Long-Term Angiographic Follow-Up of Robotic-Assisted Coronary Artery Revascularization

Maria E. Currie, MD, Jonathan Romsa, MD, Stephanie A. Fox, RRCP, William C. Vezina, MD, Cigdem Akincioglu, MD, James C. Warrington, MD, R. Scott McClure, MD, Larry W. Stitt, MS, Alan H. Menkis, MD, W. Douglas Boyd, MD, and Bob Kiaii, MD

Division of Cardiac Surgery, Department of Surgery, and Department of Nuclear Medicine, London Health Sciences Centre, London, Ontario; Department of Clinical Epidemiology and Biostatistics, The University of Western Ontario, London, Ontario; Cardiac Sciences Program, University of Manitoba, Winnipeg, Manitoba, Canada; and Department of Cardiothoracic Surgery, University of California, Sacramento, California

Background. **Robotic-assisted coronary artery bypass grafting (CABG) has been shown in short-term studies to increase patient satisfaction and to reduce surgical morbidity and recovery times. However, the long-term patency rate of robotic-assisted CABG is unknown. Therefore, the objective of this study was to assess the long-term patency rate of robotic-assisted coronary artery bypass grafts.**

Methods. **The study cohort included all patients who underwent robotic-assisted conduit dissection for CABG at London Health Sciences Centre between September 1999 and December 2003. These patients had selective graft patency assessment using cardiac catheterization or computed tomography angiography (CTA), or both, and stress myocardial perfusion scintigraphy (MPS) 5 to 10 years after surgery to evaluate graft patency and to give functional information on the hemodynamic significance of any graft stenosis. Patients also completed quality of life questionnaires.**

Results. **From a total of 160 patients who underwent robotic-assisted CABG, 82 eligible patients were followed with graft patency assessments for a mean period of 8 years ± 16.3 months. The patency rate of all robotic-assisted CABG grafts in this patient cohort was 92.7%. The patency rate of left internal thoracic artery grafts to the left anterior descending artery after robotic-assisted CABG in this patient cohort was 93.4%. Patients consistently attained high scores on quality of life questionnaires after surgery.**

Conclusions. **The long-term patency rate of grafts after robotic-assisted CABG was 92.7% at a mean follow-up period of 95.8 ± 16.3 months. Specifically, the patency rate of left internal thoracic artery grafts to the left anterior descending artery after robotic-assisted CABG was 93.4%.**

(Ann Thorac Surg 2012;93:1426–31)

Robotic-assisted cardiac surgery is a rapidly evolving technology. In 1994, Benetti and colleagues [1] introduced the limited anterior thoracotomy for left anterior descending artery (LAD) bypass. Throughout the 1990s, endoscopic, video-assisted, and finally, robotic-assisted left internal thoracic artery (LITA) dissection were performed, and led to the subsequent development of robotic-assisted endoscopic atraumatic coronary artery bypass (endoACAB). In endoACAB, the internal thoracic artery (ITA) is harvested endoscopically using robotic assistance, and the distal anastomosis is completed through a minianterior thoracotomy using the off-pump beating heart technique [2]. In 1998, Loulmet and colleagues [3] reported the feasibility of totally endoscopic coronary artery bypass (TECAB) on an arrested heart using the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA) to harvest the LITA and perform a LITA to LAD coronary anastomosis. In 2000, Boyd and colleagues [4] and Falk and associates [5] independently reported the first off-pump TECAB using different robotic surgical systems.

Short-term outcome studies have shown that this technology reduces surgical morbidity and recovery times because these surgeries involve smaller incisions and do not require sternotomy or the heart-lung machine [6]. Whereas the impact of LITA graft patency on favorable outcomes in conventional coronary artery bypass graft surgery (CABG) is definitive, the long-term patency rates of robotic-assisted CABG are unknown. Loop and co-

Accepted for publication Nov 14, 2011.

Address correspondence to Dr Currie, Division of Cardiac Surgery, University of Western Ontario, 339 Windermere Rd, London, ON N6A 5A5, Canada; e-mail: maria.currie@londonhospitals.ca.

Published by Elsevier Inc

0003-4975/$36.00
doi:10.1016/j.athoracsur.2011.11.031

Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CT	= computed tomography
CTA	= computed tomography angiography
EndoACAB	= endoscopic atraumatic coronary artery bypass
ITA	= internal thoracic artery
LAD	= left anterior descending artery
LITA	= left internal thoracic artery
MIBI	= technetium-99m 2-methoxyisobutyl-isonitrile
MPS	= myocardial perfusion scintigraphy
SAQ	= Seattle Angina Questionnaire
SF-36	= Medical Outcomes Study 36-Item Short-Form Health Survey
TECAB	= totally endoscopic coronary artery bypass

workers [7] and Cameron and associates [8] have shown the survival benefit of the LITA graft extends to 10 and 15 years, respectively, with patency rates of greater than 90%. Similarly, studies to assess the long-term patency rates of robotic-assisted bypass grafts are necessary to determine its long-term benefits. Robotic-assisted CABG requires proper evaluation to ensure that the established short-term benefits are gained without compromising the patency of bypass grafts.

Therefore, the objectives of this observational, cohort study were to assess the long-term patency rate of bypass grafts using cardiac angiography, computed tomography angiography (CTA), and stress myocardial perfusion scintigraphy (MPS) with technetium-99m 2-methoxy-isobutyl-isonitrile (MIBI) 5 to 10 years after robotic-assisted CABG.

Patients and Methods

Patients

The study population included patients who underwent robotic-assisted dissection of the left or right ITA for endoACAB or TECAB at London Health Sciences Centre between September 1999 and December 2003. During this time, patients underwent endoACAB using either the Automated Endoscopic Stabilizer for Optimal Positioning 3000 (AESOP; Computer Motion, Goleta, CA), the Zeus robotic surgical system (Computer Motion), or the da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA). The AESOP is a single-arm robot that facilitates video thoracoscopic ITA dissection by providing steady images and voice-activated camera control. Using the AESOP, robot-assisted, video-enhanced CABG is performed through a limited-access incision using a Harmonic Scalpel (Ethicon EndoSurgery, Cincinnati, OH) for ITA dissection and voice-activated robotic assistance [9]. The Zeus telemanipulation system is a multiple-arm robotic telemanipulator that incorporates voice-activated robotic and video assistance and allows control of surgical instruments within the thorax from a distant console. Using the Zeus telemanipulation system, internal thoracic arteries were harvested with a Harmonic Scalpel, and either endoACAB was performed under direct vision through a 5-cm to 6-cm anterolateral muscle-sparing minithoracotomy [6, 9, 10], or TECAB was performed using Zeus needle driver and forceps [4]. The da Vinci telemanipulation system is a computer-assisted telemicromanipulator with an operating console and three-dimensional endoscopic camera. This surgical system was used to perform both endoACAB and TECAB. Postoperative cardiac angiography was completed before discharge to assess graft patency.

After approval from the Ethics Review Board of the University of Western Ontario, all eligible robotic-assisted CABG patients were contacted for their informed consent to participate in the study. Patients who had died, were unable or unwilling to give informed consent, or who had any history of allergic reaction to radiographic contrast used in CTA or severe adverse reactions to medications used in MPS-MIBI procedures were excluded from this study.

Evaluating Graft Patency

Patients who agreed to be a part of the study underwent a comprehensive function and anatomic cardiac assessment according to a 1-day protocol using MPS and CTA. The MPS was performed using Tc-99m MIBI according to a 1-day rest (350 to 450 MBq)/stress (1,000 to 1,500 MBq) protocol. All MPS studies were acquired with attenuation correction on GE Infinia Hawkeye cameras (General Electric Healthcare, Milwaukee, WI). All studies were processed and analyzed using both QGS/QPS and EC Tool Box software programs (General Electric Healthcare). Calcium scoring followed by coronary CTA (using Visipaque 320 or Isovue 370; General Electric Healthcare) was performed on a GE Light Speed VCT 64-slice CT (General Electric Healthcare). Calcium scores were calculated using the Smartscore software (General Electric Healthcare). The CT angiograms were processed and reviewed using the AW 4.4 workstations and software (General Electric Healthcare).

Functional and anatomic imaging allowed for complete assessment of the graft function. The MPS added another layer of information to the anatomic findings from CTA, so that in equivocal cases where the grafts where not clearly patent or occluded, an assessment could be made regarding hemodynamic significance (Table 1). In addition, an evaluation could be made with regards to coronary stents and the functional significance of coronary artery disease in other vascular territories. All CT angiograms and MPS-MIBIs were performed and graded by both a nuclear medicine physician and a cardiac surgeon.

Assessment of Quality of Life

At the time of follow-up, patients completed two validated health-related quality of life questionnaires, the Seattle Angina Questionnaire (SAQ) and the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-

Table 1. Grading System Developed for Assessing Graft Patency and Hemodynamic Significance of Any Occluded or Stenosed Bypass Graft

Grade	Graft Quality
1	Patent
2A	Artifact or stenosis on coronary CTA, not hemodynamically significant on stress MPS-MIBI
2B	Artifact or stenosis on coronary CTA, hemodynamically significant on stress MPS-MIBI
3	Occlusion

CTA = computed tomography angiography; MPS-MIBI = myocardial perfusion scintigraphy with technetium-99m 2-methoxyisobutyl-isonitrile.

36). The SAQ is sensitive to clinical changes in cardiovascular disease [11]. The SF-36 is a general quality of life questionnaire that assesses eight health concepts: (1) limitations in physical activities because of health problems; (2) limitations in social activities because of physical or emotional problems; (3) limitations in usual role activities because of physical health problems; (4) bodily pain; (5) general mental health (psychological distress and well-being); (6) limitations in usual role activities because of emotional problems; (7) vitality (energy and fatigue); and (8) general health perceptions [12].

Statistical Analysis

All statistical analysis was performed using Microsoft Excel (Redmond, WA). Continuous variables are expressed as mean with standard deviation (SD). Categorical variables are expressed as percentages.

Results

Patient Characteristics

Between September 1998 and December 2003, 160 patients underwent robotic-assisted CABG at London Health Sciences Centre. Fifteen patients were converted to conventional CABG with sternotomy and cardiopulmonary bypass or to percutaneous coronary intervention with stent placement during their initial coronary revascularization surgery or before their discharge from hospital. In addition, 25 of these patients underwent robotic ITA harvest and subsequent sternotomy with off-pump CABG. These patients were excluded from long-term follow-up analysis. Among the 120 eligible patients, 26 patients did not give informed consent to participate in the study, and 7 patients had died. Three deaths were due to acute myocardial infarctions. Three deaths were from noncardiac causes (1 malignancy, 1 renal failure, and 1 pulmonary fibrosis), and 1 death was from unknown causes. Five patients underwent MPS-MIBI with no CTA or angiogram and were excluded from further analysis. Therefore, 82 patients, or 68.3% of the eligible patient population, were included in this study. Preoperative characteristics of these patients are illustrated in Table 2.

Thirty-two patients had robotic-assisted CABG using the AESOP 3000; 47 patients had robotic-assisted CABG surgery using the Zeus telemanipulation surgical system; and 3 patients had robotic-assisted CABG surgery using the da Vinci telemanipulation system. All patients underwent first-time CABG. Seventy-six patients underwent robotic-assisted CABG with a LITA to LAD bypass. Five patients underwent hybrid procedures with concomitant stent placement. The mean hospital stay for patients was 3.8 ± 1.1 days (Table 3).

Graft Patency

The mean interval from operation to follow-up was 8 years ± 16 months (range, 58 to 125 months). At follow-up, there were six graft occlusions. Five patients had conduit tapering at the anastomosis; however, no ischemia was identified in the graft territories of these patients, and their estimated left ventricular ejection fractions were normal by MPS-MIBI. The overall patency of ITA conduits at 8 years ± 16.3 months after endoACAB or TECAB grafts was 92.7% (Table 4). Specifically, the overall patency of the robotic-assisted LITA to LAD graft after endoACAB or TECAB was 93.4% (71 of 76 conduits). The patency rate of endoACAB and TECAB RITA and LITA grafts, excluding composite LITA-SVG grafts, was 73 of 79 grafts, or 92.4%.

Furthermore, an additional 7 patients who had under-

Table 2. Preoperative Patient Data

Characteristic	Population (n = 82)
Age, mean (SD)	55.5 (9.8)
Female	5 (6.1)
Body mass index >30 kg/m^2	30 (36.6)
Myocardial infarction within 30 days	7 (8.5)
Number of diseased coronary vessels	
1	70 (85.4)
2	11 (13.4)
3	1 (1.2)
Diabetes mellitus	10 (12.2)
Chronic obstructive pulmonary disease	7 (8.5)
Peripheral vascular disease	2 (2.4)
Cerebral vascular disease	2 (2.4)
Canadian Cardiovascular Society angina class	
1	1 (1.2)
2	11 (13.4)
3	45 (54.9)
4A	20 (24.4)
4B	3 (3.7)
4C	2 (2.4)
Ventricular grade	
1	66 (80.5)
2	14 (17.1)
3	2 (2.4)
4	0 (0)

Values are n (%), unless otherwise indicated.

SD = standard deviation.

Table 3. Perioperative and Postoperative Patient Characteristics

Characteristic	Population (n = 82)
Elective case	72 (87.8)
Urgent case	10 (12.2)
AESOP	32 (39)
Zeus	47 (57.3)
Da Vinci	3 (3.7)
EndoACAB	70 (85.4)
TECAB	12 (14.6)
LITA to LAD	76 (92.7)
Composite LITA and SVG to LAD	3 (3.65)
RITA to RCA	3 (3.65)
Hybrid revascularization	5 (6.1)
Complete revascularization	75 (91.5)
Postoperative angiogram	73 (89)
Days in hospital, mean (SD)	3.8 (1.1)
Readmission to hospital in 30 days	5 (6.1)

Values are n (%) unless otherwise indicated.

AESOP = Automated Endoscopic Stabilizer for Optimal Positioning; EndoACAB = endoscopic atraumatic coronary artery bypass; LAD = left anterior descending artery; LITA = left internal thoracic artery; RCA = right coronary artery; RITA = right internal thoracic artery; SVG = saphenous vein graft; TECAB = totally endoscopic coronary artery bypass; Zeus = Zeus robotic surgical system.

gone robotic-assisted RITA or LITA dissection, sternotomy, and off-pump CABG underwent follow-up angiogram and MIBI with CTA. Of these 7 patients, 6 had fully patent robotic-assisted ITA conduits. Therefore, the overall patency rate of all the robotic-assisted ITA dissected conduits at a follow-up period of 7.9 years ± 16.1 months was 82 of 89 grafts, or 92.1%. An additional 5 patients underwent MPS-MIBI only at the time of follow-up. Four of these patients underwent endoACAB with LITA to LAD bypass. One patient underwent robotic-assisted LITA dissection with sternotomy and off-pump CABG LITA to LAD bypass. All of these patients had no ischemic myocardium at a mean follow-up time of 95 ± 12.7 months.

Table 4. Angiographic, CTA, and Stress MPS-MIBI Patency

Graft Grade	Population (n = 82)
Grade 1	
Patent bypass graft	71 (86.6)
Grade 2A	
Artifact or stenosis, not hemodynamically significant	5 (6.1)
Grade 2B	
Artifact or stenosis, hemodynamically significant	0 (0)
Grade 3	
Occluded bypass graft	6 (7.3)
Total patency	76 (92.7)

Values are given as n (%).

CTA = computed tomography angiography; MPS-MIBI = myocardial perfusion scintigraphy with technetium-99m 2-methoxyisobutyl-isonitrile.

Table 5. Preoperative and Perioperative Characteristics of Patients Assessed for Quality of Life

Preoperative and Perioperative Characteristics	Population (n = 67)
Male	63 (94)
Diabetes mellitus	10 (14.9)
Hypertension	30 (44.8)
Dyslipidemia	49 (73.1)
Smoking history	41 (61.2)
Family history of premature coronary artery disease	46 (68.7)
Bypass conduit	
LITA	62 (92.5)
RITA	2 (3)
Composite LITA-SVG	3 (4.5)
Robotic surgical device	
AESOP	24 (35.8)
Zeus	40 (59.7)
Da Vinci	3 (4.5)
Robotic surgical procedure	
EndoACAB	57 (85.1)
TECAB	10 (14.9)

Values are presented as n (%).

AESOP = Automated Endoscopic Stabilizer for Optimal Positioning; EndoACAB = endoscopic atraumatic coronary artery bypass; LITA = left internal thoracic artery; RITA = right internal thoracic artery; SVG = saphenous vein graft; TECAB = totally endoscopic coronary artery bypass; Zeus = Zeus robotic surgical system.

Quality of Life

Sixty-seven patients consented to complete quality of life questionnaires at the time of their follow-up. The preoperative and perioperative characteristics of these patients are illustrated in Table 5. At the time of follow-up, 1 patient had symptoms of angina with exertion. The CTA revealed that this patient's LITA conduit was grafted to the diagonal branch of the LAD, rather than the intended LAD target. This patient was found to have an occluded LITA graft and

Table 6. Follow-Up Patient SF-36 Scores

Domains of SF-36	SF-36 Score
Physical functioning	79.6 (25.3)
Role limitations due to physical health	89.6 (25.8)
Role limitations due to emotional problems	91 (22.9)
Energy/fatigue	66.8 (19.3)
Emotional well-being	81.1 (15.1)
Social functioning	92.4 (14.4)
Pain	82.4 (19)
General health	70 (16.7)

Values for all domains are given as mean (SD).

SD = standard deviation; SF-36 = Medical Outcomes Study 36-Item Short-Form Health Survey.

Table 7. Follow-Up Patient Seattle Angina Questionnaire Results

Domains of Seattle Angina Questionnaire	Score
Physical limitation	61.7 (13.3)
Angina stability	80.6 (26.8)
Angina frequency	94.8 (11.5)
Treatment satisfaction	89.6 (14.8)
Disease perception	85.3 (17.5)

Values are shown as mean (SD).

subsequently underwent percutaneous coronary intervention with stent placement to the proximal LAD. All other patients were symptom free.

The SF-36 results revealed that patients consistently had positive perceptions of their general health. Patients' perceptions of their physical functioning, ability to perform usual roles, and vitality were all above average (50 ± 10), where a score of 100 is symptom free and full level of functioning (Table 6). The SAQ results revealed patients scored consistently high in the areas of physical function, angina stability, angina frequency, treatment satisfaction, and health perception (Table 7). These quality of life scores were compared to the quality of life questionnaire scores from patients enrolled in the Synergy Between PCI With Taxus and Cardiac Surgery (SYNTAX) trial 1 year after conventional CABG for triple-vessel or left main coronary artery disease [13]. Patients who underwent robotic-assisted CABG had either significantly higher quality of life scores or comparable SF-36 and SAQ scores compared with patients who had undergone conventional CABG (Tables 6 and 7).

Comment

Robotic-assisted CABG is a rapidly advancing field that requires proper evaluation to ensure that the established short-term benefits are gained without compromising the known benefits of conventional CABG. This is the first long-term study of patency rates of grafts after robotic-assisted CABG using cardiac angiography, CTA, and MPS-MIBI.

In addition, this study evaluates conduit patency using 64-multidetector row CTA and MPS-MIBI that describes both angiographic patency and myocardial perfusion and function. Previous investigators who have examined long-term graft patency in conventional CABG used the FitzGibbon score that is based solely on angiographic qualities and does not examine the functional significance of graft stenosis [14]. Previous studies have reported the sensitivity and specificity of CTA to detect greater than 50% coronary stenosis. With 64-slice technology, the sensitivity for graft stenosis approaches 100% with a specificity of greater than 85% [15, 16]. One study reported 64-multidectector row coronary CTA had a sensitivity and specificity of 95% and 83% to detect coronary stenosis greater than 50% according to conventional coronary angiography [17]. Another study reported 64-multidetector row coronary CTA had a sensitivity and specificity of 85% and 90% to detect coronary stenosis greater than 50% according to conventional coronary angiography [18]. In addition, a literature review of the diagnostic value of 64-multislice CTA in the detection of coronary artery disease compared to conventional coronary angiography reported no significant difference in diagnostic sensitivity and specificity between the two imaging techniques when the coronary calcium score is low [19]. There is a limitation of CTA to visualize the graft lumen in the vicinity of metal clips, motion artifact, heavy coronary calcification, and small vessel diameter. However, when employed in concert with MPS-MIBI, an overall assessment of any graft irregularities and their functional significance based on the presence and location of myocardial ischemia was possible.

Using this combined assessment tool, we have demonstrated that the overall patency rate of the robotic-assisted ITA bypass grafts is 92.7% at a mean follow-up period of 95.8 ± 16.3 months after endoACAB or TECAB. Specifically, the overall patency rate of the LITA graft after endoACAB or TECAB is 93.4%. These results are comparable to long-term patency rates of LITA grafts in conventional CABG with a 10-year patency of more than 90% [20, 21]. Early conversions from robotic-assisted CABG to sternotomy and cardiopulmonary bypass were not included in long-term analysis.

In addition to providing comparable long-term LITA patency, we have demonstrated that robotic-assisted CABG has an overall positive long-term impact on patient quality of life using a general health questionnaire, the SF-36, and the SAQ, which is more sensitive to clinical change in coronary artery disease in comparison to more generic quality of life questionnaires [22].

Study Limitations

This is a single-center study with no control group. Robotic-assisted graft patency was compared to conventional CABG conduit patency reported in previous literature. In addition, as robotic-assisted CABG is always advancing with new technology, the patients in this study underwent robotic-assisted CABG with different robotic technology as it evolved. The use of newer devices, techniques, and surgical approaches was associated with a learning curve that may have affected the quality of the anastomoses. This effect was not examined in this study. Conversely, these advances in robotic technology and endoscopic stabilizers will most likely improve the quality of anastomoses. Further studies examining long-term graft patency should be conducted using these more advanced robotic technologies and different revascularization strategies as they evolve.

In summary, robotic-assisted CABG provides both a long-term graft patency rate comparable to that of conventional CABG and a positive impact on patient quality of life.

We would like to thank Ryan MacDonald, Meaghan Mahadeo, and Mahmoud Badreddine of the Department of Nuclear Medicine, London Health Sciences Centre, London, Ontario, Canada, for their assistance in collecting data.

References

1. Benetti FJ, Ballester C, Barnia A. [Uso de la toracoscopia en cirugia coronaria para disección de la mamaria izquierda.] Prensa Medica Argentina 1994;81:877–9.
2. Vassiliades TA. Endoscopic-assisted atraumatic coronary artery bypass. Asian Cardiovasc Thorac Ann 2003;11:359–61.
3. Loulmet D, Carpentier A, d'Attellis N, et al. Endoscopic coronary artery bypass grafting with the aid of robotic-assisted instruments. J Thorac Cardiovasc Surg 1999;118:4–10.
4. Boyd WD, Rayman RR, Desai ND, et al. Closed-chest coronary artery bypass grafting on the beating heart with the use of a computer-enhanced surgical robotic system. J Thorac Cardiovasc Surg 2000;120:807–9.
5. Falk V, Diegleler A, Walther T, et al. Total endoscopic computer enhanced coronary artery bypass grafting. Eur J Cardiothorac Surg 2000;17:38–45.
6. Kiaii B, McClure RS, Stitt L. Prospective angiographic comparison of direct, endoscopic, and telesurgical approaches to harvesting the internal thoracic artery. Ann Thorac Surg 2006;82:624–9.
7. Loop FD, Lytle BW, Cosgrove DM. Influence of the internal-mammary-artery graft on 10-year survival and other cardiac events. N Engl J Med 1986;314:1–6.
8. Cameron A, Davis KB, Green G, Schaff HV. Coronary bypass surgery with internal-thoracic-artery grafts—effects on survival over a 15-year period. N Engl J Med 1996;334:216–9.
9. Boyd WD, Kiaii B, Novick RJ, et al. RAVECAB: improving outcome in off-pump minimal access surgery with robotic assistance and video enhancement. Can J Surg 2001;44:45–50.
10. Holzhey DM, Jacobs S, Mochalski M, et al. Minimally invasive hybrid coronary artery revascularization. Ann Thorac Surg 2008;86:1856–60.
11. Spertus JA, Winder JA, Dewhurst TA, et al. Development and evaluation of the Seattle Angina Questionnaire: a new functional status measure for coronary artery disease. J Am Coll Cardiol 1995;25:333–41.
12. Ware JE, Sherbourne CD. The MOS 36-Item Short-Form Health Survey (SF-36): I. Conceptual framework and item selection. Med Care 1992;30:473–83.
13. Cohen DR, Van Hout B, Serruys PW, et al. Quality of life after PCI with drug-eluting stents or coronary-artery bypass surgery. N Engl J Med 2011;364:1016–26.
14. Fitzgibbon GM, Kafka HP, Leach AJ, Keon WJ, Hooper GD, Burton JR. Coronary bypass graft fate and patient outcome: angiographic follow-up of 5,065 grafts related to survival and reoperation in 1,388 patients during 25 years. J Am Coll Cardiol 1996;28:616–26.
15. Ropers D, Pohle F-K, Kuettner A, et al. Diagnostic accuracy of noninvasive coronary angiography in patients after bypass surgery using 64-slice spiral computed tomography with 330-ms gantry rotation. Circulation 2006;114:2334–41.
16. Weustink AC, Nieman K, Pugliese F, et al. Diagnostic accuracy of computed tomography angiography in patients after bypass grafting. J Am Coll Cardiol Img 2009;2:816–24.
17. Budoff MJ, Dow D, Jollis JG, et al. Diagnostic performance of 64-multidetector row coronary computed tomographic angiography for evaluation of coronary artery stenosis in individuals without known coronary artery disease: results from the prospective multicenter ACCURACY (Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography) trial. J Am Coll Cardiol 2008;52:1724–32.
18. Miller JM, Rochitte CE, Dewey M, et al. Diagnostic performance of coronary angiography by 64-row CT. N Engl J Med 2008;359:2324–36.
19. Sun Z, Lin C, Davidson R, Dong C, Liao Y. Diagnostic value of 64-slice CT angiography in coronary artery disease: a systematic review. Eur J Radiol 2008;67:78–84.
20. Shah PJ, Durairah M, Gordon I, et al. Factors affecting patency of internal thoracic artery graft: clinical and angiographic study in 1434 symptomatic patients operated between 1982 and 2002. Eur J Cardiothorac Surg 2004;26:118–24.
21. Sabik JH, Lytle BW, Blackstone EH, Houghtaling PL, Cosgrove DM. Comparison of saphenous vein and internal thoracic artery graft patency by coronary system. Ann Thorac Surg 2005;79:544–51.
22. Spertus JA, Winder JA, Dewhurst TA, Deyo RA, Fihn SD. Monitoring the quality of life in patients with coronary artery disease. Am J Cardiol 1994;74:1240–4.