

# Analysis of Ascending and Transverse Aortic Arch Repair in Octogenarians

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**Background.** Increasing numbers of older patients are requiring complex thoracic aortic surgery. This retrospective study analyzed early and late outcomes after ascending and transverse arch surgery using hypothermic circulatory arrest (HCA).

**Methods.** Between January 1991 and December 2006, 779 patients requiring HCA were treated. Outcomes are reported by age group: group 1, 80 years or more (37, 4.8%); and group 2, less than 80 years (742, 95.2%). Univariate and multivariate analyses were used to identify risk factors for morbidity and mortality.

**Results.** Early mortality and stroke did not differ between groups. Thirty-day mortality was 13.5% (5 of 37) in group 1 and 10% (78 of 742) in group 2 ( $p = 0.57$ ). Stroke occurred in 8% (3 of 37) of group 1 patients and 2.7% (20 of 742) of group 2 patients ( $p = 0.09$ ). Predictors of stroke were prior stroke ( $p = 0.003$ ) and pump time ( $p = 0.02$ ).

Predictors of early mortality were low glomerular filtration rate ( $p = 0.0001$ ), long cardiopulmonary bypass time ( $p = 0.0001$ ), and emergent repair ( $p = 0.0009$ ). Retrograde cerebral perfusion was protective against stroke ( $p = 0.0001$ ) and reduced early mortality ( $p = 0.02$ ). Age was not a predictor of stroke ( $p = 0.12$ ) or early mortality ( $p = 0.39$ ). Survival in group 1 compared with the age-matched US population at 1 year was 56% versus 86% ( $p = 0.02$ ); at 2 years, 48% versus 76% ( $p = 0.03$ ); at 5 years, 36% versus 48% (not significant); and at 10 years, 20% versus 20%.

**Conclusions.** Ascending and aortic arch surgery in octogenarians involving profound HCA resulted in reasonable morbidity and short- and long-term mortality rates. The use of profound HCA for aortic surgery remains warranted in octogenarians.

(Ann Thorac Surg 2008;86:774–9)

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**I**ncreasing life expectancy in industrialized countries has led to increasing numbers of older patients requiring major cardiovascular surgery. With advancements in surgical technique, myocardial protection, anesthesia, and critical care, marked and sustained improvements in early and late outcomes in coronary [1] and valvular surgery [2, 3] have been observed among octogenarians. Some debate, however, still remains on whether ascending and aortic arch surgery requiring profound hypothermic circulatory arrest (HCA) should be performed on octogenarians [4–6].

Although the optimal approach for these complex aortic repairs has been direct open repair using profound hypothermic circulatory arrest (HCA), other “hybrid” techniques have been described touting lower morbidity and mortality [7]. With these concerns in mind, this study analyzed early and late outcomes after ascending and transverse arch surgery using HCA in octogenarians.

## Patients and Methods

Data for this study were drawn from our Institutional Review Board–approved clinical research/quality im-

provement database. Consent for the database was waived by our Institutional Review Board.

## Study Population

Between January 1991 and December 2006, 779 patients underwent ascending and arch repair using HCA. Patients were categorized as group 1, aged 80 years or older (4.8%, 37) and group 2, aged less than 80 years (95.2%, 742). Patients’ median age was 67 years (range, 16 to 90) with 301 females (38.6%) and 478 males (61.4%). Reason for repair included aneurysms in 401 cases (51.5%), and aortic dissections in 378 cases (48.5%): acute dissection in 220 (28.2) and chronic dissection in 158 (20.3). The elephant trunk reconstruction was performed in 199 cases (25.6%). In this series, retrograde cerebral perfusion was used in 742 cases (95.3%).

## Operative Technique

Basic features of our current technique for acute dissection or aneurysm of the distal ascending or transverse aortic arch included cardiopulmonary bypass, profound hypothermia, circulatory arrest, and retrograde cerebral perfusion. Cardiopulmonary bypass was established by directly cannulating the ascending aorta after interrogation with either transesophageal echocardiography or epiaortic ultrasonography for aneurysmal disease. For aortic dissection, peripheral cannulation is preferred with the femoral artery or axillary artery. Cerebral mon-

Accepted for publication May 8, 2008.

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Table 1. Patient Characteristics: Univariate Analysis of Age Group Differences

Variable	Total (%)	≥ 80 (%)	< 80 (%)	OR	95% CI	p Value
<b>Preoperative variables</b>						
All patients	779 (100)	37 (4.8)	742 (95.2)			
Female	301 (38.6)	23 (62.2)	278 (37.5)	2.74	1.39-5.42	0.002
Male	478 (61.4)	14 (37.8)	464 (62.5)			
Ruptured	45 (5.8)	6 (16.2)	39 (5.3)	3.49	1.37-8.86	0.006
Not ruptured	734 (94.2)	31 (83.8)	703 (94.7)			
<b>GFR</b>						
< 53	155 (21.0)	25 (71.4)	130 (18.5)			0.0001
54-73	201 (27.3)	7 (20.0)	194 (27.6)			
74-96	182 (24.7)	3 (8.6)	179 (25.5)			
> 97	199 (27.0)	0 (0.0)	199 (28.4)			
<b>Operative variables</b>						
<b>Coronary bypass</b>						
Done	100 (12.8)	11 (29.8)	89 (12.0)	3.1	1.48-6.50	0.002
Not done	679 (87.2)	26 (70.3)	653 (88.0)			

CI = confidence interval; GFR = glomerular filtration rate; OR = odds ratio.

itoring with near-infrared spectroscopy or power mode transcranial Doppler was used to confirm adequate cerebral perfusion during perfusion. Systemic cooling was initiated, and the patient's temperature was monitored using both a nasopharyngeal and rectal temperature probe. Myocardial protection was achieved using continuous retrograde cold blood cardioplegia through the coronary sinus, supplemented with direct antegrade coronary ostia infusion once the aorta is opened. A 10-lead electroencephalogram monitored cerebral function. Once the electroencephalogram was isoelectric, which coincides with a nasopharyngeal temperature of 15° to 20°C, cardiopulmonary bypass was discontinued and circulation was arrested. Retrograde cerebral perfusion was begun through the superior vena cava cannula. Retrograde cerebral pressure and flow were guided by cerebral monitoring as previously reported [8].

For the ascending and arch portions of extensive aortic aneurysms, we performed the first stage of the elephant trunk technique. In the case of a severely atheromatous descending thoracic aorta, we often modified the elephant trunk procedure by placing a separate Dacron (C.R. Bard, Haverhill, Pennsylvania) tube graft into the proximal descending thoracic aorta and reconstructing a beveled transverse arch. In the case of total arch replacement, the great vessels (innominate, left common carotid, and subclavian arteries) were reattached as an island to the graft. If the great vessels were aneurysmal, they were replaced by separate bypass grafts. After completion of the distal arch reconstruction, retrograde cerebral perfusion was discontinued, and an aortic cannula was placed into the side arm of the new aortic graft. With the patient in the Trendelenberg position, cardiopulmonary bypass flow was initiated antegrade through the newly inserted aortic cannula, and all debris and air were evacuated before applying the cross clamp. Proximal reconstruction included supracoronary anastomosis, aortic valve replacement, aortic root replacement with a composite

valve graft, valve-preserving root replacement, or root reconstruction for acute dissection.

Data Definitions, Collection, and Analysis

All the preoperative and intraoperative variables were collected prospectively in both groups and entered into a database. The analysis was retrospective (Table 1). Survival was ascertained in octogenarians by direct patient contact and through the Social Security Death Index.

Operative mortality refers to deaths that occurred within 30 days in hospital. Chronic obstructive pulmonary disease was defined by a history of chronic bronchitis and emphysema, or less than 60% of predicted forced expired volume in one second (FEV<sub>1</sub>). A serum creatinine level of greater than 2.0 mg/dL or the need for dialysis defined renal dysfunction. For glomerular filtration rate (GFR), the Cockcroft-Gault equation was used [9]. Rupture included both free and contained rupture. Repairs involving dissection were considered acute if surgery was performed less than 14 days from the onset of pain, and chronic if performed after 14 days for either symptoms or aneurysm formation. Cerebrovascular disease was defined by history of cerebrovascular accident or intervention for carotid artery disease. Cerebrovascu-

Table 2. Risk Factors for Early Mortality: Multiple Logistic Regression

Variable	Variable Estimate	OR	95% CI	p Value
Intercept	-1.5276			
Age ≥ 80 years	-0.4987	0.61	0.19-1.89	0.39
Emergency	0.9136	2.49	1.46-4.27	0.0009
GFR	-0.0262	0.97	0.96-0.98	0.0001
Pump time	0.0123	1.01	1.00-1.02	0.0001
RCP	-1.3101	0.27	0.10-0.74	0.02

CI = confidence interval; GFR = glomerular filtration rate; OR = odds ratio; RCP = retrograde cerebral perfusion.

Table 3. Risk Factors for Stroke: Multiple Logistic Regression

Variable	Variable Estimate	OR	95% CI	p Value
Intercept	-2.4386			
Age $\geq$ 80 years	1.0983	2.99	0.76-11.80	0.12
Prior stroke	1.7273	5.63	1.89-16.79	0.002
Pump time	0.0043	1.01	1.00-1.01	0.02
RCP	-2.2199	0.11	0.04-0.31	0.0001

CI = confidence interval; OR = odds ratio; RCP = retrograde cerebral perfusion.

lar accidents were identified by a thorough independent neurologic examination and confirmed by computed tomography scan or magnetic resonance imaging of the head. Temporary neurologic deficit was defined according to Ergin and colleagues [10]. We defined "ascending replacement" as those cases in which it was not possible to clamp to do the distal anastomosis, "arch replacement" as replacement of concavity of arch, and "total arch replacement" as elephant trunk with replacement of the great vessels as an island or separately.

Continuously distributed data were inspected for normality and descriptive statistics were computed. Univariate analyses were performed by contingency-table methods using two-by-two tables for dichotomous variables and four-by-two tables for continuous variables arrayed in quartiles. Univariate survival analysis was conducted using the Kaplan-Meier method. Multivariate analyses were performed using multiple logistic regression. All computations were accomplished using SAS Software version 9.1.3 service pack 4 (SAS, Cary, North Carolina). The overall goal of the analysis was to determine whether age greater than 80 is an independent risk factor for poor outcome. While the group size for octogenarians is small relative to the overall cohort, in the multivariable analyses, this has the effect of octogenarian status being a moderately low prevalence risk factor in the population. Otherwise, the sample size difference between octogenarian and suboctogenarian cohorts is inconsequential to the analysis.

Table 4. Major Morbidity

Variable	Total (%)	$\geq$ 80 Years (%)	< 80 Years (%)	OR	95% CI	p Value
All patients	779 (100)	37 (4.8)	742 (95.2)			
Renal failure	106 (13.6)	7 (18.9)	99 (13.3)	1.52	0.65-3.54	0.33
No renal failure	673 (86.4)	30 (81.1)	643 (86.7)			
ARDS	30 (3.8)	1 (2.7)	29 (3.9)	0.68	0.09-5.16	0.71
No ARDS	749 (96.2)	36 (97.3)	713 (96.1)			
Bleeding	20 (2.6)	1 (2.7)	19 (2.6)	1.06	0.24-8.12	0.96
No bleeding	759 (97.4)	36 (97.3)	723 (97.4)			
MI	9 (1.2)	1 (2.7)	8 (1.1)	2.55	0.31-20.93	0.37
No MI	770 (98.8)	36 (97.3)	734 (98.9)			
Sepsis	74 (9.5)	6 (16.2)	68 (9.2)	1.92	0.77-4.76	0.16
No sepsis	705 (90.5)	31 (83.8)	674 (90.8)			

ARDS = adult respiratory distress syndrome; CI = confidence interval; MI = myocardial infarction; OR = odds ratio.

Table 5. Risk Factors for Major Morbidity: Multiple Logistic Regression

Variable	Variable Estimate	OR	95% CI	p Value
Intercept	-0.642			
Age $\geq$ 80 years	-0.1900	0.83	0.36-1.89	0.65
COPD	0.4856	1.63	1.07-2.46	0.03
Preoperative stroke	1.2093	3.35	1.75-6.42	0.0003
GFR	-0.0105	0.99	0.98-1.00	0.0006
Pump time	0.0045	1.01	1.00-1.01	0.006
RCP time	0.0121	1.01	1.00-1.02	0.03
RCP	-1.1435	0.32	0.12-0.82	0.02

CI = confidence interval; COPD = chronic obstructive pulmonary disease; GFR = glomerular filtration rate; OR = odds ratio; RCP = retrograde cerebral perfusion.

## Results

### Descriptive Statistics

Proportions of patients with low GFR, aortic rupture, female sex, and requirement for coronary revascularization were greater among octogenarian than among younger patients (Table 1). Fewer octogenarian patients were smokers. Otherwise, the age groups were similar on the following factors: cerebrovascular disease, history of coronary artery bypass graft surgery, history of carotid endarterectomy, history of chronic or acute aortic dissection, repair of aortic valve, use or nonuse of retrograde cerebral perfusion, and retrograde cerebral perfusion time, clamp time, and pump time.

### Early Mortality

Early mortality did not differ between groups: 13.5% (5 of 37) in group 1 and 10% (78 of 742) in group 2 ( $p = 0.57$ ). Independent risk factors for early mortality included emergency status, preoperative renal insufficiency (decreasing GFR), and increasing cardiopulmonary bypass time. Age over 80 years was not associated with early mortality, and statistical adjustment for age did not substantially alter other risk factor effects. Retrograde cerebral perfusion was protective against early death (Table 2).

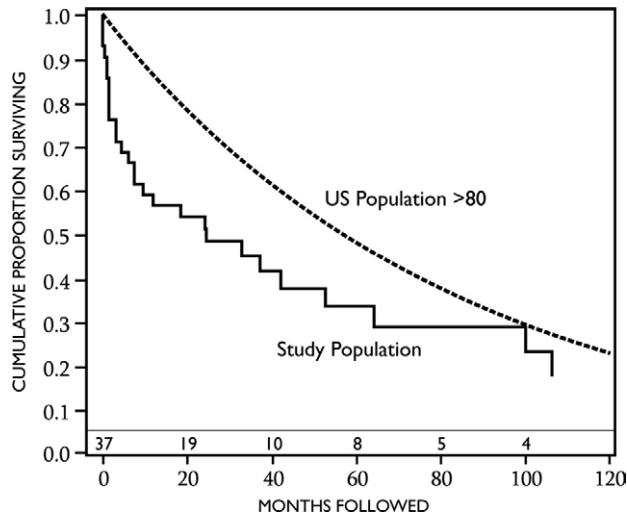


Fig 1. Comparison of long-term survival between octogenarians and the normal United States octogenarian population.

### Neurologic Morbidity

The incidence of stroke was 8% (3 of 37) in group 1 and 2.7% (20 of 742) in group 2 ( $p = 0.09$ ). Strokes that occurred in group 1 were ischemic in origin. The incidence of transient neurological deficit was not significantly different between groups. Independent risk factors for stroke included increasing cardiopulmonary bypass time and a history of prior stroke. Age over 80 years was not associated with stroke. The use of retrograde cerebral perfusion was protective against stroke (Table 3).

### Major Morbidity

Other major morbidity in the octogenarians (group 1) included the following: renal dysfunction occurred in 18.9% of patients, with the need for dialysis in 5.4%, respiratory failure in 2.7%, bleeding requiring reoperation in 2.7%, myocardial infarction in 2.7% and sepsis in 16.2%, which did not differ statistically from group 2 (Table 4). The results of multiple logistic regression for major morbidity risk factors are shown in Table 5. Again, age over 80 years was not independently associated with major morbidity, and adjustment for age did not affect conclusions about the other risk factors.

### Acute Dissection

Of 37 octogenarians, 13 had acute dissections. There were 2 deaths (15.5%), no adult respiratory distress syndrome, no reexploration for bleeding, no sepsis, 1 renal dysfunction (7.7%), and no neurologic events.

### Length of Stay

Both intensive care unit length of stay and hospital length of stay differed, with octogenarians requiring longer hospitalizations. The median intensive care and hospital stay for group 1 versus group 2 was 6.5 versus 4 days ( $p = 0.01$ ) and 16 versus 13 days ( $p = 0.033$ ), respectively.

### Survival

Survival in group 1 compared with the age-matched United States population postoperatively was 56% versus 86% ( $p = 0.02$ ) at year 1, 48% versus 76% ( $p = 0.03$ ) at year 2, 36% versus 48% at year 5, and 20% versus 20% at year 10 ( $p > 0.10$ ). Thus, survival differences, when compared with the age-matched US population, were present as long as 2 years postoperatively, but disappeared after 2 years ( $p = 0.10$ ; Fig 1). The only multivariate predictor of improved long-term survival was use of retrograde cerebral perfusion ( $p = 0.03$ ).

### Comment

As our population ages and life expectancy extends, significant cardiovascular disease requiring operative repair will develop in greater numbers of patients. Indications for surgical intervention are well established for coronary artery disease and valvular heart disease, with age not being an absolute contraindication for intervention. As with many medical situations, individualization of each patient is required. Unlike coronary artery bypass or isolated valve surgery, complex thoracic aortic surgery, however, remains debatable in this patient subgroup. Some have advocated nonoperative management in the setting of acute type A aortic dissection, as early and late outcomes were dismal [11–14]. Prolonged exposure to cardiopulmonary bypass and profound HCA have been implicated in early morbidity and mortality during these repairs. Results of this study suggest that performing thoracic aortic surgery in the octogenarian population using profound HCA can be accomplished with reasonable success.

Although the mainstay for approach for these complex aortic repairs has been direct open repair using profound HCA, other “hybrid techniques” have been reported with lower morbidity and mortality [7]. These techniques, however, have not been performed in large series with long-term outcomes, with the most obvious limitation being the durability.

In this study, octogenarians (group 1) undergoing ascending and transverse arch repair under profound HCA, had an acceptable early mortality rate of 13.5%. This mortality did not differ significantly from those patients under the age of 80 years (10%). The mortality rate, which included emergent and dissection cases, was consistent with results of other series [5, 11–13], and much better than other studies that justified either not operating or using great caution when dealing with octogenarians [6, 14]. In addition, the Swedish heart surgery register found age to be a predictor of increased mortality for operations on proximal thoracic aorta [15]. The mortality with thoracic aortic surgery has also been reported to be similar to the mortality for octogenarians undergoing plain aortic valve replacement (9%) or a combination of aortic valve replacement and coronary artery bypass graft surgery (13%) [3], and for those octogenarians undergoing any cardiac surgical procedures (13.5%) [1]. The relatively low mortality in one

study [4] of 5% can be explained by a smaller number of complex arch reconstructions as represented by the small number of the elephant trunk procedure performed. In our study, 35% of patients had acute dissections, 16% with rupture, 71% with GFR less than 53 mL/min, 83% with arch involvement, and 32% underwent elephant trunk procedures.

Most operative series have implicated age as a predictor of stroke during cardiovascular procedures. One study of 10,860 patients showed age to be a strong predictor of stroke in coronary surgery (odds ratio, 1.07/year) [16]. Another study, however, demonstrated no difference in stroke incidence with increasing age for cardiac surgical procedures performed in octogenarians [1]. In our series, the overall stroke incidence was 3%, with 8% occurring in the octogenarian group. This incidence among octogenarians was similar to that of other series involving arch repair with profound HCA, ranging from 10% [5] to 20% [4]. The high stroke rate seen in this latter study may have been due to the utilization of some form of cerebral protection other than hypothermia, namely, antegrade cerebral perfusion [4]. Interestingly, the use of RCP (in 95% of cases in this series), unlike the previous studies [17-19], was identified as an independent factor protective against early mortality, stroke, major morbidity, and late death.

Major morbidity in octogenarians in this series was similar to that of the other reported studies [1]. In a previous study [1], the octogenarian group had a higher incidence of severe low output, reintubation, and atrial fibrillation as compared with younger patients. Another study in octogenarians [3] showed isolated aortic valve replacement was associated with a myocardial infarction incidence of 4%, dialysis requirement of 5%, reexploration for bleeding of 4%, and prolonged mechanical ventilation of 21%.

As in other studies, this series found a prolonged length of hospital and intensive care unit stay. Although complete recovery and return to acceptable quality of life is achievable, there is little doubt that increased need for hospital resources is required in the octogenarian group. It also appeared that length of stay may be independent of type of degree of surgery, observing the length of stay reported in this series was similar to other series with ascending/arch repair, aortic valve replacement, and coronary artery bypass [1, 5].

As in our previous studies [8, 19], GFR was a very strong predictor of postoperative mortality. The mortality increased exponentially with decreasing GFR from 97 mL/min, 74 to 96 mL/min, 54 to 73 mL/min, less than 53 mL/min has early mortality of 3%, 9%, 10%, and 21%, respectively. Decreasing GFR was also found to be a predictor of major morbidity. The reason we postulate for GFR being such a strong predictor of mortality and morbidity in our studies is that it is most likely a marker of poor physiologic function. Also it is very important to know that a patient may have a "normal" creatinine but diminished GFR [8, 20, 21].

Late survival in the octogenarian group was dissimilar when compared with the age-matched US population at

1 and 2 years, with the majority of deaths occurring at the by the first year. The decreased 1-year survival remains concerning and underscores the impact of undergoing these complex aortic repairs in the older population. Interestingly, however, for unclear reasons, the difference in mortality disappeared at 5 and 10 years. Late survival in this series was comparable to others [4, 5]. Thus, survival beyond 1 year predicted a favorable long-term outcome.

In conclusion, although octogenarians required increased hospital resources with increased length of stay, aortic surgery requiring profound HCA can be performed with reasonable early and late outcomes. Retrograde cerebral perfusion appears safe to use during profound HCA and may protect against stroke and early and late death. Although individualization of each patient should be undertaken when deciding to perform repair, age over 80 years should not be considered an absolute contraindication for complex aortic repair.

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The research reported here was supported by Grant 5 P50 HL083794-02 (TAAD-SCCOR) from the National Heart, Lung and Blood Institute. The opinions contained herein are solely those of the authors. We thank G. Ken Goodrick for his editorial assistance and Chris Akers for medical illustrations.

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## INVITED COMMENTARY

This article [1] is both timely and pertinent. For more than 15 years, 779 patients required hypothermic circulatory arrest (HCA) to treat aneurysmal disease of the ascending aorta. Of the total 37 patients (4.8%), who were 80 years of age or older, the outcome in this aging group was the focus of this study. Operative technique included central cannulation when possible, profound hypothermic cooling, cerebral monitoring with spectroscopy, and transcranial Doppler studies to confirm adequate cerebral perfusion during cooling, 10-lead electroencephalographic monitoring to determine the time of iso-electric activity and initiation of circulatory arrest (nasopharyngeal temperature of 15 to 20 centigrade, cooling time not specified), and the use of retrograde cerebral perfusion through the superior vena cava during HCA. When the distal anastomosis was completed, cardiopulmonary was re-established with cannulation of the newly inserted Dacron graft. Mortality for the octogenarians is 13.5% compared with 10% for the nonoctogenarians. Of the 37 octogenarians there were 13 acute dissections (mortality, 15.5%), 6 patients with acute rupture and 11 patients required coronary artery bypass grafting. Not surprisingly the median hospital stay was longer for octogenarians (16 vs 13 days) as was the intensive care unit stay (6.5 vs 4 days). For unknown reasons, the late survival was comparable with an age match group of "healthy octogenarians" after the initial 24 months had elapsed. Age was not associated with an increased risk of

stroke, whereas it was with prolonged cardiopulmonary bypass time and prior history of stroke. The authors conclude that retrograde cerebral perfusion was protected against stroke; however, because all the patients receive this modality along with the others, the foundation for this conclusion is not apparent. Two findings make this article an important contribution. First, octogenarian patients with ascending aortic aneurysmal disease can be operated on with an acceptable mortality after a standardized protocol and experience satisfactory recovery with moderate morbidity. Second, as the population ages, increasing numbers of older patients will require complex aortic repair and this should no longer be regarded as an insuperable problem.

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