Peripheral Arterial Disease (PAD) refers to any pathologic process causing obstruction to blood flow in the arteries exclusive of the coronary and cerebral vessels. In this article we focus on lower extremity PAD, which is a chronic obstructive disease of the aortic, iliac, and lower limb arteries usually caused by atherosclerosis.1,2

The most widely accepted, objective definition of PAD is a resting ankle-brachial index (ABI) of less than 0.90 (ie, the ratio of the ankle systolic blood pressure [as measured by Doppler ultrasound] and the higher of the 2 brachial systolic pressures is less than 0.90).1,2 An ABI of less than 0.90 is up to 95% sensitive in detecting angiogram-positive disease.1 A cutoff of less than 0.95 has been used in some epidemiologic studies3 but may overestimate disease prevalence.

PAD affects approximately 20% (95% confidence interval [CI], 10%-30%) of adults older than 55 years and an estimated 27 million persons in North America and Europe.2,4-12 About half of all people with PAD are asymptomatic.4-13 The prevalence of PAD increases with age and prolonged exposure to smoking, hypertension, and diabetes.2,4,5,14

About one fifth of people with PAD have typical symptoms of intermittent lower limb claudication, “rest pain,” ulceration, or gangrene, and another third have atypical exertional leg symptoms.13 The incidence of symptomatic PAD (intermittent claudication) in the general population in the Netherlands has been reported to be 1.0 (95% CI, 0.7-7.5) per 1000 population per year overall; 0.4 (95% CI, 0.3-10.0) for men, and 1.8 (95% CI, 1.0-10.3) for women.2 The Framingham study reported higher incidence rates and a 2-fold male predominance (1.8% for women and 3.6% for men),13 as did the Quebec Cardiovascular Study16 and others.17,18 The incidence of first-ever acute peripheral arterial events, defined as aortic events (ruptured or acute symptomatic aortic or iliac aneurysm, or any thoracic aortic dissection), acute thromboembolic events (of the limbs or viscera), and critical limb ischemia (rest pain or ulceration) has been reported to be 1.0 (95% CI, 0.7-7.5) per 1000 person-years in the general population.1

Conclusion The substantial and increasing burden of PAD, and its local and systemic complications, can be reduced by lifestyle modification (smoking cessation, exercise) and medical therapies (nicotine replacement therapy, bupropion, antihypertensive drugs, statins, and antiplatelet therapy).

Acknowledgments S. Lauer, MD, at lauerm@ccf.org. We encourage authors to submit papers for consideration as a Clinical Review. Please contact Michael S. Lauer, MD, at lauerm@cf.org.

Clinical Review Section Editor: Michael S. Lauer, MD.
MEDICAL TREATMENT OF PERIPHERAL ARTERIAL DISEASE

Table 1. Studies Reporting Risks of Death From All Causes and From Cardiovascular Disease in Patients With Peripheral Arterial Disease (PAD)

<table>
<thead>
<tr>
<th>Study</th>
<th>No.</th>
<th>Age, y</th>
<th>Sex</th>
<th>PAD Symptoms</th>
<th>All-Cause Death Controls, %</th>
<th>Patients, %</th>
<th>ARI, %</th>
<th>RR (95% CI)</th>
<th>Cardiovascular Death Controls, %</th>
<th>Patients, %</th>
<th>ARI, %</th>
<th>RR (95% CI)</th>
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<tbody>
<tr>
<td>Criqui et al,23 1992</td>
<td>256</td>
<td>38-72</td>
<td>Men</td>
<td>...</td>
<td>1.7</td>
<td>6.2</td>
<td>4.5</td>
<td>3.3 (1.9-6.0)</td>
<td>5.1 (2.4-10.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>309</td>
<td></td>
<td>Women</td>
<td>...</td>
<td>1.2</td>
<td>3.3</td>
<td>2.1</td>
<td>2.5 (1.2-5.3)</td>
<td>4.8 (1.6-14.7)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Vogt et al,24 1993</td>
<td>1492</td>
<td>&gt;65</td>
<td>Women</td>
<td>...</td>
<td>1.1</td>
<td>5.4</td>
<td>4.3</td>
<td>3.1 (1.7-5.5)</td>
<td>4.0 (1.3-8.5)</td>
<td></td>
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<tr>
<td>Kornitzer et al,25 1995</td>
<td>2023</td>
<td>40-55</td>
<td>Men</td>
<td>No</td>
<td>0.4</td>
<td>1.0</td>
<td>0.6</td>
<td>2.8 (1.4-5.5)</td>
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<tr>
<td>Leng et al,26 1996</td>
<td>1592</td>
<td>55-74</td>
<td>Men and women</td>
<td>Yes</td>
<td>2.0</td>
<td>3.8</td>
<td>1.8</td>
<td>1.6 (0.9-2.8)</td>
<td>2.7 (1.3-5.3)</td>
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<td>No</td>
<td>2.0</td>
<td>6.1</td>
<td>4.1</td>
<td>2.4 (1.6-3.9)</td>
<td>2.1 (1.1-3.8)</td>
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<tr>
<td>Newman et al,27 1997</td>
<td>569</td>
<td></td>
<td>Men</td>
<td>1.5</td>
<td>5.3</td>
<td>3.8</td>
<td>3.0</td>
<td>2.8 (5.3)</td>
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<tr>
<td></td>
<td>868</td>
<td></td>
<td>Women</td>
<td>1.3</td>
<td>3.8</td>
<td>2.5</td>
<td>2.7</td>
<td>1.6 (4.6)</td>
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<tr>
<td>Newman et al,28 1999</td>
<td>5714</td>
<td>≥65</td>
<td>Men and women</td>
<td>4.5</td>
<td>7.8</td>
<td>3.3</td>
<td>1.5</td>
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<tr>
<td>Hooi et al,29 2004</td>
<td>3649</td>
<td>40-78</td>
<td>Men and women</td>
<td>All (n = 367)*</td>
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<td>4.4</td>
<td>3.3</td>
<td>1.4 (1.1-1.7)</td>
<td>1.6 (1.2-2.1)</td>
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<td></td>
<td></td>
<td></td>
<td>Yes (n = 117)</td>
<td>1.1</td>
<td>...</td>
<td>...</td>
<td>1.4 (1.0-2.0)</td>
<td>1.6 (1.0-2.5)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No (n = 245)</td>
<td>1.1</td>
<td>4.3</td>
<td>2.2</td>
<td>1.4 (1.1-1.8)</td>
<td>1.5 (1.1-2.2)</td>
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</tbody>
</table>

Abbreviations: ARI, absolute risk increase; CI, confidence interval; ellipses, not available; RR, relative risk.
*Includes 5 patients with PAD of unspecified type.

EVIDENCE ACQUISITION

We searched MEDLINE (January 1990 to November 2005) and the Cochrane electronic database (August 2005) for English-language articles that addressed the medical treatment of PAD. The search used the following terms, singly and in combination: peripheral arterial disease, peripheral artery disease, PAD, randomized controlled trial, controlled trial, randomized, and meta-analysis. We focused on randomized controlled trials (RCTs) or meta-analyses of RCTs because they provide the least biased and most robust evidence for the efficacy of treatments. We sought trials that studied the effect of medical treatments for PAD both on leg symptoms (intermittent claudication and walking distance) and on death and major coronary and cerebrovascular events.

EVIDENCE SYNTHESIS

Improving Leg Symptoms

Smoking Cessation. Smoking is the dominant modifiable risk factor for PAD; a dose-dependent relationship is present between smoking and severity of PAD. Smoking cessation among patients with intermittent claudication does not significantly improve walking capacity but may reduce the severity of claudication and the risk of developing rest pain.

Smoking cessation can be facilitated to a modest extent in the general population by physician advice to quit smoking and by use of nicotine replacement therapy and bupropion (TABLE 2). This likely also applies to patients with PAD, although there have been no RCTs of methods of smoking cessation specifically in PAD.

Exercise. In patients with stable intermittent claudication, exercise significantly improves maximal walking time and overall walking ability. Exercise is more effective than angioplasty for improving walking time and is also more effective than antiplatelet therapy, but it does not differ significantly from surgical treatment. The optimal exercise program for improving distances walked without claudication pain in patients with PAD involves intermittent walking to near-maximal pain over a period of at least 6 months. The mechanism by which exercise improves leg symptoms is uncertain, but it does not appear to operate through improvement of the ABI or growth of collateral vessels.

Statin Drugs. In the randomized Scandinavian Simvastatin Survival Study (4S), simvastatin (20 to 40 mg/d) significantly reduced the incidence of new intermittent claudication from 3.6% (placebo) to 2.3% (simvastatin) over a median period of 5.4 years in 4444 patients with prior MI or angina pectoris (relative risk reduction [RRR], 0.62%; 95% CI, 0.44%-0.88%).
simvastatin and atorvastatin also improve pain-free walking time. Nevertheless, observational data suggest that it is the non–cholesterol-lowering properties of statins that favorably influence leg function in patients with PAD.37,66

Blood Pressure–Lowering Drugs. Contrary to prior belief, β-adrenergic antagonist drugs do not worsen intermittent claudication in patients with PAD but, if indicated, should be used with caution in severely affected patients.49 The combination of atenolol and nifedipine marginally reduces maximal treadmill walking distance,50 while angiotensin-converting enzyme inhibitors (captopril, perindopril) may improve walking distances.51,52

Cilostazol. Cilostazol is an inhibitor of phosphodiesterase type 3 and thereby inhibits platelet aggregation and causes vasodilation. A meta-analysis of 8 RCTs involving 2702 patients demonstrated that cilostazol improved maximum walking distance and pain-free walking distance.53 Although cilostazol has not been associated with the increase in cardiac mortality seen with other phosphodiesterase inhibitors such as milrinone (which was developed for the treatment of heart failure), it remains contraindicated in patients with PAD who have coexistent cardiac failure.

Other Treatments. Ticlopidine54 and ginkgo biloba special extract (Egb 761)55,56 significantly increase pain-free walking distance. Numerous other therapies, such as nafidrofuryl, pentoxifylline, garlic, testosterone, levocarnitine, propionyl-L-carnitine, and chelation therapy have been evaluated in RCTs but have not been shown to be effective or are less effective than established treatments.57-60 A variety of strategies to stimulate new collateral channels in peripheral ischemia, such as the use of growth factors and autologous bone marrow cells, are currently being evaluated.61,62

Preventing Systemic Complications of Coronary and Cerebral Atherosclerotic Arterial Disease

Smoking Cessation. Smoking cessation in the general population is associated with a rapid reduction in cardiovascular risk.63 It is plausible to expect similar benefits of smoking cessation in patients with PAD, although the only RCT that examined the effect of smoking advice on mortality in such patients reported no statistically significant differences in death rates at 20 years.36 However, observational data indicate that smoking cessation reduces MI and cardiac deaths and improves overall survival at 10 years among patients with intermittent claudication.57

Lowering Blood Pressure. The 5 main classes of antihypertensive drugs (diuretics, β-blockers, calcium channel blockers, angiotensin-converting enzyme inhibitors, and angiotensin II receptor antagonists) are all effective for preventing cardiovascular events, and the magnitude of their effect is mainly determined by the magnitude of blood pressure lowering.64,65

Among 4051 patients with PAD (ABI <0.90) enrolled in the Heart Outcomes Prevention Evaluation (HOPE) study, random assignment to ramipril (10 mg/d) (n=1966) was associated with an RRR of subsequent stroke, MI, and vascular death of approximately 25% (95% CI, 14%-37%), from 22% (placebo) to 17% (ramipril) after 5 years (mean) follow-up.66 This result was consistent with that observed in all 9297 patients at high vascular risk (RRR, 22%; 95% CI, 14%-30%).66

In the Appropriate Blood Pressure Control in Diabetes (ABCD) trial, more intensive blood pressure control was more effective than moderately intensive control for preventing cardiovascular events in 53 patients with PAD and type 2 diabetes.57 The benefit of intensive blood pressure control was independent of drug class.

The results of the HOPE and ABCD trials in patients with PAD are consistent with those of a recent systematic review of RCTs assessing the effect of blood pressure lowering in all individuals, which showed that lowering blood pressure by about 10 to 12 mm Hg systolic and 5 to 6 mm Hg diastolic reduces the relative risk of stroke by about 38% and the risk of coronary events by about 16%, and that more intensive blood pressure lowering is more effective than less intensive lowering.68

There is some recent evidence suggesting that β-blockers are less effective than other antihypertensive drugs.69 It remains uncertain whether angiotensin-converting enzyme inhibitors and angiotensin II receptor antagonists have significant additional prophylactic ef-

<table>
<thead>
<tr>
<th>Table 2. Medical Treatment of Peripheral Arterial Disease</th>
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<tbody>
<tr>
<td>Indication</td>
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<tr>
<td>-------------------------------------</td>
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<tr>
<td>Improving leg symptoms</td>
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<td></td>
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<tr>
<td>Preventing systemic complications</td>
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</table>

*No randomized evidence but based on convincing observational data. 
†Efficacy unproven in randomized trials, but observational data are compelling.
effects on coronary and cerebrovascular events that is independent of their effects on blood pressure.66,67,68

Lowering Blood Cholesterol Levels. Among 6748 patients with a history of PAD (with or without a history of coronary heart disease) and a plasma total cholesterol concentration of 3.5 mmol/L (135 mg/dL) or greater, random allocation to simvastatin (40 mg/d) (n = 3384) was associated with an approximately 1.0-mmol/L (38.6-mg/dL) reduction in low-density lipoprotein cholesterol (LDL-C) concentration and an RRR of stroke, MI, vascular death, and revascularization procedures of approximately 20% (95% CI, 13%-27%), from 32.7% (placebo) to 26.4% (simvastatin) after 5 years of follow-up.70 The results were similar among patients with a history of PAD only (from 30.5% [placebo] to 24.7% [simvastatin] after 5 years of treatment; RRR, 21%; 95% CI, 7%-33%) and in each subclass category based on sex, age, or baseline concentrations of total plasma cholesterol and LDL-C.70

These results are consistent with those of a recent meta-analysis of more than 90,000 individuals at high vascular risk, among whom statin therapy safely reduced the 5-year incidence of major vascular events by about one fifth.71 By comparison, the results of the Antithrombotic Trialists' Collaboration meta-analysis of 195 trials of antiplatelet therapy in patients with platelet therapy in patients with PAD (5.8% vs 7.1%; 23% odds reduction; P <.004) was similar to that seen in other high-risk groups (acute or previous acute MI, previous stroke), and the benefits were evident in patients with PAD who experience intermittent claudication as well as those undergoing peripheral angioplasty or bypass surgery.72,73

Aspirin is the most widely evaluated antiplatelet agent for preventing cardiovascular events.70,74 Individual trials in patients with PAD have not definitively established a benefit of aspirin for preventing MI, stroke, or cardiovascular death, but the results with aspirin are consistent with the overall effects of antiplatelet therapy in patients with PAD.70,75,81 Likewise, the effectiveness of different doses of aspirin has not been definitively evaluated in PAD, but direct and indirect comparisons of different aspirin doses in the Antithrombotic Trialists' Collaboration meta-analysis suggest that 75 to 150 mg/d is at least as effective as higher doses (>150 mg/d) and is less likely to cause gastrointestinal and bleeding complications.70,81

Aspirin has not been shown to improve claudication, but it delays the rate of progression, reduces the need for intervention, and reduces graft failure in patients who have undergone revascularization procedures.70,83,84

Ticlopidine (250 mg twice daily) compared with placebo reduces the risk of MI, stroke, or death by about one third in patients with PAD.82,83 However, it also causes thrombocytopenia (in approximately 2%-3% of patients), thrombotic thrombocytopenic purpura (in approximately 0.03% of patients), and potentially fatal neutropenia and has now largely been replaced by clopidogrel as the thienopyridine of choice.

The Clopidogrel vs Aspirin in Patients at Risk of Ischemic Events (CAPRIE) trial demonstrated that clopidogrel (75 mg/d) compared with aspirin (325 mg/d) reduced the risk of MI, stroke, or cardiovascular death by 8.7% (95% CI, 0.3%-16.5%; P = .04) in a broad range of high-risk patients.86 The greatest benefit was evident in the subgroup of 6452 patients with PAD in whom there was a 23.8% (95% CI, 8.9%-36.2%) RRR for MI, stroke, or cardiovascular death in patients treated with clopidogrel compared with aspirin (4.9% per year vs 3.7% per year for aspirin vs clopidogrel, respectively).86

Several novel antiplatelet drugs, including ticagrelor (inhibits thromboxane A2 synthase) and prasugrel (inhibits platelet aggregation and vascular inflammation), and ketanserin (S2 serotonin receptor antagonist) have not been shown to be superior to aspirin for preventing systematic complications in patients with PAD.79

The combination of aspirin and clopidogrel is currently being compared with aspirin for preventing cardiovascular events in high-risk patients with PAD; results of the comparison are due to be presented in March 2006.87

Anticoagulant Therapy. No benefit of heparin, low-molecular-weight heparin, or oral anticoagulants has been established for intermittent claudication, but there is an increased risk of major bleeding, especially with oral anticoagulants.88

Patients undergoing infragenual venous bypass may benefit from treatment with a vitamin K antagonist instead of, or in addition to, aspirin to maintain graft patency and improve survival, but the evidence is not conclusive.89,90 The combination of
aspirin and warfarin compared with aspirin alone for the treatment of PAD, including among patients undergoing revascularization procedures, is currently being evaluated in the Warfarin and Vascular Evaluation (WAVE) trial.91

**Summary of Treatment Evidence for PAD**

**Improving Leg Symptoms.** Smoking cessation reduces the severity of claudication and may be enhanced by physician advice coupled with nicotine replacement therapy or bupropion.

Exercise at least 2 times per week, even in the presence of pain from intermittent claudication, increases walking time. For patients with claudication who consider their leg pain a barrier to exercise, structured exercise programs are appropriate. Walking through the claudication pain is not harmful and gradually increases walking distance.

Simvastatin reduces the incidence of new intermittent claudication, and simvastatin and atorvastatin both significantly increase pain-free walking time. Angiotensin-converting enzyme inhibitors appear to provide symptomatic relief of PAD, but the data are limited. Cilostazol maximizes maximal and pain-free walking distance and is a suitable treatment for disabling claudication, except in patients with symptoms of heart failure.

**Preventing Systemic Complications of Coronary and Cerebral Atherosclerotic Arterial Disease.** Although RCTs have not shown that smoking cessation saves lives, the evidence from observational studies for reduced mortality after smoking cessation is compelling. Smoking cessation is the main priority in risk factor management.

For patients with PAD, ramipril reduces the risk of serious vascular events by approximately one quarter and simvastatin by approximately one fifth. Because all patients with PAD are at increased risk of a vascular event, they should be considered for prolonged treatment with at least 1 blood pressure–lowering agent and a statin, irrespective of their baseline blood pressure and cholesterol level. Modest reductions in blood pressure and cholesterol level achieve substantial and significant reductions in serious vascular events. The absolute benefit relates chiefly to an individual’s absolute risk of such events and to the absolute reduction achieved in blood pressure and LDL-C level.

Early detection of diabetes and glucose intolerance, followed by careful control of glycemia and vascular risk factors to target levels (Box), is likely to improve long-term outcome.19,92 According to current data, rigorous control of blood pressure and blood cholesterol level is more important than rigorous control of blood glucose level in preventing serious vascular events among individuals with diabetes.

Weight reduction should be a component of the management strategy of overweight patients with PAD.

Antiplatelet therapy should be used in all patients with PAD who do not have a specific contraindication. Aspirin is the preferred antiplatelet drug because it is effective and inexpensive. Clopidogrel is safer than ticlopidine and slightly more effective than aspirin, but it is much more expensive.

Anticoagulants are not indicated for the medical management of PAD but may have a role after infrainguinal bypass surgery.

**Controversies and Uncertainties**

**Should ABI Be Used to Screen the General Population for PAD and Risk of Vascular Disease?** The ABI is a simple, noninvasive, and reliable test that can be complementary to conventional vascular risk factor profiles to identify individuals from the general population who are at high risk of developing cardiovascular disease and could benefit from preventive measures.93 After adjusting for conventional cardiovascular risk factors and prevalent cardiovascular disease, a low ABI (<0.90) is an independent predictor of cardiovascular risk.94 A low ABI is also highly specific (88%-93%) for predicting future cardiovascular events (ie, a low ABI helps to “rule in” a high-risk patient), with likelihood ratios of about 2.5 (95% CI, 1.4-4.4) for coronary heart disease, 2.4 (95% CI, 1.8-3.4) for stroke, and 5.6 (95% CI, 3.4-9.1) for cardiovascular death.94 However, because the sensitivity of a low ABI to predict future cardiovascular outcomes is low (ie, a normal ABI does not “rule out” a high-risk patient), the ABI lacks usefulness as a screening test for PAD in the general population.95 Its optimal application may be as part of the vascular risk assessment among selected individuals without established vascular disease but older than 70 years or among those who are aged 50 to 69 years and have 1 or more cardiovascular risk factors (ie, elevated serum cholesterol level, hypertension, dysglycemia, tobacco exposure, or a family history of atherosclerotic disease).94 Further clarification of the role of ABI awaits evaluation of its incremental predictive value over conventional methods of risk assessment in patients who may be at increased risk of cardiovascular disease.95

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**Box. Management of Patients With Peripheral Arterial Disease Who Have Diabetes**

**Target Levels of Risk Factors in Patients With Diabetes**14,92

- Blood pressure <130/80 mm Hg
- Low-density lipoprotein cholesterol level <2.6 mmol/L (100 mg/dL)
- Triglycerides level <1.7 mmol/L (150 mg/dL)
- High-density lipoprotein cholesterol >1.1 mmol/L (40 mg/dL)†
- Glycosylated hemoglobin level <7%

*To achieve targets, lifestyle interventions (diet and exercise) are recommended first, followed by pharmacological interventions, if necessary. Recommendations from the American Diabetes Association (2003).
†In women, a level above 1.3 mmol/L (50 mg/dL) may be appropriate.
Is There a Role for Screening and Modifying Novel Risk Factors? Elevated blood levels of C-reactive protein predict the development of PAD in apparently healthy men, independently of elevated blood lipid levels, and elevated blood levels of homocysteine, C-reactive protein, and fibrinogen have been reported in patients with PAD. However, it remains to be shown that these are both causal and modifiable risk factors for atherosclerosis.

Traditional risk factors are still likely to account for most of the risk of cardiovascular disease worldwide.

CONCLUSION
Peripheral arterial disease, particularly asymptomatic disease, is common and is likely to become more common as the population ages and as the diagnosis of hitherto unrecognized asymptomatic disease improves.

The importance of recognizing asymptomatic PAD is that it helps refine assessment of vascular risk and identify individuals at considerable risk for MI and stroke. This risk, along with severity of claudication in symptomatic patients, can be substantially reduced by modest reductions in the prevalence and level of causal risk factors by means of lifestyle modification and effective medical therapies. An enormous opportunity—and responsibility—exists to begin to translate the evidence into practice.

Author Contributions: Dr Eikelboom had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Hankey, Eikelboom. Acquisition of data: Hankey, Norman. Analysis and interpretation of data: Hankey, Norman, Eikelboom.

Drafting of the manuscript: Hankey, Norman, Eikelboom. Critical revision of the manuscript for important intellectual content: Hankey, Norman, Eikelboom.

Study supervision: Hankey.

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