Lipid lowering therapy, low-density lipoprotein level and risk of intracerebral hemorrhage – a meta-analysis

Full title

Lipid lowering therapy, LDL level and risk of intracerebral haemorrhage – a meta-analysis

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Abstract

Background

The association of lipid lowering therapy and intracerebral haemorrhage risk is controversial.

Methods

We performed a cumulative meta-analysis of lipid lowering trials that reported intracerebral haemorrhage. Statin, fibrate, ezetimibe, PCSK9 and CETP trials were included. We explored whether the association of lipid lowering therapy and risk of intracerebral haemorrhage may vary by baseline LDL level, mean change in LDL or baseline cardiovascular risk of population.

Results

Among 39 trials (287,651 participants), lipid lowering therapy was not associated with a statistically significant increased risk of ICH in primary and secondary prevention trials combined (odds ratio, 1.12; 95% CI, 0.98 to 1.28). Lipid lowering was associated with an increased risk of ICH in secondary prevention trials (odds ratio, 1.18; 95% CI, 1.00 to 1.38), but not in primary prevention trials (odds ratio, 1.01; 95% CI, 0.78 to 1.30), but the test for interaction was not significant (P for interaction = 0.31). Meta-regression of baseline LDL or difference in LDL reduction between active and control did not explain significant heterogeneity between studies for ICH risk. Of 1,000 individuals treated for one year for secondary prevention, we estimated 9.17 (95% CI, 5.78 to 12.66) fewer ischemic strokes and 0.48 (95% CI, 0.06 to 1.02) more ICH, and a net reduction of 8.69 in all stroke per 1,000 person-years.

Conclusion

The benefits of lipid lowering therapy in prevention of ischemic stroke greatly exceed the risk of ICH. Concern about ICH should not discourage stroke clinicians from prescribing lipid lowering therapy for secondary prevention of ischemic stroke.

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Introduction

Randomised controlled trials have shown that low-density lipoprotein cholesterol (LDL-C) lowering with statins (3-hydroxy-3-methylglutaryl–coenzyme A reductase inhibitors) reduce the risk of ischaemic stroke (1), but there is controversy about whether lipid lowering agents increase the risk of intracerebral haemorrhage (ICH) (2,3). While epidemiological studies report a positive association between high serum LDL-C and ischaemic stroke (4–6), the association with LDL-C and ICH appears inverse (6–8).

Prior meta-analyses, evaluating the association of statin therapy and ICH, have reported no overall increase in risk of ICH (10), although one large trial reported an increased risk of ICH among those randomised to high-dose statin therapy (11). Proposed mechanisms, through which an increased risk of ICH may be mediated, include low levels of LDL-C weakening the endothelium of intracerebral arteries, causing haemorrhagic stroke in the setting of hypertension (6). Another potential mechanism is the pleiotropic antiplatelet/antithrombotic effect of lipid lowering therapies, especially statins (12). To date, meta-analyses of randomized controlled trials evaluating statin therapy, have reported on the risk of ICH, but have not explored all lipid lowering therapies and whether baseline LDL, or cardiovascular risk changes the association of all lipid lowering therapies with ICH.

In this meta-analysis of lipid lowering phase III trials, we sought to determine whether lipid lowering therapy increased the risk of ICH overall, and within pre-specified subgroups of participants (i.e. those with lower baseline LDL-C level, larger magnitude of LDL reduction and prior cardiovascular disease).

Methods

Cumulative meta-analysis

We extracted data from two previous meta-analyses: one of randomised controlled trials of statin therapy for cardiovascular prevention, reporting ICH outcomes (10) and the other of randomized controlled trials of fibrates for prevention of cardiovascular outcomes, reporting ICH (14). We limited our search to dates not included in these reviews (2012 – 2018) and repeated primary data extraction for all papers to confirm accuracy.

Selection Criteria

We performed a systematic review, adhering to the PRISMA guidelines (15), to select randomised controlled trials of lipid lowering therapy that reported haemorrhagic stroke on follow-up. We included all trials with: subjects > 18 years, lipid lowering therapy and haemorrhagic stroke outcome data. We limited our search to published, peer-reviewed studies in English.

Search strategy

We developed a search strategy for the PUBMED database. The database was searched from Jan 2012 to May 2018. Four reviewers (CJ, SR, MC, RM) independently screened titles and abstracts. Full texts were sourced for relevant articles. Inclusion criteria were assessed independently, and the final list was agreed by consensus. We also screened the reference list of similar review articles and earlier published meta-analyses obtained in our search.

Data extraction

For each study, we extracted the title, year of publication, active and control numbers, major bleeding and stroke outcome data. Stroke outcome was classified as either ischaemic or haemorrhagic, if available. We also collected baseline mean LDL-C, mean HDL-C and change in LDL-C from baseline to follow-up (if available). We labelled the studies as either

primary or secondary prevention. We used a definition of greater than fifty percent baseline cardiovascular disease (stroke, myocardial infarction) as our secondary prevention cut-off. Reviewers independently extracted data, compared for inconsistencies, and merged into a final data set.

Data synthesis and analysis

We present a descriptive analysis of each individual trial and summarise this analysis in both table (Supplementary Table I) and figures (Figure 1-3). We calculated odds ratio (OR) and 95% confidence intervals from individual studies. Weighted pooled treatment effects were calculated using a random effects model. The variability across studies due to heterogeneity was estimated with the I^2 statistic. We tested for an interaction between subgroup relative risks by dividing the difference in log relative risk by its standard error (16). Statistical analysis was performed using the Metafor package (17) on R Statistical Software (V3.4.3).

Results

In total, thirty-nine randomised controlled trials were eligible that recruited 287,651 participants and reported 27,376 deaths, 7092 ischaemic strokes and 1035 intracerebral haemorrhages. Our updated search results found 1026 studies, 974 were exclude after title and abstract screening, 29 were excluded after full text review including 18 studies that did not report intracerebral haemorrhage, leaving 5 studies for inclusion (Supplementary Figure 1). Thirty-one were trials of statins (18–28,11,29–48), four were studies of fibrates (49–52), two were studies of statins in combination with ezetimibe (50,53), one was a study of a proprotein convertase subtilisin/kexin type 9 (PCSK9) inhibitor (54) and one was a study of a cholesteryl ester transfer protein (CETP) inhibitor (55). The mean follow-up across all studies was 3.97 years. The mean age was 62.4 years in the active group and 62.4 years in the control group. 38,750 (26.9%) patients were female in the active group and 37,949 (26.4%) were female in the control group.

Meta-analysis of intracerebral haemorrhage

In all trials, ICH occurred in 549 (0.38%) patients in the active group and 486 (0.34%) patients in the control group (odds ratio, 1.12; 95% CI, 0.98 to 1.28) (Figure 1). The P for heterogeneity was 0.23, I^2=4.2%, Q=44.02, and degrees of freedom=38.

Meta-analysis of intracerebral haemorrhage (Primary and Secondary Prevention)

We repeated the analysis, separately, for primary and secondary prevention trials. Active therapy was associated with an increased risk for ICH in secondary prevention trials (odds ratio, 1.18; 95% CI, 1.00 to 1.38) (Figure 1). The P for heterogeneity was 0.2646, I^2=5.36%, Q=24.6078, and degrees of freedom=21. Active therapy was not associated with an increased risk for ICH in primary prevention trials (odds ratio, 1.01; 95% CI, 0.78 to 1.30) (Figure 1). The P for heterogeneity was 0.31, I^2=12.44%, Q=18.3126, and degrees of freedom=16. The P for interaction was not significant (0.31).

Meta-analysis of ischaemic stroke and all-cause mortality

Ischaemic stroke occurred in 3,213 (2.23%) patients in the active group and 3,879 (2.7%) patients in the control group. Lipid lowering therapy was associated with a significant decrease in ischaemic stroke (odds ratio, 0.82; 95% CI, 0.76 to 0.88) and all-cause mortality (odds ratio, 0.94; 95% CI, 0.90 to 0.98). (Figure 2 and 3).

Meta-regression - baseline LDL, LDL reduction (Active) and difference in LDL reduction between Active and Control

Three meta-regressions were performed to examine whether any between-study heterogeneity could be explained by baseline LDL-C value, mean LDL-C difference pre and post treatment and by the difference in mean LDL-C reduction between active and control treatments. The regression coefficient for baseline LDL-C was not statistically significant at 0.0005 (95% CI, -0.0044 to 0.0054, p=0.8323, I^2=7.45%) (Figure 3). The regression coefficient for mean LDL-

C difference was small and not statistically significant at 0.0039 (95% CI, -0.0050 to 0.01280, p=0.3914, I^2=0.00%) (Supplementary Figure 3). The regression coefficient for difference in LDL-C reduction was small and not statistically significant at 0.0011 (95% CI, -0.0080 to 0.0103, p=0.8068, I^2=7.88%) (Supplementary Figure 4).

Discussion

Main findings

We performed a systematic review and meta-analysis of all randomised controlled trials of lipid lowering therapy to investigate the relationship between lipid lowering and ICH. We did not find a statistically significant increased risk of ICH with lipid lowering overall (odds ratio, 1.12; 95% CI, 0.98 to 1.28), but on subgroup analysis of trials, secondary prevention was significant for lipid lowering and ICH risk in secondary prevention trials (odds ratio, 1.18; 95% CI, 1.00 to 1.38), however, the P for interaction was not significant (0.31). Lipid lowering therapy was associated with a statistically significant reduced risk of ischaemic stroke (odds ratio, 0.82; 95% CI, 0.76 to 0.88). An additional meta-regression analysis was performed: baseline LDL (active), difference in LDL reduction (active) or difference in LDL reduction between active and control did not explain significant heterogeneity between studies for ICH risk.

Prior meta-analyses have not reported an increased risk of ICH with lipid lowering (1,10,56), but these only included statin trials. In contrast, we included trials of all lipid lowering therapies on the premise that lower LDL levels may increase the risk of ICH, as suggested by epidemiologic studies (6–8), and may not be related to a class effect. Therefore, our work builds on these studies by adding data from additional statin trials since 2012 (two), lipid lowering fibrate trials (four), PCSK9 inhibitors (one), CETP inhibitors (one) and a meta-

regression of baseline LDL, LDL reduction (active) and LDL reduction between active and control.

The ICH risk becomes more apparent with an increased event rate, this occurs in two scenarios, one, when there is a higher risk of bleeding i.e. secondary prevention higher risk population and two, large studies. Supplementary figure 5 demonstrates these two scenarios by showing a linear association between ICH event rates and ischaemic stroke rates, which is expected and consistent with other epidemiological observations and relates to common risk factors for ischemic stroke and ICH.

There is uncertainty and reluctance to continue lipid lowering medications immediately post acute stroke (9). The 2013 ACC/AHA guidelines only give statin prescribing a moderate IIa rating (57). To illustrate how our findings apply to everyday clinical practice, we applied the relative risk of lipid lowering on ICH (1.12) to the absolute baseline risk of ICH from the control group of our meta-analysis (0.34%). The corresponding Number Needed to Harm (NNH) for ICH with lipid lowering was 2451 (95% CI, 1158 to 20875). We then applied the relative risk of lipid lowering on ischaemic stroke (0.82) to the baseline risk of ischaemic stroke from the control group of our meta-analysis (2.7%). The corresponding Number Needed to Treat (NNT) for preventing ischaemic stroke with lipid lowering was 206 (95% CI, 150 to 328). This means, of 1,000 individuals treated for one year with lipid lowering therapy, we estimated 9.17 (95% CI, 5.78 to 12.66) fewer ischemic strokes and 0.41 (95% CI, 0.05 to 0.86) more ICH, and a net reduction of 8.77 in all stroke per 1,000 person-years. We were unable to identify a clinical scenario that would discourage stroke clinicians from prescribing lipid lowering therapy.

Strengths and limitations

The definition of ICH varies between clinical studies and failure to classify correctly could lead to a non-differential misclassification bias. Eighteen studies did not report ICH outcome data and had to be excluded from the analysis, introducing a possible reporting bias. There was clinical heterogeneity between the participants in the selected trials, as this was not an individual participant level meta-analysis, we were unable to consider prior history of ICH. Strengths of this systematic review include the inclusion of five classes of lipid lowering drugs and subgroup analysis by prevention type and combining the relative risk reduction of lipid lowering and ICH with the absolute risk of ICH which should provide some level of reassurance to physicians with regards to the risk-benefit profile of lipid lowering in stroke patients.

Implications

In conclusion, lipid lowering therapy is not associated with a statistically significant increased risk of ICH overall. Baseline LDL level, change in LDL post treatment or difference in LDL reduction between active and control are not associated with a statistically significant increased risk of ICH.

In the general population, the benefits of lipid lowering therapy in prevention of ischemic stroke greatly exceed the risk of ICH.

Contributors

CJ, SR, MC, RM were responsible for data collection. CJ performed the analysis. All authors contributed to data interpretation and critical revision of the report.

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The corresponding author certifies that no other persons have made substantial contributions to the research and/or manuscript.

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Disclosures

All authors declare no competing interests.

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References

1. Amarenco P, Labreuche J. Lipid management in the prevention of stroke: review and updated meta-analysis of statins for stroke prevention. Lancet Neurol. 2009 May;8(5):453–63.

2. Goldstein LB. Statin Therapy Should be Discontinued in Patients With Intracerebral Hemorrhage. Stroke. 2013 Jul 1;44(7):2058–9.

3. Bustamante A, Montaner J. Statin Therapy Should Not be Discontinued in Patients With Intracerebral Hemorrhage. Stroke. 2013 Jul 1;44(7):2060–1.

4. Leppala JM, Virtamo J, Fogelholm R, Albanes D, Heinonen OP. Different Risk Factors for Different Stroke Subtypes : Association of Blood Pressure, Cholesterol, and Antioxidants. Stroke. 1999 Dec 1;30(12):2535–40.

5. Ebrahim S, Sung J, Song Y-M, Ferrer RL, Lawlor DA, Davey Smith G. Serum cholesterol, haemorrhagic stroke, ischaemic stroke, and myocardial infarction: Korean national health system prospective cohort study. BMJ. 2006 Jul 1;333(7557):22.

6. Iso H, Jacobs DR, Wentworth D, Neaton JD, Cohen JD, for the MRFIT Research Group*. Serum Cholesterol Levels and Six-Year Mortality from Stroke in 350,977 Men Screened for the Multiple Risk Factor Intervention Trial. N Engl J Med. 1989 Apr 6;320(14):904–10.

7. Reed DM. The paradox of high risk of stroke in populations with low risk of coronary heart disease. Am J Epidemiol. 1990 Apr;131(4):579–88.

8. Yano K, Reed DM, MacLean CJ. Serum cholesterol and hemorrhagic stroke in the Honolulu Heart Program. Stroke. 1989 Nov;20(11):1460–5.

9. Fitzgerald C. Use of High-Intensity Statin in Patients with Ischemic Stroke: Observation and Opinion of a Clinical Pharmacist in the Inpatient Setting. Austin J Pharmacol Ther. 2014 Nov 10;2(11).

10. McKinney JS, Kostis WJ. Statin therapy and the risk of intracerebral hemorrhage: a meta-analysis of 31 randomized controlled trials. Stroke. 2012 Aug;43(8):2149–56.

11. The Stroke Prevention by Aggressive Reduction in Cholesterol Levels (SPARCL) Investigators. High-Dose Atorvastatin after Stroke or Transient Ischemic Attack. N Engl J Med. 2006 Aug 10;355(6):549–59.

12. Mitsios JV, Papathanasiou AI, Goudevenos JA, Tselepis AD. The antiplatelet and antithrombotic actions of statins. Curr Pharm Des. 2010;16(34):3808–14.

13. Clarke M, Brice A, Chalmers I. Accumulating Research: A Systematic Account of How Cumulative Meta-Analyses Would Have Provided Knowledge, Improved Health, Reduced Harm and Saved Resources. Gluud LL, editor. PLoS ONE. 2014 Jul 28;9(7):e102670.

14. Jun M, Foote C, Lv J, Neal B, Patel A, Nicholls SJ, et al. Effects of fibrates on cardiovascular outcomes: a systematic review and meta-analysis. Lancet Lond Engl. 2010 May 29;375(9729):1875–84.

15. Moher D. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. Ann Intern Med. 2009 Aug 18;151(4):264.

16. Altman DG, Bland JM. Interaction revisited: the difference between two estimates. BMJ. 2003 Jan 25;326(7382):219.

17. Viechtbauer W. Conducting Meta-Analyses in *R* with the **metafor** Package. J Stat Softw [Internet]. 2010 [cited 2018 May 13];36(3). Available from: http://www.jstatsoft.org/v36/i03/

18. Ito H, Ouchi Y, Ohashi Y, Saito Y, Ishikawa T, Nakamura H, et al. A Comparison of Low Versus Standard Dose Pravastatin Therapy for the Prevention of Cardiovascular Events in the Elderly : The Pravastatin Anti-atherosclerosis Trial in the Elderly (PATE). J Atheroscler Thromb. 2001;8(2):33–44.

19. Wanner C, Krane V, März W, Olschewski M, Mann JFE, Ruf G, et al. Atorvastatin in Patients with Type 2 Diabetes Mellitus Undergoing Hemodialysis. N Engl J Med. 2005 Jul 21;353(3):238–48.

20. Yusuf S, Bosch J, Dagenais G, Zhu J, Xavier D, Liu L, et al. Cholesterol Lowering in Intermediate-Risk Persons without Cardiovascular Disease. N Engl J Med. 2016 May 26;374(21):2021–31.

21. de Lemos JA, Blazing MA, Wiviott SD, Lewis EF, Fox KAA, White HD, et al. Early Intensive vs a Delayed Conservative Simvastatin Strategy in Patients With Acute Coronary Syndromes: Phase Z of the A to Z Trial. JAMA. 2004 Sep 15;292(11):1307.

22. Holdaas H, Fellström B, Jardine AG, Holme I, Nyberg G, Fauchald P, et al. Effect of fluvastatin on cardiac outcomes in renal transplant recipients: a multicentre, randomised, placebo-controlled trial. The Lancet. 2003 Jun;361(9374):2024–31.

23. Furberg CD, Adams HP, Applegate WB, Byington RP, Espeland MA, Hartwell T, et al. Effect of lovastatin on early carotid atherosclerosis and cardiovascular events. Asymptomatic Carotid Artery Progression Study (ACAPS) Research Group. Circulation. 1994 Oct 1;90(4):1679–87.

24. GISSI-HF investigators. Effect of rosuvastatin in patients with chronic heart failure (the GISSI-HF trial): a randomised, double-blind, placebo-controlled trial. The Lancet. 2008 Oct;372(9645):1231–9.

25. Bone HG, Kiel DP, Lindsay RS, Lewiecki EM, Bolognese MA, Leary ET, et al. Effects of Atorvastatin on Bone in Postmenopausal Women with Dyslipidemia: A Double-Blind, Placebo-Controlled, Dose-Ranging Trial. J Clin Endocrinol Metab. 2007 Dec;92(12):4671–7.

26. Schwartz GG. Effects of Atorvastatin on Early Recurrent Ischemic Events in Acute Coronary SyndromesThe MIRACL Study: A Randomized Controlled Trial. JAMA. 2001 Apr 4;285(13):1711.

27. Kleemann A. Effects of lovastatin on progression of non-dilated and dilated coronary segments and on restenosis in patients after PTCA. The Cholesterol Lowering Atherosclerosis PTCA Trial (CLAPT). Eur Heart J. 1999 Oct;20(19):1393–406.

28. Knopp RH, d'Emden M, Smilde JG, Pocock SJ, on behalf of the ASPEN Study Group. Efficacy and Safety of Atorvastatin in the Prevention of Cardiovascular End Points in Subjects With Type 2 Diabetes: The Atorvastatin Study for Prevention of Coronary Heart Disease Endpoints in Non-Insulin-Dependent Diabetes Mellitus (ASPEN). Diabetes Care. 2006 Jul 1;29(7):1478–85.

29. Pedersen TR. High-Dose Atorvastatin vs Usual-Dose Simvastatin for Secondary Prevention After Myocardial InfarctionThe IDEAL Study: A Randomized Controlled Trial. JAMA. 2005 Nov 16;294(19):2437.

30. LaRosa JC, Grundy SM, Waters DD, Shear C, Barter P, Fruchart J-C, et al. Intensive Lipid Lowering with Atorvastatin in Patients with Stable Coronary Disease. N Engl J Med. 2005 Apr 7;352(14):1425–35.

31. Study of the Effectiveness of Additional Reductions in Cholesterol and Homocysteine (SEARCH) Collaborative Group. Intensive lowering of LDL cholesterol with 80 mg versus 20 mg simvastatin daily in 12 064 survivors of myocardial infarction: a double-blind randomised trial. The Lancet. 2010 Nov;376(9753):1658–69.

32. Cannon CP, Braunwald E, McCabe CH, Rader DJ, Rouleau JL, Belder R, et al. Intensive versus Moderate Lipid Lowering with Statins after Acute Coronary Syndromes. N Engl J Med. 2004 Apr 8;350(15):1495–504.

33. The ALLHAT Officers and Coordinators for the ALLHAT Collaborative Research Group. Major Outcomes in Moderately Hypercholesterolemic, Hypertensive Patients Randomized to Pravastatin vs Usual Care: The Antihypertensive and Lipid-Lowering Treatment to Prevent Heart Attack Trial (ALLHAT-LLT). JAMA J Am Med Assoc. 2002 Dec 18;288(23):2998–3007.

34. MRC/BHF Heart Protection Study of cholesterol lowering with simvastatin in 20 536 high-risk individuals: a randomised placebocontrolled trial. The Lancet. 2002 Jul;360(9326):7–22.

35. Shepherd J, Blauw GJ, Murphy MB, Bollen EL, Buckley BM, Cobbe SM, et al. Pravastatin in elderly individuals at risk of vascular disease (PROSPER): a randomised controlled trial. The Lancet. 2002 Nov;360(9346):1623–30.

36. Prevention of Cardiovascular Events and Death with Pravastatin in Patients with Coronary Heart Disease and a Broad Range of Initial Cholesterol Levels. N Engl J Med. 1998 Nov 5;339(19):1349–57.

37. Sever PS, Dahlöf B, Poulter NR, Wedel H, Beevers G, Caulfield M, et al. Prevention of coronary and stroke events with atorvastatin in hypertensive patients who have average or lower-than-average cholesterol concentrations, in the Anglo-Scandinavian Cardiac Outcomes Trial—Lipid Lowering Arm (ASCOT-LLA): a multicentre randomised controlled trial. The Lancet. 2003 Apr;361(9364):1149–58.

38. Downs JR, Clearfield M, Weis S, Whitney E, Shapiro DR, Beere PA, et al. Primary Prevention of Acute Coronary Events With Lovastatin in Men and Women With Average Cholesterol Levels: Results of AFCAPS/TexCAPS. JAMA. 1998 May 27;279(20):1615.

39. Colhoun HM, Betteridge DJ, Durrington PN, Hitman GA, W Neil HA, Livingstone SJ, et al. Primary prevention of cardiovascular disease with atorvastatin in type 2 diabetes in the Collaborative Atorvastatin Diabetes Study (CARDS): multicentre randomised placebo-controlled trial. The Lancet. 2004 Aug;364(9435):685–96.

40. Nakamura H, Arakawa K, Itakura H, Kitabatake A, Goto Y, Toyota T, et al. Primary prevention of cardiovascular disease with pravastatin in Japan (MEGA Study): a prospective randomised controlled trial. The Lancet. 2006 Sep;368(9542):1155–63.

41. Scandinaviansimvastatinsurvival. Randomised trial of cholesterol lowering in 4444 patients with coronary heart disease: the Scandinavian Simvastatin Survival Study (4S). The Lancet [Internet]. 1994 Nov [cited 2018 Apr 6];344(8934). Available from: http://linkinghub.elsevier.com/retrieve/pii/S0140673694905665

42. Results of the low-dose (20 mg) pravastatin GISSI Prevenzione trial in 4271 patients with recent myocardial infarction: do stopped trials contribute to overall knowledge? GISSI Prevenzione Investigators (Gruppo Italiano per lo Studio della Sopravvivenza nell'Infarto Miocardico). Ital Heart J Off J Ital Fed Cardiol. 2000 Dec;1(12):810–20.

43. Fellström BC, Jardine AG, Schmieder RE, Holdaas H, Bannister K, Beutler J, et al. Rosuvastatin and Cardiovascular Events in Patients Undergoing Hemodialysis. N Engl J Med. 2009 Apr 2;360(14):1395–407.

44. Kjekshus J, Apetrei E, Barrios V, Böhm M, Cleland JGF, Cornel JH, et al. Rosuvastatin in Older Patients with Systolic Heart Failure. N Engl J Med. 2007 Nov 29;357(22):2248–61.

45. Ridker PM, Danielson E, Fonseca FAH, Genest J, Gotto AM, Kastelein JJP, et al. Rosuvastatin to Prevent Vascular Events in Men and Women with Elevated C-Reactive Protein. N Engl J Med. 2008 Nov 20;359(21):2195–207.

46. Sacks FM, Pfeffer MA, Moye LA, Rouleau JL, Rutherford JD, Cole TG, et al. The Effect of Pravastatin on Coronary Events after Myocardial Infarction in Patients with Average Cholesterol Levels. N Engl J Med. 1996 Oct 3;335(14):1001–9.

47. Hosomi N, Nagai Y, Kohriyama T, Ohtsuki T, Aoki S, Nezu T, et al. The Japan Statin Treatment Against Recurrent Stroke (J-STARS): A Multicenter, Randomized, Open-label, Parallel-group Study. EBioMedicine. 2015 Sep;2(9):1071–8.

48. Treatment with atorvastatin to the national cholesterol educational program goals versus usual care in secondary coronary heart disease prevention. The greek atorvastatin on coronary-heart-disease evaluation (greace) study. Atheroscler Suppl. 2002 Oct;3(2):70.

49. Effects of long-term fenofibrate therapy on cardiovascular events in 9795 people with type 2 diabetes mellitus (the FIELD study): randomised controlled trial. The Lancet. 2005 Nov;366(9500):1849–61.

50. Cannon CP, Blazing MA, Giugliano RP, McCagg A, White JA, Theroux P, et al. Ezetimibe Added to Statin Therapy after Acute Coronary Syndromes. N Engl J Med. 2015 Jun 18;372(25):2387–97.

51. Frick MH, Elo O, Haapa K, Heinonen OP, Heinsalmi P, Helo P, et al. Helsinki Heart Study: Primary-Prevention Trial with Gemfibrozil in Middle-Aged Men with Dyslipidemia. N Engl J Med. 1987 Nov 12;317(20):1237–45.

52. THE VETERANS ADMINISTRATION COOPERATIVE STUDY GROUP. The Treatment of Cerebrovascular Disease With Clofibrate: Final Report of the Veterans Administration Cooperative Study of Atherosclerosis, Neurology Section. Stroke. 1973 Jul 1;4(4):684–93.

53. Baigent C, Landray MJ, Reith C, Emberson J, Wheeler DC, Tomson C, et al. The effects of lowering LDL cholesterol with simvastatin plus ezetimibe in patients with chronic kidney disease (Study of Heart and Renal Protection): a randomised placebo-controlled trial. The Lancet. 2011 Jun;377(9784):2181–92.

54. Sabatine MS, Giugliano RP, Keech AC, Honarpour N, Wiviott SD, Murphy SA, et al. Evolocumab and Clinical Outcomes in Patients with Cardiovascular Disease. N Engl J Med. 2017 04;376(18):1713–22.

55. HPS3/TIMI55–REVEAL Collaborative Group, Bowman L, Hopewell JC, Chen F, Wallendszus K, Stevens W, et al. Effects of Anacetrapib in Patients with Atherosclerotic Vascular Disease. N Engl J Med. 2017 28;377(13):1217–27.

56. Cholesterol Treatment Trialists' (CTT) Collaboration. Efficacy and safety of more intensive lowering of LDL cholesterol: a meta-analysis of data from 170 000 participants in 26 randomised trials. The Lancet. 2010 Nov;376(9753):1670–81.

57. Jauch EC, Saver JL, Adams HP, Bruno A, Connors JJ, Demaerschalk BM, et al. Guidelines for the Early Management of Patients With Acute Ischemic Stroke: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. Stroke. 2013 Mar 1;44(3):870–947.

58. Delgado-Rodriguez M. Bias. J Epidemiol Community Health. 2004 Aug 1;58(8):635–41.

Figure Legends

Figure 1 – Lipid lowering and intracerebral haemorrhage

Figure 1 - Forest plot for intracerebral haemorrhage. Forest plot showing the effect of lipid lowering therapy on intracerebral haemorrhage. The forest plot is divided in two sections according to type of prevention trial a) primary b) secondary. The squares and bars represent the mean values and 95% confidence intervals of the effect sizes, while the size of the squares reflects the weight of the studies. The combined effects (sub-summary and summary) appear as diamonds and the vertical dashed line represents the line of no effect.

Figure 2 – Lipid lowering and ischaemic stroke

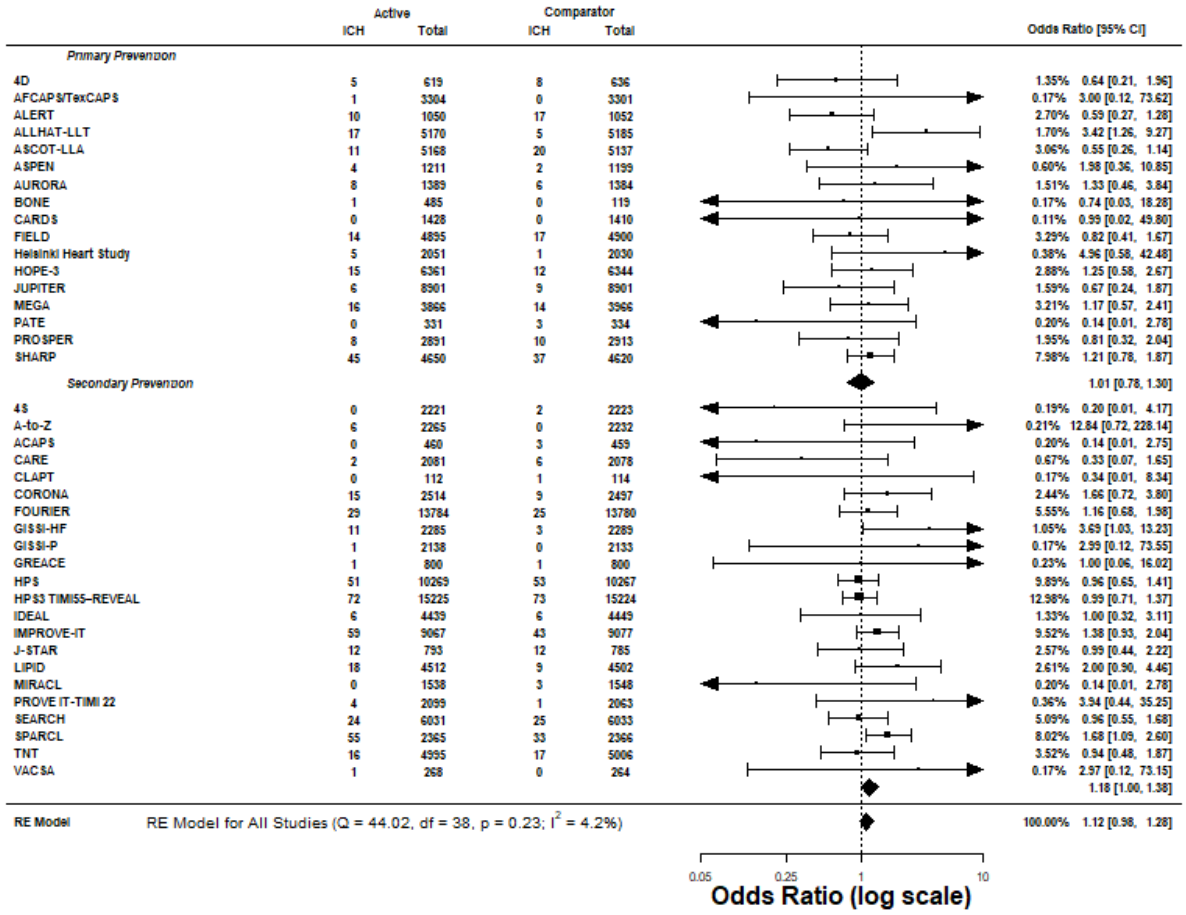
Figure 1 - Forest plot for ischaemic stroke. Forest plot showing the effect of lipid lowering therapy on ischaemic stroke. The forest plot is divided in two sections according to type of prevention trial a) primary b) secondary. The squares and bars represent the mean values and 95% confidence intervals of the effect sizes, while the size of the squares reflects the weight of the studies. The combined effects (sub-summary and summary) appear as diamonds and the vertical dashed line represents the line of no effect.

Figure 3 – Meta-regression scatterplot – baseline mean LDL (active) and intracerebral haemorrhage

Figure 3 – A scatterplot of the risk ratio for each study by baseline LDL cholesterol (predictor). Each study is represented by a circle. The circle sizes are proportional to the inverse of the standard errors (i.e., larger/more precise studies are shown as larger points). The solid line represents the predicted average risk ratio as a function of baseline LDL cholesterol (predictor). The dashed lines represent the 95% confidence interval.

Figures

Figure 1 – Lipid lowering and intracerebral haemorrhage



1 Figure 2 – Lipid lowering and ischaemic stroke

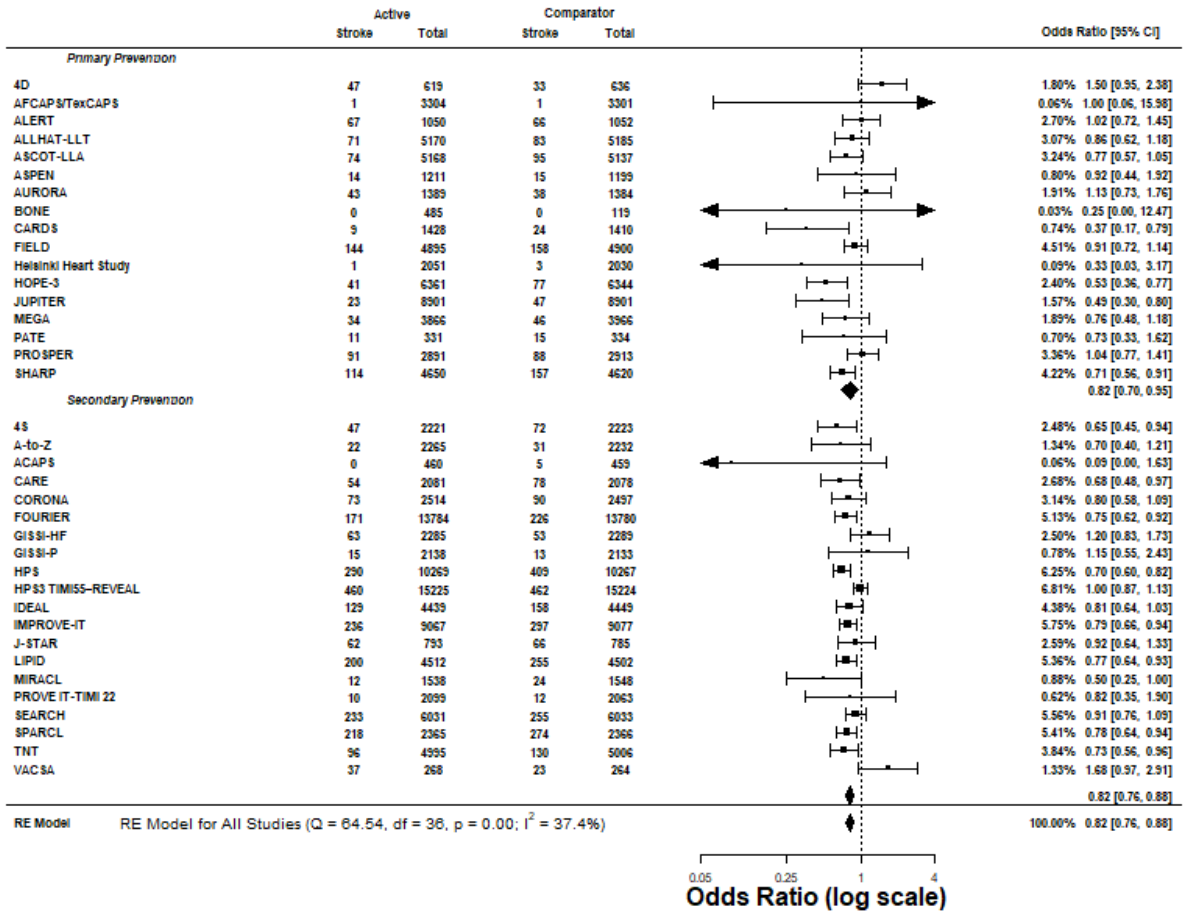


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Figure 3 - Meta-regression scatterplot – baseline mean LDL (active) and intracerebral haemorrhage