Outcomes After Surgical Treatment for Type A Acute Aortic Dissection in Octogenarians: A Multicenter Study

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Background. Management of octogenarian patients with acute type A acute aortic dissection is controversial. This study analyzed the surgical outcomes to identify patients who should undergo operations.

Methods. Beginning January 2000, we established a registry including all octogenarian patients operated on for type A acute aortic dissection. We evaluated 57 consecutive patients enrolled up to December 2006. Their median age was 82 (range, 80 to 89 years). Compassionate indication operations were attempted in 2 moribund patients and in 5 presenting with shock associated with neurologic symptoms or renal failure, or both. Operations followed the standard procedure recommended in younger patients. Follow-up was 100% complete (mean, 3.9 ± 2 years; range, 5 months to 8 years).

Results. There were 26 (45.6%) in-hospital and 6 late deaths. Multivariate analysis identified compassionate indication ($p \leq 0.0001$) and total arch replacement ($p = 0.0060$) as risk factors for in-hospital mortality. Postoperative complications occurred in 36 patients (69.2%) and were associated with a higher mortality ($p = 0.0001$). Overall survival was 51% at 1 year and 44% at 5 years. Excluding patients with compassionate indication and those who underwent total arch replacement, or both, overall survival was 66% at 1 year and 57% at 5 years.

Conclusions. Surgical treatment for type A acute aortic dissection in octogenarians shows satisfactory midterm results among survivors. However, the high mortality rate imposes a requirement for better perioperative management. Compassionate cases should be managed medically. A less aggressive approach should improve outcomes of surgical treatment.

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Important demographic changes are taking place in Western populations. In the European Union, according to the on-line data set of the Statistical Office of the European Communities, the octogenarian population has grown from 1.5% in 1960 to 4.8% in 2007 and is expected to reach 7.4% in 2030 (Appendix 1).

During the last 15 years, a higher number of elderly patients have been referred for cardiac operations. If recent reports reveal that elective cardiac operations can improve mortality, morbidity, and quality of life in selected elderly individuals [1–3], controversy still exists about whether surgical intervention should be avoided in patients with type A acute aortic dissection (TAAD) on the sole basis of advanced age.

Recent studies have shown satisfactory results in elderly patients operated for TAAD [4–7], but specific outcomes in patients aged 80 years and older are not yet precise. Indeed, published series to date report in-hospital mortality of 0% to 83% and a survival rate of 0% to 55% at 5 years [8–12]. We therefore established a multicenter registry including all octogenarian patients operated for TAAD, documenting the precise clinical presentation, operative management, and outcomes in the aim to identify a subgroup of octogenarian patients who could benefit from surgical intervention.

Patients and Methods

The Registry

The registry was planned to assess the risk factors for in-hospital mortality, incidence of postoperative complications, and outcomes of octogenarian patients operated on for TAAD (Appendix 2).

TAAD was defined as the involvement of the ascending aorta presenting within 14 days of symptoms onset. Beginning January 1, 2000, all patients operated for TAAD at the participating centers and aged 80 years or older, were enrolled in the registry. Data from patients presenting with iatrogenic dissection or intramural he-

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Table 1. Demographics and History of Octogenarian Patients Operated on for Type A Acute Aortic Dissection

Variable Mean ± SD (Range), No. (%)	Overall (N = 57)	Discharged (n = 31)	Not Discharged (n = 26)	*p* Value
Demographics				
Age, y	82 ± 2 (80–89)	81.9 (80–89)	82.1 (80–89)	0.7384
Age ≥85 y,	9 (15.8)	4 (12.9)	5 (19.2)	0.5149
Male	30 (52)	16 (51.6)	14 (53.8)	0.8664
Etiology and history				
Hypertension	43 (75)	24 (77.4)	19 (73.1)	0.7048
Coronary artery disease	7 (12)	3 (9.7)	4 (15.4)	0.5140
BMI ≥ 30 kg/m^2	3 (5)	0 (0)	3 (11.5)	0.0889
Diabetes mellitus	0			
Smoking	11 (19)	7 (22.6)	4 (15.4)	0.4900
COPD	5 (8.7)	3 (9.7)	2 (7.7)	1.0000
Marfan syndrome	0			
Previous AV replacement	4 (7)	1 (3.2)	3 (11.5)	0.3215
Bicuspid AV	3 (5)	0	3 (11.5)	0.0889
Iatrogenic	0			

AV = aortic valve; BMI = body mass index; COPD = chronic obstructive pulmonary disease; SD = standard deviation.

matoma were excluded. Patients were identified prospectively at presentation or retrospectively by searching hospital discharge diagnosis records or surgical, pathology, and echocardiography databases, or both. The Institutional Ethics Committee at each participating center approved the study protocol and authorized its conduct and follow-up. Individual patient consent for inclusion in the study was obtained.

Data Collection

Data on patient demographics, results of imaging studies, details of medical and surgical treatment, and patient outcomes were collected by physicians at hospital discharge or by review of hospital records (Appendix 2). At the end of the study, data were forwarded to the coordinating center at the "Amiens-Picardie" University Hospital. Forms were reviewed and validated by the coordinating physician (A. P.) before statistical analysis.

Study Period and Follow-Up

We report data on all consecutive patients operated on between January 1, 2000, and December 31, 2006. Follow-up was 100% complete at April 30, 2008. Patients were followed up directly in the outpatient clinic or contacted directly by telephone interview. Mean follow-up was 3.9 ± 2 years, extended to a maximum of 8 years.

Data Analysis

Data analysis was performed with the JMP statistical analysis software (SAS Institute, Cary, NC). Continuous

Table 2. Clinical Presentation of Octogenarian Patients Operated for Type A Acute Aortic Dissection

Variable No. (%)	Overall (N = 57)	Discharged (n = 31)	Not Discharged (n = 26)	*p* Value
Clinical presentation				
Dissection				
Not complicated	32 (56.2)	21 (67.7)	11 (42.3)	0.0529
Complicated	25 (43.8)	10 (32.3)	15 (57.7)	0.0529
Neurologic deficits	11 (19.3)	2 (6.4)	9 (34.6)	0.0155[a]
Coma	2 (3.5)	0	2 (7.7)	0.2036
Stroke	7 (12.3)	2 (6.4)	5 (19.2)	0.2275
Paraplegia	2 (3.5)	0	2 (7.7)	0.2036
Mesenteric ischemia	3 (5.2)	0	3 (11.5)	0.0889
Shock	13 (22.8)	6 (19.3)	7 (26.9)	0.4983
CPR required	2 (3.5)	0	2 (7.7)	0.2036
Compassionate indication[b]	7 (12.3)	0 (0)	7 (26.9)	0.0025[a]

[a] Data entered into the stepwise analysis for multivariate model. [b] Compassionate indication: surgery attempted in moribund patients or in patients presenting with shock associated either with neurologic symptoms or renal failure, or both.

CPR = cardiopulmonary resuscitation.

Table 3. Surgical Procedures for Octogenarian Patients Operated on for Type A Acute Aortic Dissection

Variable No. (%) or mean ± SD (range)	Overall (N = 57)	Discharged (n = 31)	Not Discharged (n = 26)	*p* Value
Aortic replacement				
Ascending aorta	16 (28.1)	9 (29)	7 (26.9)	0.8598
+ Arch	33 (57.9)	17 (54.84)	16 (61.54)	0.6095
Hemiarch	27 (47.4)	16 (51.6)	11 (42.3)	0.4830
Total arch	6 (10.5)	0	6 (100)	0.0063[a]
+ Root	5 (8.8)	5 (16.1)	0	0.0563
+ Root + hemiarch	3 (5.7)	0	3 (11.5)	0.0889
Operative variables				
Subclavian artery cannulation	10 (17.5)	2 (6.4)	8 (30.8)	0.0142
Cardiocirculatory arrest	36 (63.2)	17 (54.8)	19 (73.1)	0.1521[a]
Antegrade arterial reperfusion	20 (35.1)	7 (22.6)	13 (50)	0.0300
Mean circulatory arrest time, min	44 ± 30	36 ± 19	51 ± 47	0.1566
Cardiocirculatory arrest ≥ 80 min	5 (8.8)	0	5 (100)	0.0445[a]
Circulatory arrest temp, °C[b]	19.7 ± 3 (15–26)	19.7 ± 3 (15–26)	19.4 ± 2.5 (16–20)	0.7348
Antegrade cerebral perfusion[c]	19 (33.3)	7 (22.6)	12 (46.1)	0.1399
Cross-clamp time, min	87 ± 45	78 ± 40	97 ± 50	0.1172
Cross-clamp time ≥ 77 min	31 (55.3)	14 (45.2)	17 (54.8)	0.1098[a]
CPB time, min	182 ± 81	155 ± 46	213 ± 101	0.0061
CPB time ≥ 200 min	18 (31.6)	5 (27.8)	13 (72.2)	0.0096[a]
Associated procedure				
≥CABG	6 (10.5)	1 (3.2)	5 (19.2)	0.0828[a]

[a] Data entered into the stepwise analysis for multivariate model. [b] Nasopharyngeal temperature. [c] Antegrade cerebral reperfusion: antegrade cerebral perfusion during circulatory arrest.

CABG = coronary artery bypass grafting; CPB = cardiopulmonary bypass; SD = standard deviation.

variables are presented as mean ± standard deviation and categoric variables are expressed as frequencies.

For the purpose of the statistical analysis, we included in a "compassionate patient" group all patients for whom operations were not denied despite a preoperative moribund status or a preoperative shock status associated with a neurologic deficit or renal failure, or both.

Early risk factors for hospital mortality were identified with univariate analysis before being processed in a multivariate analysis. Continuous variables were compared with the *t* test or the Wilcoxon rank sum test. For those that reached a value of $p \leq 0.2$, a receiver operating characteristic (ROC) curve analysis was first performed to identify the cutoff values. Then, continuous variables were categorized according to the cutoff values and analyzed as categoric variables. Categoric variables were compared by means of the χ^2 test or Fisher exact test (two-tailed) if the expected count in any cell was less than 5.

All variables that reached $p \leq 0.2$ at the univariate analysis were included into a stepwise logistic regression, provided they were present in at least 2% of the sample. Retention of risk variables was determined by using the likelihood ratio test. We considered a $p < 0.05$ to be significant. Survival was determined by the Kaplan-Meier method and is expressed as the proportion ± standard error.

Results

Study Population

During the study period, 435 patients underwent operations for TAAD at the participating centers. Among these, 57 (13%) were octogenarians and were enrolled in the registry. The male/female ratio approached 1:1 (Table 1). Patients were a mean age of 82 ± 2 years (range, 80 to 89 years), and 9 (15.8%) were aged 85 years or older. Most patients had a history of hypertension (75%). Coronary artery disease (12%) and active smoking (19%) were rather frequent. Four patients (7%) had a history of aortic valve replacement.

Clinical presentations are summarized in Table 2. One or more dissection-related complications were present in 25 patients (43.8%). Neurologic deficit (19.3%) and shock (22.8%) were common. Indication for operation was compassionate in 7 patients (12.3%) because they were moribund or presented in preoperative shock status associated either with neurologic symptoms or renal failure, or both.

Surgical Procedures

Surgical procedures are reported in Table 3. All operations occurred within 48 hours from the onset of symptoms. The diagnosis of TAAD was confirmed at operation. A standard median sternotomy and total cardiopulmonary bypass (CPB) were performed in all

patients. As recommended for younger patients, a tear-oriented approach was performed for all patients to find and resect the proximal intimal tear. Thus, all patients underwent replacement of the ascending aorta, extended to the arch in 33 (57.9%) and to the root in 8 (14%). At the root level, no patients underwent isolated aortic valve replacement.

Because of the characteristics of the registry, details of surgical technique varied among the participating centers, but the goal of the operations always followed the current rules of surgical management of TAAD. If the hemodynamic status was stable and surgeon planned hypothermic circulatory arrest, the CPB was established by a left subclavian artery cannulation. Nevertheless, the femoral artery was site of arterial cannulation in 82.5%.

In 63.2% of patients, deep (at nasopharyngeal temperature of 18°C) or moderate (at nasopharyngeal temperature of 25°C) hypothermic circulatory arrest was a planned procedure to allow arch inspection and open distal anastomosis. The proximal repair was usually started during the period of core cooling and accomplished during the rewarming period. After the distal anastomosis was completed under hypothermic circulatory arrest, antegrade arterial perfusion was through the left subclavian artery or by direct cannulation of the ascending aorta prosthesis in 55.5% of patients.

In the remaining 36.8%, the procedure was performed without circulatory arrest. These patients were cooled to a nasopharyngeal temperature of 30°C, and both anastomoses were performed during aortic cross-clamping. The replacement technique always included the interposition of a Dacron tube with Teflon strip (DuPont, Wilmington, DE) reinforcement of the aortic stump. The use of biologic glue was not constant among centers.

Outcomes

EARLY MORTALITY. There were 5 intraoperative deaths (9%). In 2 patients, a dramatic rupture of the descending thoracic aorta occurred after the distal repair was performed (isolated ascending aorta and total arch replacement). The femoral artery was the site of cannulation in both patients. The proximal intimal tear was resected, but the CPB was not switched to antegrade blood perfusion during the rewarming period. Two other patients could not be weaned from CPB due to a severe persistent left ventricular failure. Both patients underwent replacement of the ascending aorta and of the hemiarch, with a mean cross-clamping time of 88 minutes (range, 77 to 99 minutes). One patient underwent isolated ascending aorta replacement complicated by massive hemorrhage at the level of the ventricular-aortic junction that could be not controlled.

Table 4. Causes of In-hospital Mortality Among Octogenarian Patients

Variable	No. (%)
Cardiac failure	10 (38.5)
Cardiocirculatory arrest	5
Low cardiac output	3
Not weaned from CPB	2
Bleeding	2 (7.7)
Intraoperative	1
Postoperative	1
Cerebral	3 (11.5)
Stroke	2
Coma	1
Respiratory failure	3 (11.5)
Multiorgan failure	5 (19.2)
Intraoperative aortic rupture	2 (7.7)
Sepsis	1 (3.9)

CPB = cardiopulmonary bypass.

Table 5. Independent Predictors of In-hospital Mortality for Octogenarian Patients Operated on for Type A Acute Aortic Dissection

Variable	p Value
Preoperative variables	
Compassionate indication	≤0.0001
Operative variables	
Total arch replacement	0.0060
CABG	0.0514
Cross-clamp time ≥77 min	0.2642
CPB time ≥ 200 min	0.6547

CABG = coronary artery bypass grafting; CPB = cardiopulmonary bypass.

The 30-day mortality was 40.3% (23 of 57 patients). Overall in-hospital mortality was 45.6% (26 of 57 patients), ranging from 29.5% (13 of 44 patients) in those without preoperative dissection-related complications or total arch replacement to 100% (13 of 13 patients) in those referred as a compassionate indication or who had total arch replacement, or both. In-hospital mortality for patients aged 85 years or older was higher, at 55.5% vs 43.7%, without reaching a significant level ($p = 0.5149$).

Patients who died during hospitalization were significantly more likely to be referred with a compassionate indication, to have preoperative neurologic deficits, and to have undergone surgical procedure with a cardiocirculatory arrest time exceeding 80 minutes or a CPB time exceeding 200 minutes (Tables 2 and 3). More than half of patients died of cardiac events (38.5%) or multiorgan failure (19.2%). Two of 3 patients who died of neurologic damage had presented with preoperative stroke and coma (Table 4).

INDEPENDENT PREDICTORS OF IN-HOSPITAL DEATH. Stepwise logistic regression identified compassionate indication as the only preoperative independent risk factor for in-hospital mortality ($p \leq 0.0001$). Total arch replacement ($p = 0.0025$) was recognized as the only operative independent risk factor for in-hospital death (Table 5).

Postoperative Complications

Postoperative complications were common. Among the 52 patients who initially survived the operation, 36

Table 6. Postoperative Complications of Octogenarian Patients Operated on for Type A Acute Aortic Dissection

Variable No. (%)	Overall (N = 52)	Discharged (n = 31)	Not Discharged (n = 21)	p Value
All in-hospital complications	36 (69.2)	15 (48.4)	21 (100)	0.0001
Hemorrhage	2 (3.8)	0	2 (9.5)	0.1584
All neurologic deficits	8 (15.4)	2 (6.4)	6 (28.6)	0.0491
Stroke	7 (13.5)	1 (3.2)	6 (25.6)	0.0134
Paraplegia	1 (1.9)	1 (3.2)	0	1.0000
Coma	1 (1.92)	0	1 (4.7)	0.4038
Intubation > 48 h	23 (44.2)	8 (25.8)	15 (71.4)	0.0012
Respiratory failure	4 (7.7)	0	4 (19)	0.0221
Hemodialysis	14 (27)	5 (16.1)	9 (42.9)	0.0338
Low cardiac output syndrome	3 (5.8)	0	3 (14.3)	0.0602
Multiorgan failure	2 (3.8)	0	2 (9.5)	0.1584
Cardiocirculatory arrest	9 (17.3)	1 (3.2)	8 (38.1)	0.0018
Sepsis	8 (15.4)	4 (12.9)	4 (19)	0.6997

(69.2%) presented with at least one postoperative complication that led to in-hospital death in 21 (58.3%; p = 0.0001).

Nearly half of the patients (44.2%) required prolonged intubation. Continuous venovenous hemodiafiltration was established in 14 (27%). Of the 8 patients with postoperative neurologic complications, 5 presented with preoperative stroke or coma.

Univariate analysis found prolonged postoperative intubation, cardiac arrest, stroke, and continuous venovenous hemodiafiltration to be risk factors of in-hospital death (Table 6).

Mean lengths of stay, excluding in-hospital death, were 8 ± 7 days (range 2 to 36 days) in the intensive care unit and 20 ± 13 days (range 7 to 60 days) in the hospital.

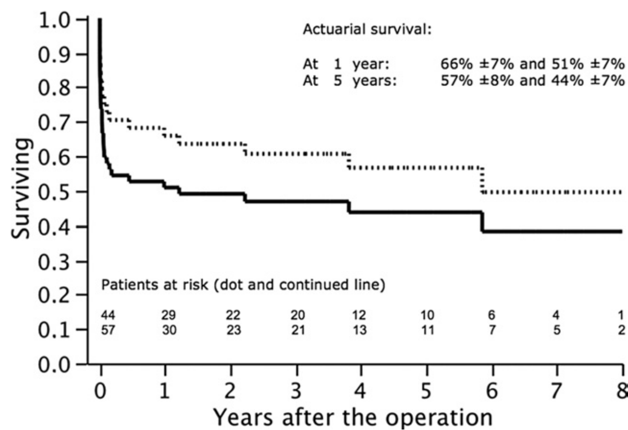

Fig 1. Actuarial survival at 1 and 5 years is shown for octogenarian patients who underwent operations for acute type A aortic dissection. The solid line shows overall survival. The dotted line shows survival excluding patients with a preoperative moribund status, preoperative shock associated with neurologic deficit or renal failure, or both, or patients who underwent total arch replacement.

Late Survival

Fig 1 shows the survival curves estimated by the Kaplan-Meier method. There were 6 late deaths. Overall survival rates were 51% ± 7% at 1 year and 44% ± 7% at 5 years. Among discharged patients, the probability of survival was 93% ± 6% at 1 year and 80% ± 6% at 5 years.

Excluding patients with a compassionate indication or those who underwent total arch replacement, overall survival was 66% ± 7% at 1 year and 57% ± 8% at 5 years. Among discharged patients, the probability of survival was 93% ± 6% at 1 year and 80% ± 6% at 5 years.

Reoperation

All discharged patients were included in a follow-up program based on annual transthoracic echocardiography and aortic computed tomography angiography to assess the evolution of the proximal and distal aorta. During the follow-up, no patient required reoperation on the proximal or distal aorta.

Comment

Even in this era of diminishing economic resources for health care, the question of whether expensive surgical therapy should be offered to high-risk patients with poor expectancy life needs to be guided by the practice of evidence-based medicine rather than by cost-saving measures. The statement that all patients aged older than 80 years should be not operated on because intervention on a series of 24 octogenarians did not reverse the unfavorable prognosis of the disease appears too excessive [9]. Indeed, Hata and colleagues [12] recently reported a spectacular success rate in a series of octogenarians who underwent operations. In the absence of practice guidelines, the management of octogenarian patients still remains unclear.

Using the largest database actually available, we analyzed risk factors for early death, surgical approach, and

midterm survival to identify a subgroup of octogenarian patients that could benefit from surgical intervention.

Early Mortality

Our study confirms the surgical outcomes reported by the International Registry of Acute Aortic Dissection (IRAD) investigation and compares favorably with the 60% in-hospital mortality rate for patients managed medically [13–15]. However, comparison may be not appropriate because these series reporting on medical management consisted of patients who refused an operation or were considered inoperable, thus overestimating the mortality of medical treatment.

As has been well demonstrated for younger patients [16, 17], our study clearly demonstrates the effect of preoperative clinical conditions on outcomes, finding 34% of deaths occurred in patients without any preoperative complication vs 100% in those operated on with a compassionate indication. As a result, the preoperative clinical status was the most significant factor predicting in-hospital death. Our data support the idea that a surgical option should be an effective treatment only in patients with a good preoperative clinical status, reserving medical treatment for patients with critical preoperative conditions.

Factors involved in the decision of withholding treatment are strongly influence by ethical, social, and cultural considerations. In France and Italy, the request for maximal life support by the patient, relatives, and physicians imposes the requirement that surgical intervention be attempted in almost all cases. We believe that our findings should help physicians to justify and propose medical treatment in patients with very compromised preoperative clinical conditions.

Octogenarian patients have high rates of postoperative complications. These data support the idea that elderly patient tolerate the operation but they do not tolerate postoperative complications. Considering the high mortality rate in those with postoperative complications, maintaining such patients into an active intensive care process, resulting in a postoperative extensive application of high-cost technology, should only be the result of a multidisciplinary decision after an enlightened discussion with the closest relatives.

Surgical Procedures

An analysis of the registry data shows the extent of the aortic replacement seriously affects the in-hospital mortality rate, increasing from low for isolated ascending aorta, moderate for hemiarch, to prohibitive for total arch replacement. As a result, the arch replacement is the only preoperative risk factor. Despite some groups who have claimed that an extensive aortic resection benefits patients by preventing rupture of the residual false lumen, this approach seems pointless for octogenarian patients in whom long-term potential complications are not necessarily an issue [18, 19].

We believe that performing operations with a minimum of invasive stress is a key factor to reduce the mortality rate. In the aim to minimize operative time and postoperative complications, Hata and colleagues [12] proposed a "less invasive quick replacement," reporting no postoperative complication and 0% mortality in a short series of octogenarian patients. Aiming at reducing the rewarming period, this interesting technique needs an attentive investigation in a larger cohort of octogenarians. If confirmed, the less invasive quick replacement could be a good compromise between surgical aggressiveness and invasive stress.

Late Survival

In this registry, operative repair reverses the unfavorable prognosis of the TAAD. The overall survival of 44% at 5 years is severely affected by the high in-hospital mortality rate. Among discharged patients, the probability of survival is 80% at 5 years, which is the life expectancy of octogenarian patients in the general population. In fact, after the acute postoperative phase, survival decreases slowly and shows very satisfactory midterm results (Fig 1). Information about survival of patients treated with medical management is sparse. The natural history with medical therapy alone would predict a 90-day mortality of 70% to 90% [20]. However, recent studies have showed how optimized medical management may change the catastrophic prognosis in patients deemed inoperable, reporting 5-year survival of 30% to 35% [13–15].

Our registry clearly shows that if we deny interventions for moribund octogenarians or for those with preoperative shock associated with neurologic deficit or renal failure, or both, and if we minimize the procedure to the ascending aorta, the in-hospital mortality rate decreases and the midterm survival dramatically improves to overcome those of any published medical series (Fig 1). Data on quality of life after the operation are not available for all patients, however, and we cannot estimate how many patients returned to their preoperative living status.

Conclusions

This study aims to provide a contribution in evidence-based guidelines for the care and treatment of octogenarian patients with type A acute aortic dissection. Because surgical treatment shows satisfactory midterm results among survivors, the statement that they should be denied surgery cannot be accepted. However, the high mortality rate imposes requirements for better perioperative management. Moribund patients or those with preoperative shock status associated with neurologic symptoms or renal failure, or both, should be managed medically. A straightforward approach that includes short cross-clamping time and short CPB time should improve outcomes of surgical treatment.

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Appendix 1

Octogenarian Population in the European Union[a]

Year	Population, No. Total	≥ 80 years old	%
1960	250,624,785	3,821,385	1.52
1970	271,517,342	5,079,602	1.87
1980	284,858,356	6,612,107	2.32
1990	292,673,202	9,721,637	3.32
2000	304,261,341	10,913,818	3.58
2010[b]	319,586,172	16,188,641	5.06
2020[b]	330,668,717	20,776,760	6.28
2030[b]	335,550,827	24,868,286	7.41

[a] Data derived from the Statistical Office of the European Communities (Eurostat). Available at http://epp.eurostat.ec.europa.eu. Data from Belgium, Germany (including ex-GDR from 1991), Ireland, Greece, Spain, metropolitan France, Italy, Grand Duchy of Luxembourg, Netherlands, Austria, Portugal, Finland. [b] Population projection, convergence year 2150.

Appendix 2

The Registry of Octogenarian Patients Operated on for Type A Acute Aortic Dissection

Participating Centers
"Amiens-Picardie" University Hospital, Amiens, France (coordinating center); "San Martino" University Hospital, Genova, Italy; "Henri Mondor" University Hospital, Creteil, France; "La Timone" University Hospital, Marseille, France; "Arnault Tzank" Institut, St. Laurent du Var, France.

Covariates Assessed for In-Hospital Mortality
Demographics and history covariates: age, gender, obesity, coronary artery disease, hypertension, diabetes mellitus, active smoking, chronic obstructive pulmonary disease, previous cardiac surgery, bicuspid aortic valve.

Preoperative clinical covariates: cardiac effusion, cardiac tamponade, shock, stroke, coma, paraplegia, visceral ischemia, acute renal failure, cardiopulmonary resuscitation.

Anatomic and operative covariates: Site of arterial cannulation, site of intimal tear, resection of the proximal intimal tear, intraoperative aortic rupture, aortic cross clamping (categorical covariate), cross clamping time, cardiopulmonary bypass time, circulatory arrest, cerebral perfusion during circulatory arrest, core temperature at circulatory arrest, extension of aortic replacement, associated procedures.