Nonelective cardiac surgery in the elderly: Is it justified?

Ravi K. Ghanta, MD, Prem S. Shekar, MD, Siobhan McGurk, BS, Donna M. Rosborough, RN, MS, and Sary F. Aranki, MD

Objective: Elderly patients might be denied nonelective cardiac surgery because of the perception of poor outcomes and an unacceptable quality of life. In this study we evaluate long-term survival and quality of life in these patients.

Methods: From 1994 to 1999, 262 consecutive patients older than 80 years underwent urgent (n = 223) or emergent (n = 39) cardiac surgery. Of these patients, 160 (61%) underwent coronary artery bypass grafting, 64 (24%) underwent coronary artery bypass grafting plus valve surgery, 17 (7%) underwent valve surgery, and 21 (8%) underwent aortic surgery. Kaplan–Meier survival analysis and quality-of-life assessment were performed, and result were compared with age-adjusted population data. Risk factors for mortality were determined by using Cox regression. The utility of Society of Thoracic Surgeons and EuroSCORE risk scoring were assessed by using area under receiver operating curves.

Results: Early mortality was 11% (n = 29) overall, 7% (n = 16) in urgent cases, and 33% (n = 13) in emergent cases. Five-year survival was 50% (n = 132) overall, 53% (n = 105) in urgent cases, and 36% (n = 18) in emergent cases. There was no difference in 10-year survival between patients undergoing urgent surgical intervention and age-adjusted population data. Among survivors, quality-of-life measures were equivalent to those of the general elderly population. Risk factors for early mortality were age, emergent procedure, aortic procedure, bypass time, and postoperative complication (renal failure, myocardial infarction, cerebrovascular accident, pneumonia, and reoperation for bleeding). Risk factors for late mortality were peripheral vascular disease, emergent procedure, bypass time, and new renal failure. The EuroSCORE and Society of Thoracic Surgeons risk scores were equivalent but only moderately predictive of mortality.

Conclusions: Long-term survival and quality of life after nonelective cardiac surgery can equal that of the general elderly population. Age alone should not disqualify a patient for urgent or emergent cardiac surgery. (*J Thorac Cardiovasc Surg* 2010;140:103-9)

Supplemental material is available online.

Eighteen million persons are currently older than 75 years in the United States, and the number is expected to increase significantly over the next decade.¹ Similar trends are occurring worldwide.² Cardiovascular disease remains the leading cause of morbidity and mortality in the elderly population.³ As the elderly population increases, cardiac surgery in octogenarian and nonagenarian patients is becoming increasingly common.⁴⁻⁶ However, elderly patients are less likely to be referred for elective cardiac surgery than younger

patients. Many elderly patients view cardiac surgery as a risky proposition with little potential gain. Similarly, referring physicians also perceive poor outcomes and poor postoperative quality of life (QoL).⁷⁻⁹ For these reasons, elderly patients are more likely to present with unstable symptoms than younger patients, forcing consideration for urgent or emergent cardiac surgery.¹⁰ Several studies have demonstrated encouraging survival and QoL in elderly patients undergoing cardiac surgery but note that nonelective surgery is associated with 2 to 3 times greater risk.^{4,10-13}

No prior study has evaluated long-term survival and QoL outcomes of elderly patients undergoing urgent or emergent cardiac surgery, and few data exist to guide clinical decision making for this patient population. The goal of this study is to evaluate the long-term survival and QoL for nonelective cardiac surgery in our octogenarian and nonagenarian patients. We compare these outcomes with age-adjusted population data. We also identify risk factors for early and late mortality and evaluate the utility of existing clinical predictive algorithms for this patient population.

MATERIALS AND METHODS

Patients

All patients 80 years of age or older who underwent nonelective cardiac surgery between January 1994 and December 1999 at Brigham and

From the Division of Cardiac Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, Mass.

Supported by Brigham and Women's Hospital, Division of Cardiac Surgery.

Disclosures: None.

Received for publication July 9, 2009; revisions received Sept 16, 2009; accepted for publication Oct 3, 2009; available ahead of print Dec 14, 2009.

Address for reprints: Sary F. Aranki, MD, Division of Cardiac Surgery, Brigham and Women's Hospital, 75 Francis St, Boston, MA 02115 (E-mail: saranki@partners.org).

0022-5223/\$36.00

Crown Copyright © 2010 Published by Elsevier Inc. on behalf of The American Association for Thoracic Surgery

doi:10.1016/j.jtcvs.2009.10.001

Abbreviations and Acronyms

AUROC	= area under the receiver operating curve
CABG	= coronary artery bypass grafting
CVA	= cerebrovascular accident
LOS	= length of stay
MI	= myocardial infarction
QoL	= quality of life
SF-12	= Medical Outcomes Study Short Form 12
STS	= Society of Thoracic Surgeons

Women's Hospital were identified. Nonelective surgery was defined as an urgent or emergent operation, as defined by the Society of Thoracic Surgeons, required for acute myocardial infarction (MI), unstable angina, critical coronary anatomy, cardiogenic shock, or aortic rupture or dissection. During this 5-year period, 262 consecutive patients were identified, of whom 223 (80%) underwent urgent surgery and 39 (20%) underwent emergent surgery. Patients' preoperative, operative, and postoperative variables were retrieved from the prospective Brigham Cardiac Surgery Database. Procedures were divided into coronary artery bypass grafting (CABG) alone, valve surgery with or without CABG, and aortic surgery.

Outcomes

We evaluated the frequency of postoperative complications, length of stay (LOS), discharge disposition, early mortality, long-term survival, and long-term QoL. In all patients the postoperative course was followed, and intubation time and intensive care unit and hospital LOS and patient disposition were determined. Complications, such as death, cerebrovascular accident (CVA), pneumonia, new-onset atrial fibrillation, postoperative MI, reoperation for bleeding, and new-onset renal failure were identified. Early mortality was defined as death within 30 days of the operation or at any point while still in the hospital. CVA included strokes, transient ischemic attacks, and coma. New-onset renal failure was defined as a creatinine value of greater than 2.0 mg/dL with no history of preoperative renal failure. Pneumonia was identified in patients with positive bacterial sputum cultures or radiographic findings consistent with pulmonary infection. Postoperative MI was defined as the presence of at least 2 of the following: prolonged typical chest pain not relieved by nitrates, enzyme level increase, new wall motion abnormalities, and/or ST-segment or Q-wave electrocardiographic changes in 2 or more contiguous leads.

The vital status of all discharged patients was determined from medical records, a query of the Social Security Death Index, and/or communication with the patient's family or physician before August 2004. Survivors were then sent the Medical Outcomes Study Short Form 12 (SF-12) Health Survey, version 2, to evaluate QoL.^{14,15} The deadline for questionnaire return was March 2005. Long-term mortality through June 2008 was ascertained by means of a subsequent query of the Social Security Death Index and medical records.

Analysis and Statistical Methods

Statistical analyses were performed with SPSS 13.0 software (SPSS, Inc, Chicago, Ill), and a *P* value of less than .05 was considered statistically significant. Evaluation of dichotomous variables was done with the Fisher's exact test. One-way analyses of variance were used to evaluate continuous variables. Survival curves were calculated by using the Kaplan-Meier method.¹⁶ Observed postoperative survival was compared with predicted survival of a similarly aged cohort from United States census data.¹⁷ A univariate followed by multivariate Cox proportional hazards regression from

preoperative, operative, and postoperative variables was performed to identify risk factors for late mortality. For early/operative mortality, only a univariate Cox proportional hazards regression was performed because there were too few mortalities to perform a multivariate model. The predicted operative mortality was calculated by using the Society of Thoracic Surgeons (STS) and the logistic European system for cardiac risk assessment (EuroSCORE) algorithms to evaluate the utility of existing clinical risk stratification protocols.^{18,19} The STS- and EuroSCORE-predicted operative mortality was then compared with the observed mortality. Receiver operating curves were determined, and the area under the receiver operating curve (AUROC) was used to assess the accuracy of the score in predicting mortality.²⁰ QoL data were compared with normative data for patients 75 years or older and patients with cardiac disease.¹⁴

RESULTS**Patient Demographics**

Patient characteristics and comorbidities are summarized in Table 1. The mean age of patients at the time of surgical intervention was 83 ± 3 years, with a range of 80 to 93 years. There were 8 nonagenarians overall, with 4 undergoing urgent operations and 4 undergoing emergent operations. Preoperatively, 52% of patients demonstrated New York Heart Association Class III or IV heart failure. The most frequent preoperative comorbidities were hypertension (74%), diabetes (25%), renal failure (16%), and history of CVA (12%). Only 1 patient with preoperative renal failure was hemodialysis dependent. CABG alone was performed in 61% of patients, representing the most common surgical procedure. Valve surgery with or without CABG was performed in 31% of patients. Aortic surgery was performed in 8% of patients, including 5 patients with acute type A aortic dissection and 1 patient with a type B aortic dissection. Fourteen patients had an ascending aortic aneurysm with either possible rupture or concomitant ischemia and valve dysfunction requiring urgent or emergent repair. One patient had a ruptured descending thoracic aneurysm. Aortic surgery was more common in emergent cases. The most common indication for urgent surgery was unstable angina requiring intravenous nitroglycerin (29%). The most common indication for emergent surgery was evolving MI (41%). All procedures were performed with cardiopulmonary bypass. Thirty-one (12%) patients had undergone previous cardiac operations.

Postoperative Complications and Early Mortality

Postoperative morbidity, mortality, and LOS are summarized in Table 2. Early mortality was 11% overall, 7% in urgent cases, and 33% in emergent cases. The surgical procedures and cause of death in the emergent cases are listed in Table E1. The most frequent causes of death in this group were CVA, multisystem organ failure, and cardiac arrest. Overall, the most frequent postoperative complication was atrial fibrillation (48% of patients) followed by pneumonia (28%), new-onset renal failure (7.3%), reoperation for bleeding (7.6%), and CVA (5.7%). The median hospital LOS was 9 days, with a median intensive care unit LOS of 3

TABLE 1. Patient preoperative and surgical characteristics

	Overall		Urgent surgery		Emergent surgery	
	No.	%	No.	%	No.	%
No. of patients	262		223	85.1	39	12.2
Age (median [range])	82 (80–93)		82 (80–91)		83 (80–93)	
Female sex	130	49.6	112	50.2	18	45.0
NYHA class 3/4	136	51.9	113	50.7	23	59.0
Hypertension	195	74.4	163	73.1	32	82.1
Diabetes	66	25.2	57	25.6	9	23.1
Renal failure	42	16.0	32	14.3	10	25.6
CVA	32	12.2	29	13.0	3	7.7
Atrial fibrillation	34	13.0	30	13.5	4	10.3
BMI (median [25th–75th percentile])	25 (22–27)		25 (22–27)		26 (24–28)	
LVEF (median [25th–75th percentile])	50 (40–60)		50 (40–60)		50 (44–55)	
Previous cardiac surgery procedures	31	11.8	25	11.2	6	19.4
CABG alone	160	61.1	137	61.4	23	59.0
Proximal anastomoses	2 (1–3)		2 (1–2)		2 (1–2)	
Distal anastomoses	3 (2–4)		3 (2–4)		3 (2–3)	
CABG+valve	64	24.4	57	25.6	7	17.9
Proximal anastomoses	2 (1–3)		1 (1–2)		2 (2–3)	
Distal anastomoses	2 (1–3)		2 (1–3)		3 (2–3)	
Mitral	22	34.4	18	31.6	4	57.1
Aortic	34	53.1	32	56.1	2	28.6
Mitral + aortic	7	10.9	6	10.5	1	14.3
Tricuspid	1	1.6	1	1.8	0	
Valve alone	17	6.5	16	7.2	1	2.6
Mitral	7	41.1	7	43.8	0	
Aortic	8	47.1	7	43.8	1	100
Mitral + aortic	1	5.9	1	6.3	0	
Tricuspid	1	5.9	1	6.3	0	
Aorta	21	8.0	13	5.8	8	20.5
Reason for nonelective status						
Acute or evolving MI	35	13.4	19	8.5	16	41.0
IABP	27	10.3	27	12.1		
USA w/IV NTG	65	24.8	65	29.1		
Coronary anatomy	35	13.4	35	15.7		
Valve dysfunction	45	17.2	44	19.7	1	0.4
Worsening chest pain	9	3.4	9	4.0		
CHF	24	9.2	24	10.8		
Shock w/pressors	13	6.1			13	33.3
Aortic dissection	6	5.0			6	15.4
Angiographic accident	3	1.1			3	1.3
Bypass time, min (median [25th–75th percentile])	103 (74–140)		103 (74–140)		104 (79–142)	
Crossclamp time, min (median, 25th–75th percentile)	70 (48–101)		72 (50–104)		57 (34–79)	

Number of proximal and distal anastomoses indicates median and 25th and 75th percentiles. *NYHA*, New York Heart Association; *CVA*, cerebrovascular accident; *BMI*, body mass index; *LVEF*, left ventricular ejection fraction; *CABG*, coronary artery bypass grafting; *MI*, myocardial infarction; *IABP*, intra-aortic balloon pump; *USA w/IV NTG*, unstable angina with intravenous nitroglycerin; *CHF*, congestive heart failure.

days. Most patients (68%) were discharged to a rehabilitation facility.

Long-Term Survival

Kaplan–Meier survival curves are presented in Figure 1, which demonstrates survival in the urgent and emergent groups compared with the expected survival for an age-matched cohort from US census data. For urgent cardiac surgery 1-, 5-, and 10-year survival was 81.6%, 52.9%, and

30.7%, respectively. For emergent cardiac surgery, 1-, 5-, and 10-year survival was 48.7%, 35.9%, and 15.4%, respectively. For the age-matched cohort, 1-, 5-, and 10-year expected survival from census data was 92.4%, 62.9%, and 34.8%, respectively. There was no significant difference in 10-year survival between the general elderly population and patients requiring urgent cardiac surgery ($P = .188$). Patients who required emergent surgery, however, had decreased 10-year survival ($P < .01$). Figure E1

TABLE 2. Postoperative course, morbidity, and mortality

	Overall		Urgent surgery		Emergent surgery	
	No.	%	No.	%	No.	%
No. of patients	262		223	85.1	39	12.2
Intubation time, h (median [25th–75th percentile])	16.0 (12–30)		16.0 (12–25)		22.0 (18–47)	
ICU LOS, d (median, 25th–75th percentile)	3 (2–4)		3 (2–4)		3 (2–5)	
Hospital LOS, d (median, 25th–75th percentile)	9 (7–15)		9 (7–14)		9 (7–21)	
Discharged to rehab facility	178	67.9	158	70.9	20	51.3
Postoperative complications						
Atrial fibrillation	125	47.7	107	48.0	18	46.2
Pneumonia	72	27.5	52	23.3	20	51.3
Reoperation for bleeding	20	7.6	13	5.8	7	17.9
Renal failure	19	7.3	11	4.9	8	20.5
CVA	15	5.7	10	4.5	5	12.8
Early mortality	29	11.1	16	7.2	13	33.3
5-y Survival	132	50.4	118	52.9	14	35.9
Survival, y (median, 25th–75th percentile)	5.2 (1.7–9.8)		5.6 (2.5–9.9)		0.6 (0.2–7.8)	

ICU, Intensive care unit; LOS, length of stay; CVA, cerebrovascular accident.

demonstrates the survival curves by procedure type. Patients who underwent CABG only had the highest long-term survival. Patients who underwent aortic procedures had the highest early mortality; however, 10-year survival is similar to that seen in patients who underwent valve surgery.

Predictors of Mortality

Risk factors from the Cox regression for early and late mortality are presented in Table 3. For early mortality, significant risk factors were age, emergent status, aortic surgery, reoperative surgery, prolonged bypass time, and any major postoperative complication except for atrial fibrillation. Major postoperative complications included new-onset renal failure, pneumonia postoperative MI, CVA, and reop-

eration for bleeding. New-onset renal failure was the greatest risk factor for early mortality, with a hazard ratio of 11. Of the 19 patients with new-onset postoperative renal failure, 4 required hemodialysis. All 4 of these patients had early mortality, suggesting that requirement for hemodialysis significantly increases risk for early mortality. For late mortality, significant risk factors were concomitant peripheral vascular disease, emergent surgery, prolonged bypass time, and new-onset postoperative renal failure. Postoperative MI, CVA, pneumonia, and reoperation for bleeding did not increase the risk for late mortality. Increased body mass index decreased the risk for late mortality. Figure E2 demonstrates receiver operating curves for the existing clinical predictors for mortality: the logistic EuroSCORE- and STS-predicted 30-day mortality. There was no difference between the AUROCs of the logistic EuroSCORE and STS (0.745 vs 0.694, $P = .21$).

Quality of Life

At the time of follow-up in 2005, we identified 84 survivors, of whom 62% returned SF-12 QoL surveys. All respondents were at least 5 years postoperatively from their cardiac surgery, with a 7-year median follow-up time. Figure 2 shows the QoL scores in the respondents in comparison with normative data from subjects older than 75 years, and subjects with heart disease. Across all variables of the SF-12, our respondents had scores comparable with those of these US cohorts. There was no difference in mental and physical combined scores between surgical patients, patients with heart disease, and general elderly patients. There was also no difference between QoL in survivors of urgent and emergent cardiac surgery. Table E2 lists the physical and mental combined scores of respondents after emergent cardiac surgery. The scores are comparable with the mean values for the elderly population.

FIGURE 1. Kaplan-Meier survival analysis.

TABLE 3. Risk factors for early and late mortality

Risk factor	Hazard ratio	Confidence interval	P value
Early mortality			
Preoperative factors			
Age	1.163	1.028–1.315	.016
Female sex	1.118	0.517–2.421	.776
HTN	0.890	0.374–2.116	.792
Diabetes	0.587	0.215–1.608	.300
NHYA class III or IV	1.595	0.058–3.542	.249
Renal failure	1.676	0.574–4.894	.345
COPD	0.970	0.317–2.966	.957
PVD	1.592	0.662–3.825	.299
CVA	1.171	0.380–3.615	.783
BMI	0.935	0.843–1.037	.219
Reoperation	2.771	1.072–7.162	.035
Previous MI	1.885	0.810–4.245	.144
Emergent surgery	6.469	2.799–14.951	.001
Aortic surgery	10.159	3.522–29.301	.001
Valve surgery	1.693	0.672–4.269	.264
Postoperative factors			
Bypass time (min)	1.009	1.003–1.014	.003
Postoperative AF	0.540	0.214–1.211	.135
MI	9.500	2.567–35.174	.001
New renal failure	11.161	3.933–31.669	.001
CVA	6.493	2.121–19.871	.001
Pneumonia	5.424	2.414–12.187	.001
Reoperation for bleeding	4.081	1.430–11.643	.014
Late mortality			
PVD	1.865	1.26–2.77	.002
BMI	0.96	0.92–1.00	.035
Emergent surgery	1.51	1.01–2.27	.044
Bypass time (min)	1.006	1.00–1.01	.001
New renal failure	3.452	1.85–6.45	<.0001

HTN, Hypertension; NYHA, New York Heart Association; COPD, chronic obstructive pulmonary disease; PVD, peripheral vascular disease; CVA, cerebrovascular accident; BMI, body mass index; MI, myocardial infarction; AF, atrial fibrillation.

DISCUSSION

The principle finding of this study is that urgent and emergent cardiac surgery can be performed in octogenarian and nonagenarian patients with acceptable operative mortality,

FIGURE 2. Postoperative quality-of-life scores compared with the US population and patients with heart disease, as assessed by the Medical Outcomes Study Short Form 12.¹⁴

long-term survival, and postoperative QoL. In our series 10-year survival and postoperative QoL were equivalent to those of the general elderly population in the United States. Despite nonelective cardiac surgery being associated with 2 to 3 times greater risk in the elderly, our operative mortality rate of 11% is similar to all inclusive operative mortality rates in previous studies of octogenarian patients, where mortality ranged from 9% to 20%.^{4,10} The patients in this study presented with unstable angina, evolving acute MI, valve dysfunction and congestive heart failure, shock, aortic aneurysm rupture, or acute aortic dissection. Although there are no randomized trials comparing medical management with nonintervention in these patients, the expected mortality would be high. Without surgical intervention, we believe many of these patients would likely have not survived their hospital stay. In our study, despite poor cardiac status at presentation, patients lived as long as the general population. Stoica and colleagues¹⁰ found that octogenarians who undergo elective cardiac surgery actually outlived their peers in the United Kingdom.

As expected, operative mortality was much higher with emergent operations compared with that seen after urgent operations, particularly for aortic surgery. Patients who presented for emergent surgery had an operative mortality of 33%, nearly 5 times higher than the 7% operative mortality for those presenting for urgent operations. In octogenarian and nonagenarian patients who present with acute aortic dissection, clinical decisions regarding surgical intervention should consider this high mortality rate. For these patients, less invasive options, such as medical management or endovascular stent grafting, might be more appropriate.²¹

Like mortality, postoperative QoL is an important measure of success, particularly in this elderly population. We evaluated QoL at least 5 years postoperatively by using the well-established SF-12 assessment and compared responses with those of the general US elderly population and patients with cardiac disease.^{14,15} Postoperative patients had equivalent physical health and mental health scores. Thus patients after nonelective cardiac surgery can return to a normal physical and mental functional capacity. Even in patients who have emergent operations, excellent return of function can be achieved (Table E2). Huber and associates²² also recently found that QoL improved in octogenarians 2 years after cardiac surgery.

Preoperative risk stratification in this group of patients is critical to guide clinical decision making. The AUROC is a well-established measure of diagnostic performance of a test. The AUROC can distinguish between nonpredictive (AUROC < 0.5), less predictive (AUROC between 0.5 and 0.7), moderately predictive (AUROC between 0.7 and 0.9), and highly predictive (AUROC > 0.9) tests.^{23,24} In this series the AUROC was 0.745 for the logistic EuroSCORE-predicted and 0.694 for the STS-predicted early mortality, with no statistically significant difference between

the 2. Thus both tests are only less to moderately predictive of true operative risk in this patient population. Previous studies have also found that these existing risk models might be limited in high-risk subgroups.^{19,25,26} New models need to be developed to appropriately risk stratify elderly patients undergoing cardiac surgery.

In our study we found that age, emergent surgery, aortic or reoperative cardiac surgery, prolonged bypass time, and virtually any significant postoperative complication, with the exception of atrial fibrillation, increased the risk for early mortality. Although preoperative comorbidities, such as renal failure, diabetes, and chronic obstructive pulmonary disease, likely contribute to early mortality, they were so prevalent in our patient population that they could not be used as a useful predictor. These results are similar to those of prior large population series in octogenarians in which medical comorbidities were found to be less predictive in comparison with younger age groups.^{4,10} Given this high-risk patient population, it is not surprising that postoperative complications are poorly tolerated. Zingone and coworkers²⁷ also recently found that having a single postoperative complication doubled the risk for hospital death in 355 octogenarians after cardiac surgery. Thus to maximize outcomes in this patient population, good surgical technique must be combined with meticulous postoperative management. Preventative measures to minimize ventilator-associated pneumonias, such as early extubation, head of bed elevation, and aspiration precautions, should be emphasized.²⁸ In addition, nephrotoxic drugs should be minimized, and renal function should be closely monitored. Of the major postoperative complications, only new-onset renal failure was predictive of late mortality, further emphasizing the importance of renal protection. Because body mass index was found to reduce the risk for late mortality, the importance of nutrition should also be emphasized.

Limitations

As a single-institution retrospective study, our study has several limitations. Our sample size is small and selective, which might limit translation to the general population. The sample size also likely decreases our ability to identify some significant risk factors that can influence overall outcome. The heterogeneity of surgical interventions precluded statistical analyses by operation type. Because our study evaluated outcomes after operations from 1994 to 1995, improvements in operative technique and perioperative management might have led to further improvements in operative mortality and postoperative complications than those presented in this study. In addition, our QoL assessment included a small, self-selected group of survivors. Poorly functioning survivors might not have returned the questionnaire. A responder bias analysis, however, did not reveal any significant differences in preoperative characteristics or in-hospital outcomes between responders and non-responders. However, true postoperative QoL might be

lower than reported. These limitations should be carefully considered when interpreting our results.

CONCLUSION

Nonelective cardiac surgery can be performed in octogenarian and nonagenarian patients with acceptable mortality and long-term survival. Emergent aortic surgery has the highest rate of operative mortality. Long-term postoperative QoL equals that of the general population. Medical comorbidities and existing clinical algorithms are not predictive of early mortality and should be carefully considered before they are used as contraindications for surgical intervention. Postoperative complications were stronger risk factors for operative deaths, and efforts to minimize complications, especially renal failure, should be maximized.

References

- Day JC. Population projections of the United States by age, sex, race, and Hispanic origin: 1996 to 2050, U.S. Bureau of the Census, current population reports, P25-1130. Washington, DC: U.S. Bureau of the Census; 1996.
- United Nations, Department of Economic and Social Affairs, Population Division. Population challenges and development goals. New York, NY: United Nations; 2005.
- Association AH. Heart disease and stroke statistics—2008 update. Dallas, Texas: American Heart Association; 2008.
- Alexander KP, Anstrom KJ, Muhlbaier LH, Grosswald RD, Smith PK, Jones RH, et al. Outcomes of cardiac surgery in patients ≥ 80 years: results from the National Cardiovascular Network. *J Am Coll Cardiol*. 2000;35:731-8.
- Rosengart TK, Finnin EB, Kim DY, Samy SA, Tanheco Y, Ko W, et al. Open heart surgery in the elderly: results from a consecutive series of 100 patients aged 85 years or older. *Am J Med*. 2002;112:143-7.
- Edmunds LH Jr, Stephenson LW, Edie RN, Ratcliffe MB. Open-heart surgery in octogenarians. *N Engl J Med*. 1988;319:131-6.
- Varadarajan P, Kapoor N, Bansal RC, Pai RG. Clinical profile and natural history of 453 nonsurgically managed patients with severe aortic stenosis. *Ann Thorac Surg*. 2006;82:2111-5.
- Mirabel M, lung B, Baron G, Messina-Zeitoun D, Detaint D, Vanoverschelde JL, et al. What are the characteristics of patients with severe, symptomatic, mitral regurgitation who are denied surgery? *Eur Heart J*. 2007;28:1358-65.
- Bach DS, Radeva JI, Birnbaum HG, Fournier AA, Tuttle EG. Prevalence, referral patterns, testing, and surgery in aortic valve disease: leaving women and elderly patients behind? *J Heart Valve Dis*. 2007;16:362-9.
- Stoica SC, Cafferty F, Kitcat J, Baskett RJ, Goddard M, Sharples LD, et al. Octogenarians undergoing cardiac surgery outlive their peers: a case for early referral. *Heart*. 2006;92:503-6.
- Barnett SD, Halpin LS, Speir AM, Albus RA, Akl BF, Massimiano PS, et al. Postoperative complications among octogenarians after cardiovascular surgery. *Ann Thorac Surg*. 2003;76:726-31.
- Peterson ED, Cowper PA, Jollis JG, Bechuk JD, DeLong ER, Muhlbaier LH, et al. Outcomes of coronary artery bypass graft surgery in 24,461 patients aged 80 years or older. *Circulation*. 1995;92(suppl):II85-91.
- Ullery BW, Peterson JC, Milla F, Wells MT, Briggs W, Girardi LN, et al. Cardiac surgery in select nonagenarians: should we or shouldn't we? *Ann Thorac Surg*. 2008;85:854-60.
- Ware J, Kosinski M, Turner-Bowker D, Gandek B. How to score version 2 of the SF-12 Health Survey. Lincoln, RI: QualityMetric Inc; 2005.
- Xie J, Wu EQ, Zheng ZJ, Sullivan PW, Zhan L, Labarthe DR. Patient-reported health status in coronary heart disease in the United States: age, sex, racial, and ethnic differences. *Circulation*. 2008;118:491-7.
- Kaplan E, Meier P. Nonparametric estimation from incomplete observations. *J Am Stat Assoc*. 1958;53:457-81.
- Aries E. National vital statistics reports: National Center for Health Statistics. Atlanta, Ga: Centers for Disease Control and Prevention; 2007.
- Shroyer AL, Coombs LP, Peterson ED, Eiken MC, DeLong ER, Chen A, et al. The Society of Thoracic Surgeons: 30-day operative mortality and morbidity risk models. *Ann Thorac Surg*. 2003;75:1856-65.

19. Michel P, Roques F, Nashef SA. Logistic or additive EuroSCORE for high-risk patients? *Eur J Cardiothorac Surg*. 2003;23:684-7.
20. Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology*. 1982;143:29-36.
21. Kpodonu J, Preventza O, Ramaiah VG, Shennib H, Wheatley GH 3rd, Rodriguez-Lopez JA, et al. Endovascular repair of the thoracic aorta in octogenarians. *Eur J Cardiothorac Surg*. 2008;34:630-4.
22. Huber CH, Goeber V, Berdat P, Carrel T, Eckstein F. Benefits of cardiac surgery in octogenarians—a postoperative quality of life assessment. *Eur J Cardiothorac Surg*. 2007;31:1099-105.
23. Zweig MH, Campbell G. Receiver-operating characteristic (ROC) plots: a fundamental evaluation tool in clinical medicine. *Clin Chem*. 1993;39:561-77.
24. Greiner M, Pfeiffer D, Smith RD. Principles and practical application of the receiver-operating characteristic analysis for diagnostic tests. *Prev Vet Med*. 2000;45:23-41.
25. Dewey TM, Brown DL, Das TS, Ryan WH, Fowler JE, Hoffman SD, et al. High-risk patients referred for transcatheter aortic valve implantation: management and outcomes. *Ann Thorac Surg*. 2008;86:1450-7.
26. Nilsson J, Algotsson L, Høglund P, Lührs C, Brandt J. Early mortality in coronary bypass surgery: the EuroSCORE versus the Society of Thoracic Surgeons risk algorithm. *Ann Thorac Surg*. 2004;77:1235-40.
27. Zingone B, Gatti G, Rauber E, Tiziani P, Dreas L, Pappalardo A, et al. Early and late outcomes of cardiac surgery in octogenarians. *Ann Thorac Surg*. 2009;87:71-8.
28. Pieracci FM, Barie PS. Strategies in the prevention and management of ventilator-associated pneumonia. *Am Surg*. 2007;73:419-32.

FIGURE E1. Kaplan–Meier survival analysis by procedure type. CABG, Coronary artery bypass grafting.

FIGURE E2. Receiver operating curves of EuroSCORE and Society of Thoracic Surgeons predictive algorithms.

TABLE E1. Operative mortalities and cause of death for emergent operations

Age (y)	Mortality POD	Indication	Type of operation	Cause of death
80	0	Aortic dissection	Descending aortic dissection repair/CABG	Recurrent dissection/cardiac arrest
90	0	Aortic dissection	Ascending aortic replacement/AVR/CABG	Cardiac arrest
80	2	Ruptured aneurysm	Thoracoabdominal aneurysm repair	CVA
92	3	Aortic dissection	Ascending aortic replacement/CABG	Cardiac arrest
83	4	Evolving MI	MVP/CABG	MSOF
89	6	Ruptured aneurysm	Aortic arch replacement	CVA
84	7	Evolving MI	CABG	Respiratory failure
89	7	Angiographic accident	AVR/CABG	Ischemic bowel, CVA
90	7	Shock/MI	CABG	Cardiogenic shock
84	7	Shock/MI	CABG	Respiratory failure
82	8	Evolving MI	CABG	MSOF, CVA
88	111	Valve dysfunction/CHF	AVR/CABG	GI bleed, MSOF

POD, Postoperative day; CABG, coronary artery bypass grafting; AVR, aortic valve replacement; CVA, cerebrovascular accident; MI, myocardial infarction; MVP, mitral valve repair; MSOF, multisystem organ failure; CHF, congestive heart failure; GI, gastrointestinal.

TABLE E2. Postoperative quality of life among survivors after emergent operations

Age (y)	Type of operation	Follow-up (y)	PCS	MCS
86	CABG	8.5	34.2	35.5
82	CABG	9.3	37.6	39.3
85	CABG	8.0	37.6	21.8
80	CABG	7.6	40.9	58.6
80	CABG	6.8	41.5	41.2
80	CABG	8.0	50.7	54.2
86	CABG	6.6	54.2	58.7
Mean			42.4	44.2
National average ≥ 75 y			39.5*	50.9*

PCS, Physical Combined Score from the Medical Outcomes Study Short Form 12; MCS, Mental Combined Score from the Medical Outcomes Study Short Form 12; CABG, coronary artery bypass grafting. *No statistically significant difference.