

Non-invasive screening for coronary artery disease: calcium scoring

Raimund Erbel, Stefan Möhlenkamp, Gert Kerkhoff, Thomas Budde, Axel Schmermund

Web only references

1. Fuster VV. Tribute to Ronald W.F. Campbell, MBChB, MRCP, FRCP. *Circulation* 1998; 98: 2361-2
2. Losordo DW, Willerson JT. In memoriam Jeffrey M Isner. *Circulation* 2002; 105:268-9
3. Chambless L, Keil U, Dobson A, et al. Population versus clinical view of case fatality from acute coronary heart disease: results from the WHO MONICA Project 1985- 1990. Multinational MONItoring of Trends and Determinants in Cardiovascular Disease. *Circulation* 1997; 96:3849-59
4. Sones M. Discussion. In: *Coronary Heart Disease, 3rd Int. Symp Frankfurt*, Kaltenbach M, Lichtlen P, Balcon R, Bussmann WD (eds), Stuttgart 1978; 83.
5. Ridker PM, Buring JE, Rifai N, Cook NR. Development and validation of improved algorithms for the assessment of global cardiovascular risk in women: the Reynolds Risk Score. *JAMA* 2007; 297: 611-9
6. Akosah KO, Schaper A, Cogbill C, Schoenfeld P. Preventing myocardial infarction in the young adult in the first place: how do the National Cholesterol Education Panel III guidelines perform? *J Am Coll Cardiol* 2003; 41: 1475-9
7. Lindman AS, Selmer R, Tverdal A, et al. The Score risk model applied to recent population surveys in Norway compared to observed mortality in the general population. *Eur J Cardiovasc Prev Rehabil* 2006; 13: 731-7
8. Conroy RM, Pyorala K, Fitzgerald AP, et al, Score project group. Estimation of ten-year risk of fatal cardiovascular disease in Europe: the Score project. *Eur Heart J* 2003; 24: 987-1003
9. Keil U, Fitzgerald AP, Gohlke H, Wellmann J, Hense HW. Risikoabschätzung tödlicher Herz-Kreislauf-Erkrankungen. *Dtsch Ärzteblatt* 2005, 102: 1808-12
10. Cullen P, Schulte H, Assmann G. The Munster Heart Study (PROCAM): total mortality in middle-aged men is increased at low total and LDL cholesterol concentrations in smokers but not in non-smoker. *Circulation* 1997; 96: 2128-36
11. Gohlke H, Winter M, Karoff M, Held K. CARRISMA: A new tool to improved risk stratification and guidance of patients in cardiovascular risk management in primary prevention. *Eur J Cardiovasc Prev. Reha* 2007; 14: 141-8
12. Detrano R, Salcedo EE, Hobbs RE, Yiannikas J. Cardiac cinefluoroscopy as an inexpensive aid in the diagnosis of coronary artery disease. *Am J Cardiol* 1986; 57: 1041-6
13. Mahoney LT, Burns TL, Stanford W, et al. Coronary risk factors measured in childhood and young adult life are associated with coronary artery calcification in young adults: the Muscatine Study. *J Am Coll Cardiol* 1996; 27: 277-84
14. Rumberger JA, Simons DB, Fitzpatrick LS, Sheedy PF, Schwartz RS. Coronary artery calcium area by electron-beam computed tomography and coronary atherosclerotic plaque area: a histopathologic correlative study. *Circulation* 1995; 92: 2157-2162
15. Janowitz WR, Agatston AS, Kaplan G, Viamonte M Jr. Differences in prevalence and extent of coronary artery calcium detected by ultrafast computed tomography in symptomatic men and woman. *Am J Cardiol* 1993; 72: 247-54

16. O'Rourke RA, Brundage BH, Froelicher VF et al. American College of Cardiology/American Heart Association expert consensus document on electron- beam computed tomography for the diagnosis and prognosis of coronary artery disease. *J Am Coll Cardiol* 2000; 36:326-40
17. Rumberger JA, Schwartz RS, Simons DB, Sheedy PF 3rd, Edwards WD, Fitzpatrick LA. Relation of coronary calcium determined by electron beam computed tomography and lumen narrowing determined by autopsy. *Am J Cardiol* 1994; 73: 1169-1173
18. Hunold P, Vogt FM, Schmermund A, et al. Radiation exposure during cardiac CT: effective doses at multi-detector row CT and electron-beam CT. *Radiology* 2003; 226:145-52
19. Callister TQ, Coil B, Raya SP, Lippolis NJ, Russo DJ, Raggi P. Coronary artery disease: improved reproducibility of calcium scoring with electron-beam CT volumetric method. *Radiology* 1998; 208: 807-814
20. Busch S, Johnson TR, Nikolaou K, et al. Visual and automatic grading of coronary artery stenoses with 64-slice CT angiography in reference to invasive angiography. *Eur Radiol* 2006; 17: 1445-51
21. Austen WG, Edwards JE, Frye RL, et al. A reporting system on patients evaluated for coronary artery disease. Report of the Ad Hoc Committee for Grading of Coronary Artery Disease, Council on Cardiovascular Surgery, American Heart Association. *Circulation* 1975; 51: 5-40
22. Möhlenkamp S, Behrenbeck TR, Pump H, et al. Reproducibility of two coronary calcium quantification algorithms in patients with different degrees of calcification. *Intern J Cardiovasc Imaging* 2001; 17: 133-142
23. Schmermund A, Pump H, Möhlenkamp S, et al für die Heinz Nixdorf Recall Studiengruppe Nachweis einer exzellenten Befund-Übereinstimmung (Kappa 0,94) der Koronarkalkmessung mittels Elektronenstrahltomografie in der Heinz Nixdorf Recall Studie. *Z Kardiol* 2003;92:1/385
24. Detrano RC, Anderson M, Nelson J, et al. Coronary calcium measurements: effect of CT scanner type and calcium measure on rescan reproducibility - MESA study. *Radiology* 2005;236:477-484
25. Sevrakov AB, Bland JM, Kondos GT. Serial electron beam CT measurements of coronary artery calcium: has your patient's calcium score actually changed? *Am J Roentgenol* 2005;185:1546-1553
26. Möhlenkamp S, Schmermund A, Budde T, Erbel R. Aktuelle Studien zur Progression koronarer Kalzifikationen. *Münch med Wschr Fortschr Med* 2007;149: 75-84
27. Stary HC. The sequence of cell and matrix changes in atherosclerotic lesions of coronary arteries in the first forty years of life. *Eur Heart J* 1990; 11; Suppl E: 3-19
28. Sangiorgi G, Rumberger JA, Severson A, et al. Arterial calcification and not lumen stenosis is highly correlated with atherosclerotic plaque burden in humans: a histologic study of 723 coronary artery segments using nondecalcifying methodology. *J Am Coll Cardiol* 1998; 31:126-133
29. Simons DB, Schwartz RS, Edwards WD, Sheedy PF, Breen JF, Rumberger JA. Noninvasive definition of anatomic coronary artery disease by ultrafast computed tomographic scanning: a quantitative pathologic comparison study. *J Am Coll Cardiol* 1992; 20: 1118-1126
30. Hoff JA, Chomka EV, Krainik AJ et al. Age and gender distributions of coronary artery calcium detected by electron beam tomography in 35,246 adults. *Am J Cardiol* 2001; 87: 1335-1339
31. Mitchell TL, Pippin JJ, Devers SM, et al. Age – and sex-based nomograms from coronary artery calcium scores as determined by electron beam computed tomography. *Am J Cardiol* 2001; 87: 453-456

32. Pletcher MJ, Tice JA, Pignone M, Browner WS. Using the coronary artery calcium score to predict coronary heart disease events: a systematic review and meta-analysis. *Arch Intern Med* 2004; 164: 1285-92
33. Nasir K, Redberg RF, Budoff MJ, Hui E, Post WS, Blumenthal RS. Utility of stress testing and coronary calcification measurement for detection of coronary artery disease in women. *Arch Intern Med* 2004; 164: 1610-20.
34. Nasir K, Raggi P, Rumberger JA, *et al.* Coronary artery calcium volume scores on electron beam tomography in 12,936 asymptomatic adults. *Am J Cardiol* 2004; 93: 1146-9
35. Bild DE, Bluemke DA, Burke GL, *et al.* Multi-ethnic study of atherosclerosis: objectives and design. *Am J Epidemiol* 2002; 156: 871-881
36. Schmermund A, Möhlenkamp S, Stang A, *et al.* Assessment of clinical silent atherosclerotic disease and established and novel risk factors for predicting myocardial infarction and cardiac death in healthy middle-aged subjects: rationale and design of the Heinz Nixdorf RECALL Study. *Am Heart J* 2002; 144: 212-8
37. Erbel R, Möhlenkamp S, Moebus S, *et al.* European and American prevalence of subclinical atherosclerosis and risk factors: similarities and differences of the Heinz Nixdorf Recall Study (HNRS) and Multi-Ethnic Study of Atherosclerosis (MESA). *Eur Heart J* 2006;27Suppl1:838
38. Schmermund A, Erbel R, Silber S, Munich registry study group. Age and gender distribution of coronary artery calcium measured by four-slice computed tomography in 2,030 persons with symptoms of coronary artery disease. *Am J Cardiol* 2002; 90: 168-73
39. Ritchie CJ, Godwin JD, Crawford CR, Stanford W, Anno H, Kim Y. Minimum scan speeds for suppression of motion artefacts in CT. *Radiology* 1992; 185:37-42
40. Becker CR, Kleffel T, Crispin A, *et al.* Coronary artery calcium measurement: agreement of multirow detector and electron beam CT. *Am J Röntgenol* 2001; 176: 1295-1298
41. Knez A, Becker CR, Becker A, *et al.* Determination of coronary calcium with multi-slice spiral computed tomography: a comparative study with electron-beam CT. *Int J Cardiovasc Imaging* 2002; 18: 295-303
42. Carr JJ, Crouse JR, D'agostino RB, Peterson NP, Burke GL. Evaluation of a subsecond gated helical CT for quantification of coronary artery calcium and comparison with electron beam CT. *Am J Roentgenol* 2000; 174: 915-921
43. Glagov S, Weisenberg E, Zarins CK, Stankunavicius R, Koletti GJ. Compensatory enlargement of human atherosclerotic coronary arteries. *N Engl J Med* 1987; 316:1371-5
44. Stary HC, Chandler AB, Dinsmore RE, *et al.* A definition of advanced types of atherosclerotic lesions and a histological classification of atherosclerosis. A report from the Committee on Vascular Lesions of the Council on Arteriosclerosis, American Heart Association. *Circulation* 1995; 92:1355-74
45. Ge J, Erbel R, Zamorano J, *et al.* Coronary artery remodeling in atherosclerotic disease: an intravascular ultrasonic study in vivo. *Coron Artery Dis* 1993; 4: 981-6
46. Davies MJ, Thomas AC. Plaque fissuring – the cause of acute myocardial infarction, sudden ischaemic death, and crescendo angina. *Br Heart J* 1985; 53:363-73
47. Virmani R, Kolodgie FD, Burke AP, *et al.* Atherosclerotic plaque progression and vulnerability to rupture: angiogenesis as a source of intraplaque hemorrhage. *Arterioscler Thromb Vasc Biol* 2005; 25: 2054-61
48. Burke AP, Kolodgie FD, Farb A, *et al.* Healed plaque ruptures and sudden coronary death: evidence that subclinical rupture has a role in plaque progression. *Circulation* 2001; 103:934-40.
49. Galassi A, Spiegel DM, Bellasi A, Block G-A, Raggi P. Accelerated vascular calcification and relative hypoparathyroidism in incident haemodialysis diabetic patients receiving calcium binders. *Nephrol Dial Transplant* 2006; 21: 3215-22

50. Shaw LJ, Raggi P, Schisterman E, Berman DS, Callister TQ. Prognostic value of cardiac risk factors and coronary artery calcium screening for all-cause mortality. *Radiology* 2003; 228:826-33
51. Park R, Detrano R, Xiang M, et al. Combined use of computed tomography score and C-reactive protein levels in predicting cardiovascular events in nondiabetic individuals. *Circulation* 2002; 106: 2073-7
52. Kondos GT, Hoff JA, Sevrukov A, et al. Electron beam tomography coronary artery calcium and cardiac events: a 37-month-follow-up of 5635 initially asymptomatic low- to intermediate-risk adults. *Circulation* 2003; 107:2571-6
53. LaMonte MJ, Fitzgerald SJ, Church TS, et al. Coronary artery calcium score and coronary heart disease events in a large cohort of asymptomatic men and woman. *Am J Epidemiol* 2005; 162: 421-9
54. Greenland P, LaBree L, Azen SP, Doherty TM, Detrano RC. Coronary artery calcium score combined with Framingham score for risk prediction in asymptomatic individuals. *JAMA* 2004; 291: 210-5
55. Taylor AJ, Bindeman J, Feuerstein I, Cao F, Brazaitis M, O'Malley PG, Coronary calcium independently predicts incident premature coronary heart disease over measured cardiovascular risk factors: mean three-year outcomes in the Prospective Army Coronary Calcium (PACC) project. *J Am Coll Cardiol* 2005; 46: 807-14
56. Vliegenthart R, Oudkerk M, Hofman A, et al. Coronary calcification improves cardiovascular risk prediction in the elderly. *Circulation* 2005; 112: 572-7.
57. Wayhs R, Zelinger AB, Raggi P. High coronary artery calcium scores pose an extremely elevated risk for hard events. *J Am Coll Cardiol* 2002; 39: 225-230
58. Wilson PWF, Smith Jr SC, Blumenthal RS, Burke GL. 34th Bethesda Conference task force 4 - How do we select patients for atherosclerosis imaging? *J Am Coll Cardiol* 2003; 41: 1898-906
59. Budoff MJ, Shaw LJ, Liu ST, et al. Long-term prognosis associated with coronary calcification. *J Am Coll Cardiol* 2007; 49:1860-70
60. Baumgart D, Schmermund A, George G, et al. Comparison of electron beam computed tomography with intracoronary ultrasound and coronary angiography for detection of coronary atherosclerosis. *J Am Coll Cardiol* 1997; 30: 57-64
61. Schmermund A, Baumgart D, Görge G, et al. Coronary artery calcium in acute coronary syndromes: a comparative study of electron-beam computed tomography, coronary angiography, and intracoronary ultrasound in survivors of acute myocardial infarction and unstable angina. *Circulation* 1997; 96: 1461-9
62. Leber AW, Becker A, Knez A, et al. Accuracy of 64-slice computed tomography to classify and quantify plaque volumes in the proximal coronary system: a comparative study using intravascular ultrasound. *J Am Coll Cardiol* 2006; 47:672-7
63. Montenegro MR, Eggen DA. Topography of atherosclerosis in the coronary arteries. *Lab Invest* 1968; 18: 586-93
64. Nauth HF, Hort W, Hubinger R. Untersuchungen über die Lokalisation sklerotischer Veränderungen in den Koronararterien und ihren großen epikardialen Ästen. *Z Kardiol* 1979; 68: 832-8
65. Halon DA, Sapoznikov D, Lewis BS, Gotsman MS. Localization of lesions in the coronary circulation. *Am J Cardiol* 1983; 52:921-926
66. Schmermund A, Baumgart D, Möhlenkamp S, et al. Natural history and topographic pattern of progression of coronary calcification in symptomatic patients. *Arterioscler Thromb Vasc Biol* 2001; 21: 421-426
67. Maher JE, Bielak LF, Raz JA, Sheedy PF II, Schwartz RS, Peyser PA. Progression of coronary artery calcification: a pilot study. *Mayo Clin Proc* 1999; 74: 347-355

68. Budoff MJ, Lane KL, Bakhsheshi H, et al. Rates of progression of coronary calcium by electron beam tomography. *Am J Cardiol* 2000; 86: 8-11
69. Yoon HC, Emerick AM, Hill JA, Gjertson DW, Goldin JG. Calcium begets calcium: progression of coronary artery calcification in asymptomatic subjects. *Radiology* 2002; 224: 236-241
70. Raggi P, Cooil B, Ratti C, Callister TO, Budoff M. Progression of coronary artery calcium and occurrence of myocardial infarction in patients with and without diabetes mellitus. *Hypertension* 2005;46:238- 243
71. Hokanson JE, MacKenzie T, Kinney G, et al. Evaluating changes in coronary artery calcium: an analytic method that accounts for interscan variability. *Am J Radiology* 2004;182:1327-1332
72. Stary HC. The development of calcium deposits in atherosclerotic lesions and their persistence after lipid regression. *Am J Cardiol* 2001; 88: 16E-19E.
73. Callister TQ, Raggi P, Cooil B, Lippolis NJ, Russo DJ. Effect of HMG-CoA reductase inhibitors on coronary artery disease as assessed by electron-beam computed tomography. *N Engl J Med* 1998; 339: 1972-1978
74. Achenbach S, Ropers D, Pohle K, et al. Influence of lipid-lowering therapy on the progression of coronary artery calcification: a prospective evaluation. *Circulation* 2002; 106: 1077-82
75. Arad Y, Spadaro LA, Roth M, Newstein D, Guerci AD. Treatment of symptomatic adults with elevated coronary calcium scores with atorvastatin, vitamin C, and vitamin E, the St Francis Heart Study randomized clinical trial. *J Am Coll Cardiol* 2005; 46: 166-72
76. Raggi P, Davidson M, Callister TQ, et al. Aggressive versus moderate lipid- lowering therapy in hypercholesterolemic postmenopausal women. Beyond endorsed lipid lowering with EBT scanning (BELLES). *Circulation* 2005; 112: 563-71
77. Afilalo J, Majdan AA, Eisenberg MJ. Intensive statin therapy in acute coronary syndromes and stable coronary heart disease: a comparative meta-analysis of randomized controlled trials. *Heart* 2007; 93: 914-21
78. Möhlenkamp S, Moebus S, Schmermund A, et al. für die Studiengruppe der Heinz Nixdorf Recall Studie. Analyse des natürlichen Verlaufs der Koronargefäßverkalkung und Identifizierung ihrer Determinanten. *Herz* 2007; 32: 108-20