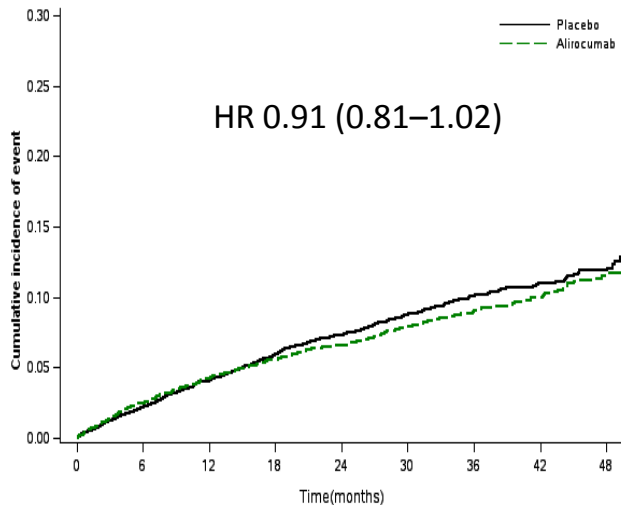


MACE Benefit Largely Driven by Patients With Baseline LDL-C ≥ 100 mg/dL

Baseline LDL-C <100 mg/dL

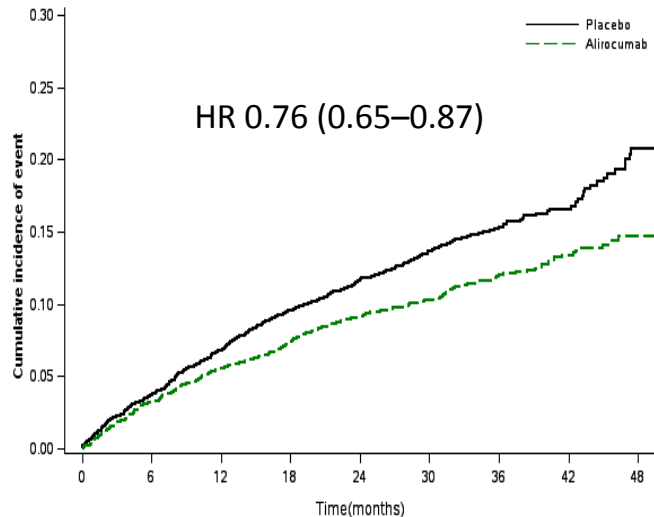
$P_{\text{interaction}} = 0.05$

Baseline LDL-C ≥ 100 mg/dL



Number at Risk

Placebo	6647	6478	6235	5947	5830	3942	2485	1279	451
Alirocumab	6648	6468	6243	6004	5914	3995	2521	1292	446



Number at Risk

Placebo	2815	2694	2567	2443	2368	1616	986	515	178
Alirocumab	2814	2710	2600	2496	2429	1692	1053	564	207

Primary endpoint: time to first occurrence of MACE (Kaplan-Meier cumulative incidence curve in ITT population)

Landmark Analysis (Post Hoc)

	All patients			Patients with ≥ 100 md/dL LDL-C at baseline		
	Overall HR	0-12 Months	Beyond 12 months	Overall HR	0-12 Months	Beyond 12 months
Time to first MACE event	0.85 (0.78–0.93)	0.94 (0.83–1.08)	0.77 (0.69–0.87)	0.76 (0.65–0.87)	0.81 (0.66–1.01)	0.71 (0.58–0.87)
Time to first all-cause death	0.85 (0.73–0.98)	1.01 (0.77–1.32)	0.79 (0.66–0.94)	0.71 (0.56–0.90)	0.79 (0.51–1.22)	0.67 (0.50–0.89)