ANNALS OF SURGERY
Vol. 223, No. 5, 492–505

A Statewide, Population-Based, Time-Series Analysis of the Outcome of Ruptured Abdominal Aortic Aneurysm

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Objectives

The purpose of this study was to perform the first statewide, population-based, time-series analysis of the frequency of ruptured abdominal aortic aneurysm (RAAA), to determine the outcomes of RAAA, and to assess the association of patient, physician, and hospital factors with survival after RAAA. The hypotheses of the study were as follows: 1) the rate of RAAA would increase over time and 2) patient, surgeon, and hospital factors would be associated with survival.

Background

Ruptured abdominal aortic aneurysm is a life-threatening emergency that presents the surgeon with a technically demanding challenge that must be met and surmounted in a short time if the patient is to survive.

Methods

Data were obtained from the following four separate data sources: 1) the North Carolina Hospital Discharge database, 2) the North Carolina American Hospital Association database, 3) the North Carolina State Medical Examiner's database, and 4) the Area Resource File. All patients with the diagnosis of an abdominal aortic aneurysm (AAA) were selected for initial assessment. Patients were grouped into those with and those without rupture of the abdominal aneurysm.

Results

During the 6 years of the study, 14,138 patients were admitted with a diagnosis of AAA. Of these, 1480 (10%) had an RAAA. The yearly number of patients with elective AAAs increased 33% from 1889 in 1988 to 2518 in 1993. The yearly number of RAAAs increased 27% from 203 to 258. The mortality rate for AAA was 5%, as compared with 54% in RAAA patients. The patient's age was found to be the most powerful predictor of survival. Univariate logistic regression analyses demonstrated an association of the surgeon's experience with RAAA and patient survival after RAAA. Analysis of the survival rates of board-certified and nonboard-certified surgeons demonstrated that patients with RAAAs who were treated by board-certified surgeons had significantly better survival. When the survival was compared in small (less than 100 beds) and large (more than 100 beds) hospitals, survival was significantly better in the larger hospitals.

Conclusions

Ruptured abdominal aortic aneurysm remains a highly lethal lesion, even in the best of hands. Despite the many improvements in the care of seriously ill patients, there was no significant improvement in the survival of RAAA during this study. This suggests that early diagnosis is the best hope of survival in these patients. The study demonstrated that survival after RAAA was related most strongly to patient age at the time of the RAAA. The physician's and the hospital's experience with RAAA, the physician's background as measured by board certification, and the type of hospital at which the operation was performed (small *vs.* large) also may be associated with survival. These findings may have important implications for the regionalization of care and the education and credentialling of physicians. Given the lack of recent progress of improving the outcome of RAAA, aggressive efforts to treat patients before rupture are appropriate.

Abdominal aortic aneurysm (AAA) often is lethal if the aneurysm ruptures. The death rate of ruptured abdominal aortic aneurysm (RAAA) has ranged from 30% to 60%.[1-3] Studies have reported a rising rate of AAA—and vascular disease in general—throughout the United States as the population ages.[1,4] Although the cause of AAA remains unknown, because of the high risk of death in the event of rupture, operative repair of the aneurysm generally is the accepted treatment for this potentially life-threatening disease.[4]

Although a number of series have described the frequency and the outcomes of ruptured abdominal aortic aneurysm (RAAA), such studies usually have been of relatively small series of patients and have not been population based. Studies often have come from either a single center or a few local hospitals. Because of a hospital's location and type, the series may exclude certain types of patients. Because of these limitations, there is significant potential for bias in these reports. Thus, the true rate of RAAA and its outcomes remain incompletely described.[1,2,5,6]

PURPOSE OF THIS STUDY

The purpose of this study was to perform a statewide, population-based, time-series analysis of the frequency of RAAA, the outcomes of these events, and the association of physician and hospital factors with patient survival after RAAA. The goal was to provide a detailed description of the disease and its relation to the frequency of elective AAA, as well as to the population of North Carolina. We wanted to describe demographics and time course of RAAA in the entire state, and to determine the association between patient, hospital, and physician characteristics and the outcome of RAAAs.

Presented at the 107th Annual Session of the Southern Surgical Association, December 3–6, 1995, Hot Springs, Virginia.

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Accepted for publication January 11, 1996.

STUDY HYPOTHESES

It was our hypothesis that both the absolute rate and the per capita rate of RAAA in North Carolina were increasing, that patient characteristics such as age and gender, and presentation factors such as shock would be associated with survival. It also was hypothesized that more severely ill patients are more likely to die and that survival after RAAA is related to both hospital and physician expertise and experience.

MATERIALS AND METHODS

Data Sources

Data were obtained from four main data sets. The source of the patient information was the state hospital discharge database, which will be described in more detail. Data on hospitals in the state were obtained from the North Carolina American Hospital Association database. Data on county demographic information was obtained from the Area Resource File. Physician-specific information (age and board certification) was obtained from the North Carolina Board of Medical Examiner's database (Table 1).

Description of North Carolina Medical Database Commission

Patient-specific data were obtained from the hospital discharge database of the North Carolina Medical Database Commission, an agency created by legislative mandate in July 1985. The goal of the database is to collect data on the utilization, price, and quality of health-care services provided in the state and to serve as a clearinghouse for the data collected. The Commission has the authority to collect data from all health-care providers and third-party payers. The available database consists of approximately 850,000 individual patient discharge records per year from the state's 157 acute care, alcohol rehabilitation, and psychiatric hospitals, and contains information about each hospitalization for all patients admitted to the hospitals of North Carolina. Each discharge record includes information about the patient's age, gender, length of stay, diagnoses (the primary diagnosis and

Table 1. DATA SOURCES USED FOR THE ANALYSES

Database	Contents
North Carolina Medical Database Commission Database	All hospital discharges form all hospitalized patients in North Carolina (patient age, gender, diagnoses, procedures, charges, length of stay, and survival)
Area Resource File	Basic demographic information on all of the counties of North Carolina (rural/urban, income, and age distribution)
American Hospital Association Database	Hospital specific information on all hospitals in North Carolina (*i.e.*, beds, medical center affiliation, residency, etc.)
North Carolina Board of Medical Examiner's Database	Physician profiles of all physicians in the state of North Carolina (*i.e.*, age, board certification)

four additional International Classification of Diseases [ICD-9]-coded diagnoses), services provided, related charges, and payer and provider information. The database's original function was the analysis of billing information, but recently, our group has demonstrated that it can be used successfully to analyze clinical information.[7-9]

American Hospital Association Database

The American Hospital Association keeps track of a variety of information on all member hospitals in the United States. This data source was used to obtain hospital size information on each of the North Carolina hospitals that cared for RAAA patients in the study.

North Carolina Medical Examiners Database

The North Carolina Board of Medical Examiners keeps a database of all physicians in North Carolina. This data source was used to gain access to surgeon information about the board certification of the operating surgeon.

Patients Selected for the Study

All patients who were admitted to any of the 157 hospitals in North Carolina with a diagnosis of either a ruptured or nonruptured abdominal aneurysm were selected, (ICD-9 diagnosis code of 441.3 AAA, ruptured [RAAA], or 441.4 AAA, without rupture) from the North Carolina Medical Database Commission. Because one of our primary interests was how AAA and RAAA were related and how their frequency changed over the course of the study, patients with ruptured and nonruptured aneurysms were selected for analyses. We were interested in the association with the rates of elective repair and the rates of RAAA in the state, and for this purpose, we chose to assess both ruptured and nonruptured cases of AAA.

Statistical Analyses

All statistical analyses were performed using SAS software (SAS, Inc., Cary, NC) for the personal computer. Categorical dependent variables were compared among groups using chi square analyses. Continuous dependent variables were compared using Student's t test when there were two independent groups. Otherwise, Tukey's modification was used to compare multiple means using analysis of variance. Regression analyses used linear regression for estimating continuous dependent variables in the model, and logistic regression was used when the dependent variable was categorical.

Study Design

Independent and Dependent Variables

Independent variables included the patient's age, gender, the presence of shock and/or the presence of postoperative complications—such as acute renal failure and adult respiratory distress syndrome, the hospital's size and rates of AAAs and RAAAs, and physician's board certification and experience with both ruptured aneurysm and elective AAA repair. The primary dependent variable was hospital survival.

RESULTS

Time-Series Analysis of the Frequency of Ruptured Abdominal Aortic Aneurysm

During the 6 years of the study, (1988–1993), there were 14,138 admissions for patients with AAA. Of these, 1480 patients (10%) received diagnoses of RAAA. The yearly number of patients with elective AAAs increased 33% from 1889 in 1988 to 2518 in 1993. The number of RAAAs per year increased 27% from 203 to 258.

The yearly rates of AAA and RAAA also were analyzed as a function of the population of North Carolina. Per capita hospitalization rates for AAA and RAAA were calculated as a rate per 10,000 population. North Carolina is the tenth largest state in the nation, and the population increased from 6.48 million in 1988 to 6.95 million in 1993. The per capita rate of AAAs increased from 2.91 AAAs/10,000 population in 1988 to a rate of 3.63/10,000 population in 1993. This is an increase of 24.7% compared with an increase of 33% in the absolute num-

Table 2. THE FREQUENCY OF ABDOMINAL AORTIC ANEURYSM AND RUPTURED ABDOMINAL AORTIC ANEURYSM DURING THE STUDY*

Year	NC State Population (×10⁶)	Elective AAAs	RAAAs	Elective AAAs/ 10,000 Population	RAAAs/ 10,000 Population
1988	6.481	1889	203	2.91	0.31
1989	6.565	2147	234	3.27	0.36
1990	6.629	2224	241	3.35	0.36
1991	6.749	2290	245	3.39	0.36
1992	6.836	2432	230	3.56	0.34
1993	6.945	2518	258	3.63	0.37

* Sixty-nine patients from 1987 and 1994 were excluded because of incomplete data for those years.
NC = North Carolina; AAA = abdominal aortic aneurysm; RAAA = ruptured abdominal aortic aneurysm.

ber of AAA patients. During this period, the per capita rate of RAAAs also increased, but less so than for AAAs, from 0.31 RAAAs/10,000 population in 1988 to 0.37/10,000 in 1993 (a 19.4% increase; Table 2, Fig. 1).

Discharge Status After Ruptured Abdominal Aortic Aneurysm

Thirty-two percent of patients with RAAA were discharged home after hospitalization. The mean hospital charges for this group were \$33,000 ± \$25,000. Six percent of patients were transferred to other hospitals, and their mean hospital charges were \$32,000 ± \$16,000. Another 6% of patients were transferred to nursing homes or to rehabilitation facilities, and their hospital charges were \$62,000 ± \$58,000.

Survival and Mortality After Ruptured Abdominal Aortic Aneurysm

During the study period, 813 (54.9%) of patients with RAAA died, an extremely high mortality rate (Table 3).

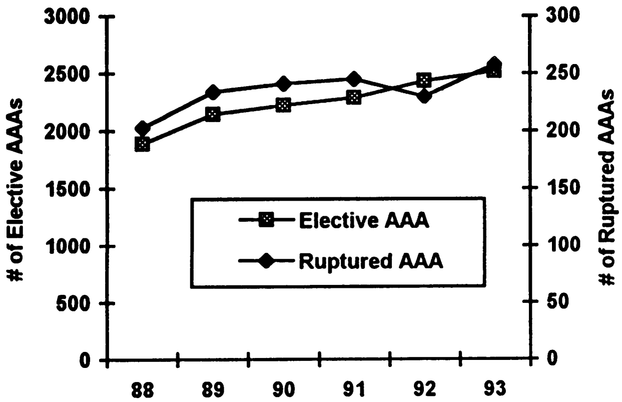

Figure 1. Frequency of elective and ruptured abdominal aortic aneurysm over time.

(Again, it should be noted that this study does not include RAAA deaths for patients who were not admitted to hospitals in the state, indicating that the true mortality rate for RAAA is even higher.)

Length of Stay in Patients with Ruptured Abdominal Aortic Aneurysm

The distribution of the length of stay for patients who did and did not survive after RAAA is shown in Figure 2.

As reported in other series, the majority of deaths occur the first 3 days after admission (Fig. 2). On the first day of hospitalization, 183 patients (34% of all deaths) died, and 340 patients (63% of all deaths) died in the first 3 days.

Survival After Ruptured Abdominal Aortic Aneurysm and the Year of Operation

The survival after RAAA over the period of the study also was analyzed (Table 4). The survival rate was 44.4% in 1988 and 46.9% in 1994 (Fig. 3). Logistic regression analysis demonstrated that although there appeared to be a slight trend toward improved survival from 1988 to 1993, this did not achieve statistical significance ($p = 0.42$).

Table 3. SURVIVAL AND FREQUENCY OF RUPTURED ABDOMINAL AORTIC ANEURYSM

Survival	Frequency	Percent
Die	813	54.9
Live	667	45.1
Total	1480	

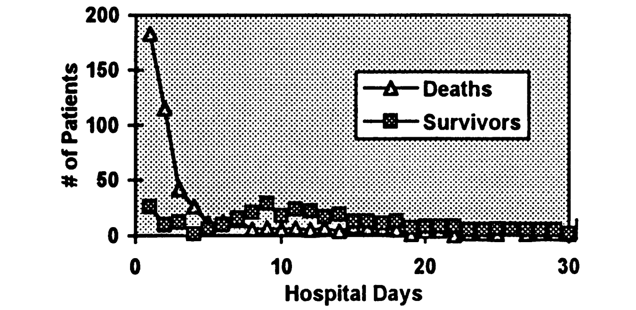

Figure 2. Length of stay after ruptured abdominal aortic aneurysm RAAA in survivors and nonsurvivors. Note: graph truncated at 30 days; many patients stayed in hospital longer, to a maximum of 204 days.

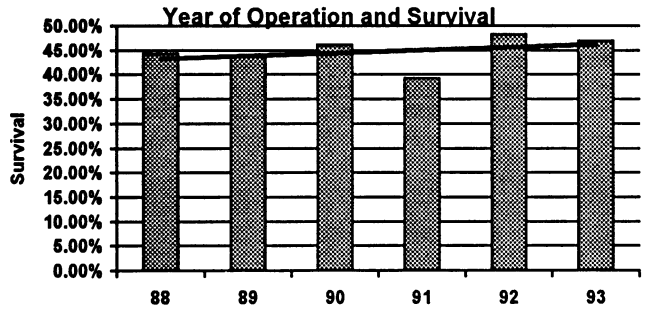

Figure 3. Survival after ruptured abdominal aortic aneurysm over time.

Gender and Age Distribution in Patients with Ruptured Abdominal Aortic Aneurysm

The genders of patients sustaining RAAA were analyzed. There were 307 women (20.7%) and 1173 men (79.3%) in the study (Table 5). The mortality rate was compared in women and men, and the death rate of 62.5% in women (192 of 307) was significantly higher than the death rate of men (621 of 1173, or 52.9%; p = 0.003).

Analysis of Age and Survival After Ruptured Abdominal Aortic Aneurysm

The average age of patients in the study was 72.2 ± 9.8 years. Survivors of RAAA had an average age of 69.2 ± 9.4 years, and patients who died had an average age of 74.6 ± 9.5 years ($p < 0.00001$; Table 6). A graph of patient age and survival is shown in Figure 4. The graph demonstrates that for patients older than 65 years of age, the mortality rate was more than 50%, and for patients less than 65 years of age, the mortality rate was less than 50%. Logistic regression analysis showed that for every additional year older a patient was, the risk of death increased 0.6% (p = 0.001)

Table 4. NUMBER OF RUPTURED AORTIC ANEURYSM (RAAA) AND SURVIVAL OVER TIME*

Year	No. of Patients	Survival	Mean Hospital Changes	Mean LOS
1988	203	44.3%	$23,871	13.1
1989	234	43.6%	$27,107	15.6
1990	241	46.1%	$32,122	13.1
1991	245	39.2%	$36,984	13.0
1992	230	48.3%	$49,014	15.1
1993	258	46.9%	$43,081	13.2

LOS = length of stay.
* Seven RAAA patients from 1988 and 62 RAAA patients from 1994 were excluded from these analyses.

Complications

The rates of acute renal failure and adult respiratory distress syndrome (ARDS) were analyzed in the data set. Of 1073 patients, 158 were coded as sustaining acute tubular necrosis (ATN). The mortality rate in patients with ATN was 60% compared with 54% in non-ATN patients.

Adult respiratory distress syndrome was coded in 74 patients. The mortality in patients with ARDS was 50%, compared with 56% in all other patients. It was our hypothesis that ARDS might not be diagnosed in patients who died soon after RAAA; thus, the data set was reanalyzed, excluding all early deaths. Including only patients hospitalized for at least 5 days, the rates and survival of patients with ARDS and ATN are shown in Table 7.

A number of other complications of RAAA were assessed and found to be associated strongly with survival. These include shock, intestinal ischemia, and cardiac arrest (10% survival in each).

Physician Board Certification and Survival

Analysis of surgeon's board certification status showed that nonboard-certified surgeons had lower survival in RAAA patients (p = 0.07; Table 8).

Table 5. GENDER DISTRIBUTION AND SURVIVAL AFTER RUPTURED ABDOMINAL AORTIC ANEURYSMS

	Total Patients	Deaths
Female	307 (20.7%)	192 (62.5%)
Male	1173 (79.3%)	621 (52.9%)*

* p = 0.003.

Table 6. STUDENT'S t TEST COMPARING THE AGE IN SURVIVORS AND NONSURVIVORS AFTER RUPTURED ABDOMINAL AORTIC ANEURYSM

Student's t Test Procedure: Variable: Age

Live Die	N	Mean	SD	Min	Max	t	df	p Value
Die	813	74.63	9.53	25	101	10.9475	1478	0.0000
Live	667	69.21	9.37	26	93			

SD: standard deviation.

Table 7. MORTALITY RATE IN ADULT RESPIRATORY DISTRESS SYNDROME AND ACUTE TUBULAR NECROSIS

N (Mortality Rate)	No ARDS	ARDS
No ATN	381 (23%)	38 (32%)
ATN	94 (53%)	20 (55%)

ARDS = adult respiratory distress syndrome; ATN = acute tubular necrosis.

Physician Experience and Survival

We assessed the physician experience in survival and the number of cases for each surgeon. The association between the physician's experience with RAAAs and patient survival was found to be statistically significant by logistic regression analysis, with a p value of 0.025 (Fig. 5). An analysis of the association of patient survival after RAAA and physician experience with all AAAs showed no statistical significance ($p = 0.96$; Fig. 6).

Survival of Ruptured Abdominal Aortic Aneurysm Patients at Different Types of Hospitals

It was our hypothesis that hospital characteristics would be associated with survival after RAAA. To test this hypothesis, survival was compared between large (> 100 beds) *versus* small (< 101 beds) hospitals. Patients who underwent surgery at smaller hospitals had significantly lower survival rates than patients who underwent surgery at larger hospitals (Fig.7).

Hospital Experience and Survival

Another hypothesis tested in this study was that hospital experience with elective AAA would be associated with patient survival after RAAA. A plot of this relationship is shown in Figure 8. Logistic regression was used to assess the association between hospital AAA case load and patient survival after RAAA. Hospital experience with elective AAAs was analyzed, and although there was a trend toward improved survival in hospitals with a greater case load of AAAs, this did not achieve statistical significance ($p = 0.59$).

Survival rate in ruptured aneurysms also was analyzed and compared with the number of RAAA cases the hospital had. This is plotted and shown in Figure 9. Again, although there appears to be a trend to improved survival with increased hospital case load, this did not reach statistical significance ($p = 0.23$).

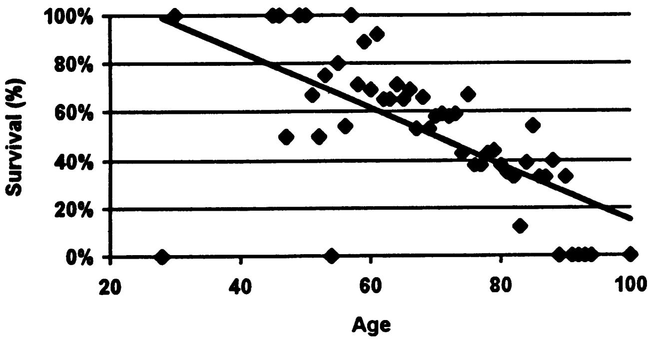

Figure 4. Age and survival after ruptured abdominal aortic aneurysm.

DISCUSSION

Studies have documented the fact that RAAA is a highly lethal lesion that presents the physician with a very difficult problem that needs to be identified and dealt with in a matter of minutes or hours. Even today, several decades after the first repair of a ruptured aneurysm was first performed, patients who sustain ruptured aneurysm still face an extremely high likelihood of death. In a recent series by Donaldson et al.,[10] the mortality rate of RAAA was reported at 43.2%, and there was a 29.2%

Table 8. SURGEON BOARD CERTIFICATION AND SURVIVAL AFTER RUPTURED ABDOMINAL AORTIC ANEURYSM

Board Certification	Total Patients (%)*	Deaths (%)
Certified	1082 (90.3%)	576 (53.2%)
Not Certified	116 (9.7%)	72 (62.1%)†

* Note: 282 patients could not be linked to practicing surgeons.
† $p = 0.07$.

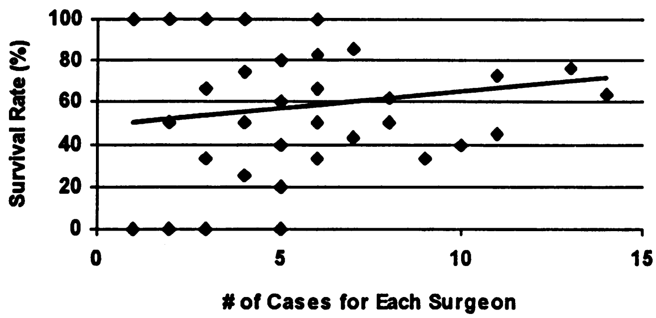

Figure 5. Surgeon's ruptured abdominal aortic aneurysm experience and patient survival after ruptured abdominal aortic aneurysm.

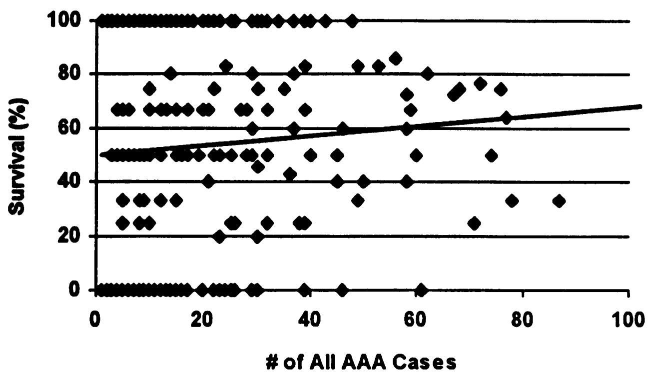

Figure 6. Surgeon's abdominal aortic aneurysm experience and partient survival after ruptured abdominal aortic aneurysm.

mortality rate among those surviving the day of surgery. These findings are similar to the results of the current study, with a mortality rate of 55%. Ruptured abdominal aortic aneurysm is a high-risk illness that continues to bedevil physicians. Studies have shown that in patients with RAAA, the diagnosis often is delayed or missed, adversely affecting survival.[1,2,6,11] Physicians need to recognize the presentation and management of ruptured AAA and the necessity for prompt diagnosis and immediate surgical intervention, combined with avoidance of shock when rupture occurs.[12]

Previous Studies

The true incidence and outcomes of RAAA are incompletely described. In addition, there is controversy over the value of hospital and physician experience with the outcomes of various illnesses. Previous studies have demonstrated that increased rates of operative experience with certain diseases can lead to improved outcomes.[12] Previous studies of RAAA have had a variety of limitations, which include small size.[1-3,5,6,12,13] A study by Martin et al.[3] included more than 100 patients from only one hospital's experience and covered a period of more than 25 years, limiting the conclusions that could be drawn. In a study from Washington, 37 patients were reported for a 5-year period, with an overall survival rate of 38%.[12] As in other studies, the development of shock before initiation of surgery was a common finding and signalled a poor prognosis[12]

Time-Series Analysis of the Frequency of Ruptured Abdominal Aortic Aneurysm

Abdominal aortic aneurysm has been reported to be an increasing problem in the United States.[4] In the report by Hallett et al.,[4] the incidence of recognized small AAAs increased 30-fold during a 30-year period. The current study is one of the largest ever reported. It also is relatively unique in that it is a population-based study including all hospitalizations from both RAAA and AAA in an entire state over a 6-year period. In this series, 14,138 patients were admitted with AAA. Ten percent (1480 patients) received diagnoses of RAAA, and the rate of RAAA increased 27% (4.5 patients) per year, from 203 to 258. Of increased interest are the per capita rates of RAAA and AAA. In most other studies of RAAA, there were no attempts to control for the changes in the population that made up the group at risk for RAAA. In controlling for the changes in the state's population, the current study demonstrates that the rise in RAAA is less than it seems. The yearly rate of AAA and of RAAA as a function of the population of North Carolina increased from 2.91 AAAs/10,000 population in 1988 to 3.63 AAAs/10,000 in 1993. This is a 24.7% increase as compared with an increase of 33% in absolute numbers. The per capita rate of RAAAs also increased during this period, but less than that of AAAs, at 0.31 RAAAs per 10,000 population in 1988 to 0.37 in 1993 (a 19.4% increase, Table 2, Fig. 1).

There have been only a few previous population-based studies of RAAAs.[4,14] In a study by Bengtsson,[14] an epidemiologic analysis of RAAAs was performed in an urban population during a 16-year period. The study was retrospective and covered a demographically defined population of 230,000 inhabitants in the city of Malmo,

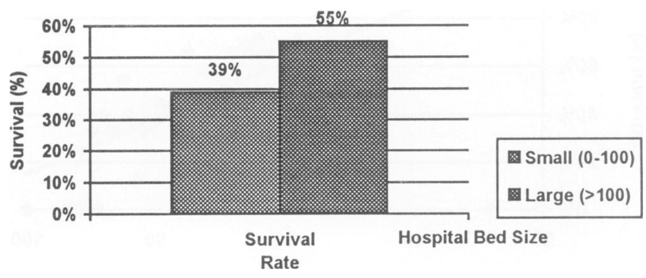

Figure 7. Hospital size and survival after ruptured abdominal aortic aneurysm.

Sweden. Reports of all identified ruptured AAAs in Malmo from 1971 to 1986 were analyzed. The autopsy rate in the city was 85% during this period. Ruptured AAAs were found in 0.56 per 10,000 population (0.84/10,000 men and 0.30/10,000 women). No increase was found during the study period after age and sex standardization. In the current study, patients dying of RAAA who did not reach the hospital to be admitted were not included in the sample population. The rates would be expected to be somewhat different when compared with the Malmo, Sweden study. Taking this into account, the current study's per capita rate of RAAA of 0.31 to 0.37 per 10,000 population is very similar to the Swedish study.

Survival and Mortality After Ruptured Abdominal Aortic Aneurysm

During the period of the study, 813 (54.9%) of RAAA patients died, for an extremely high mortality rate (Table 3). Again, it should be noted that this study does not include RAAA deaths for patients who are not admitted to hospitals in the state, indicating the true mortality rate for RAAA is even higher. This study, as others have done, shows that the time to death after the onset of RAAA is short. Sixty-three percent of all deaths after RAAA occur in the first 3 days, with 34% of these occurring on the first hospital day.

The survival after RAAA over the time of the study also was analyzed, as shown in Table 6. The survival rate was 44.4% in 1988 and 46.9% in 1994 (Fig. 3). Logistic regression analysis demonstrated that although there appeared to be a slight trend toward improved survival from 1988 to 1993, this did not achieve statistical significance ($p = 0.42$).

Gender and Survival in Patients with Ruptured Abdominal Aortic Aneurysm

The genders of patients sustaining RAAA were analyzed. There were 307 women (20.7%) and 1173 men

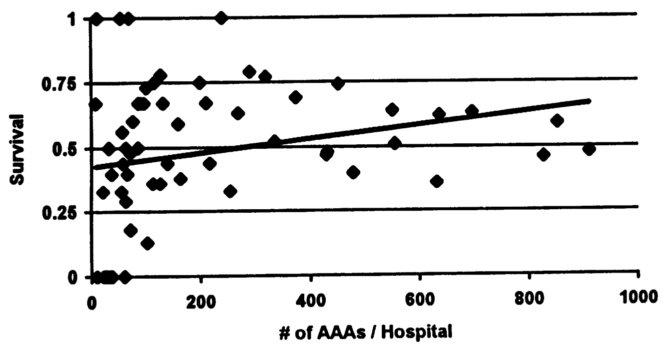

Figure 8. Hospital elective abdominal aortic aneurysm case load and survival after ruptured abdominal aortic aneurysm.

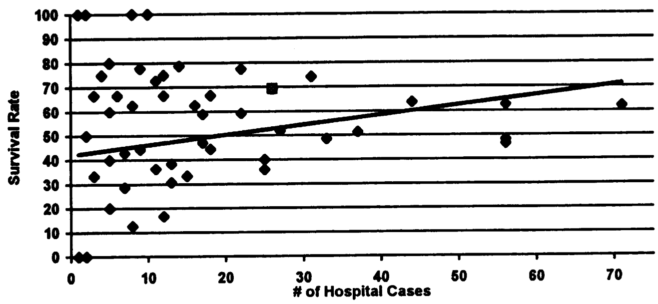

Figure 9. Hospital ruptured abdominal aortic aneurysm case load and survival after ruptured abdominal aortic aneurysm.

(79.3%) in the study (Table 7). The current study documented a significantly higher mortality rate in women than in men (62.5% *vs.* 52.9%; $p = 0.003$). Other studies have been mixed on this finding. In a series by Johnston,[15] gender was not found to have an effect on the early or late results after repair of nonruptured AAA or RAAA. However, a literature review suggested the possibility of a gender bias in the diagnosis or selection of patients for surgical treatment because the proportion of women in surgical series generally is less than the proportion determined from autopsy studies, ultrasound studies, hospital discharge data, and national mortality information.[15]

A number of studies of cardiovascular disease in women have suggested that there may be a higher mortality rate in women with cardiac disease related to delays in recognition and treatment of the disease in women. The current study cannot confirm or refute such a hypothesis, but it does raise concerns about this issue. There does not appear to be any other obvious reason for this significant discrepancy.

Analysis of Age and Survival After Ruptured Abdominal Aortic Aneurysm

The average age of patients in the study was 72.2 ± 9.8 years. Survivors of RAAA had an average age of 69.2 ± 9.4 years and patients who died had an average age of 74.6 ± 9.5 years ($p < 0.00001$; Table 6). For patients older than 65 years of age, the mortality rate was greater than 50%, and for patients younger than 65 years of age, the mortality rate was less than 50%. Logistic regression analysis showed that for every additional year older a patient was, the risk of death increased 0.6% ($p = 0.001$). There appeared to be a clear linear relation between advancing age and increasing mortality rate. In a report by Donaldson et al.[10] patient-determined variables associated with deaths included age older than 76 years, hematocrit level less than 30%, acute abnormality detected by electrocardiogram at admission, and suprarenal extension or free rupture of the AAA. Survival could be predicted with only 70% accuracy with a computerized discriminant function based on age, hematocrit level, and blood pressure values determined at admission. Events after admission associated with death were precipitous decrease or persistently low level of preoperative blood pressure, technical complications, and postoperative organ failure. Although the patient's ultimate outcome after RAAA is determined partly before intervention of the physician, efforts to address events resulting in death after admission by improving rapid diagnosis, early resuscitation, and prompt flawless surgery can increase survival.

Causes of Mortality in Ruptured Abdominal Aortic Aneurysm

Other studies have documented a number of factors associated with death after RAAA. A study by Hiatt et al.[11] identified 29 patients with ruptured AAAs who died after admission to the UCLA Hospital, Los Angeles, and to the Sepulveda (CA) Veterans Administration Hospital between 1971 and 1981. Review of the records identified four categories of error that contributed to death. These included failure to proceed with elective aneurysmectomy in 12 patients with known AAAs, error in the diagnosis of aortic rupture that led to delay in getting 9 patients to the operating room, intraoperative technical error that produced venous injury in 8 patients, and undue delay in anesthetic induction in 4 patients.

In a series by Bradbury et al.,[16] there was a direct correlation between platelet count on admission to the hospital and death after emergency repair of RAAA. Thrombocytopenia at the end of the operation was associated with a high risk of morbidity from continuing hemorrhage or multiple-organ failure. The development of postoperative thrombocytosis was associated with a high risk of thromboembolic complications. They concluded that "the platelet count provides a simple marker of outcome in patients diagnosed with and undergoing operation for ruptured AAA."

In a study by Shackleton et al.,[17] multivariate analysis with stepwise logistic regression demonstrated that elevation of the unmeasured anion gap, a history of congestive heart failure, and the patient's level of consciousness before operation were significantly and independently associated with death.

In the current study, many of these earlier studies' results were confirmed. The rate of acute renal failure and adult respiratory distress syndrome were analyzed in the data set. Of 1073 patients, 158 were coded as sustaining ATN. The mortality rate in patients with ATN was 60% compared with 54% in non-ATN patients. Adult respiratory distress syndrome was coded in 74 patients. The mortality in patients with ARDS was 50% compared with 56% in all other patients. It was our hypothesis that ARDS might not be diagnosed in patients who died soon after RAAA, and the data set was reanalyzed, excluding all early deaths. A number of other complications of RAAA were assessed and found to be strongly associated with survival. These include shock, intestinal ischemia, and cardiac arrest (10% survival in each).

The analyses showed that the diagnosis of ATN or ARDS both significantly increased the mortality of patients with RAAA. The highest mortality rate was in patients with both diagnoses (55%).

The findings in the study confirm earlier studies. The current study clearly demonstrates an association between patients' physiologic age and survival. In fact, age and other comorbid factors are far and away the strongest predictors of survival after RAAA, with younger patients having a much better survival than older patients.

Changes in Health Care

Managed Care

A variety of major changes are sweeping health care in America. Managed care is changing reimbursement patterns in the United States. In the near future, it is expected that a majority of Americans will be covered by managed care. The primary—if not the only—goal of managed care is to decrease costs. This has profound implications for the care of RAAA. Because of the perceived expense of repair of RAAA, coupled with its poor survival rate, it has been suggested that repair be withheld. Although the repair seems expensive, the actual cost of care, adequacy of reimbursement, and cost per additional life-year gained for RAAA repair had been poorly defined until a recent study reported by Seiwert et al.[18] In their study, a retrospective clinical and financial chart review of 119 consecutive patients undergoing operation for RAAA from 1986 to 1993 was performed. Similar to the findings in the current study, Seiwert found an overall in-hospital mortality of 45%. Mean hospital charge per patient in 1993 dollars was $40,763 (range, $4473–$284,374). This again is similar to the current study, which shows mean hospital charges of $43,000 in 1993. Seiwert calculated the actual mean cost for service of $22,420 and an average reimbursement of $21,360, resulting in a loss of $1060 per patient. Calculated losses were higher in Medicare patients. Survivors (n = 65) had an average length of stay of 20 days, costs of $41,045 each, and incurred an institutional loss of $298,405. Of particular note was their finding that the mean cost per additional (adjusted) life-year was $3953. One-, 3-, and 5-year survival rates after hospital discharge were 97%, 85%, and 77%, respectively. Seiwert et al.[18] concluded that emergency repair of RAAA is relatively inexpensive when compared with other commonly used health maintenance protocols and effectively restores survivors to their former health. Furthermore, they stated that "Since no clinical or physiologic parameter can predict poor outcome, operative intervention should not be denied."[18(p94)]

Specialization

With the growth of managed care, many are predicting a marked concomitant decrease in the availability and use of physician and surgeon specialists. The effect of such changes in the availability of physician and surgical specialists on the outcomes of patient care are not known. Are specialists necessary? Does the additional training and certification obtained by some surgeons make any difference in the outcome of patient care? Delays in recognition and treatment for the care of certain illnesses and lower levels of expertise and experience in the care of some diseases might lead to deterioration in the quality of patient care and to worse outcomes. What will be the impact of fewer specialists for the care of such critical illnesses as RAAA?

Regionalization

The increase in managed care also is expected to have a major impact on hospital resources, experience, distribution, and case loads. These changes may increase the trend toward regionalization of some kinds of medical care. As regionalization occurs, these trends could have significant impact on diseases that require specialized care and most especially diseases that require urgent availability of specialized care, such as RAAA.

With changing health care and health-care reimbursement in the United States, there is going to be an increased pressure toward regionalization and a decreased availability of specialized physician staff. The current study addresses both of these questions with reference to RAAA and raises some significant points and some interesting concerns. Surgical care costs continue to rise at a rate greater than overall U.S. economic growth. Government and industry have vowed to slow the growth of health-care spending. Prospective payment systems using the diagnosis-related group mechanism are being phased in for payment of inpatient hospital care.[19] One expected effect of the diagnosis-related group payment scheme is a more careful financial analysis of the components of surgical care. The study plan was to access the North Carolina Medical Database Commission Database. This is a hospital discharge database based on billing data, and therefore, there are a variety of limitations. Because of the lack of physiologic data and arrival and transfer information, there is significant chance for problems in the database. In addition, one needs to be careful about ascribing to a hospital or physician responsibility for mortality rates when there may have been significant selection bias in the transfer and access to various patient populations.

Physician Training and Experience and Survival After Ruptured Abdominal Aortic Aneurysm

The United Sates has extensive machinery in place for the training and certification of physicians and surgeon specialists. The value of this effort, although generally accepted, is not well supported in scientific studies. Measurement of quality of patient care is an extremely difficult effort, and the work in this study can only be viewed as a very preliminary attempt to assess the value of specialist care for RAAA. This database in particular is only billing data. It is lacking in the depth and accuracy necessary in a true research study to allow firm conclusions about the findings in this study. Still, the large size of the study may leave us with some indications about underlying facts in the health-care system. One of the prime hypotheses of this study was that increased physician expertise and experience would positively affect the outcome of RAAA patients. Within the severe restrictions of the study, this hypothesis was generally confirmed. Analysis of surgeon board certification status showed that nonboard-certified surgeons had lower survival in patients with RAAA ($p = 0.07$). In addition, we assessed the physician experience in survival and the number of cases for each surgeon. The association between the physician's experience with RAAAs and patient survival was found to be statistically significant by logistic regression analysis, with a p value of 0.025. An analysis of the association of survival after RAAA and experience with all AAAs showed no statistical significance ($p = 0.96$).

Survival of Patients with Ruptured Abdominal Aortic Aneurysm at Different Types of Hospitals

In line with our hypothesis concerning physician experience and expertise, it also was our hypothesis that hospital characteristics would be associated with survival after RAAA. To test this hypothesis, survival was compared between large (> 100 bed) *versus* small (< 100 bed) hospitals. Patients who underwent surgery at smaller hospitals had significantly lower survival rates than patients who underwent surgery at larger hospitals. Logistic regression was used to assess the association between hospital AAA case load and patient survival after RAAA. Hospital experience with elective AAAs was analyzed, and although there was a trend toward improved patient survival in hospitals with a greater case load of AAAs, this did not achieve statistical significance (p = 0.59). Survival rate in ruptured aneurysms also was analyzed and compared with the number of RAAA cases for which the hospital had cared. Although there appears to be a trend toward improved survival with increased hospital case load, this did not reach statistical significance (p = 0.23).

Interventions to Improve Survival

In a study reported from England,[20] the effects of screenings on the rate of RAAA was tested. From family medical practices, 15,775 men and women 65 to 80 years of age were identified and randomized into two groups: one group was invited for ultrasonographic screening for AAA, and the other acted as age- and sex-matched controls. Of the 5394 screened, AAA was detected in 218 (4.0% overall and 7.6% of men). Aortic surgery was offered to the screened group if certain criteria were met, and no patient died who was fit for operation and accepted elective treatment. The incidence of rupture was reduced by 55% in men in the group invited for screening, compared with the controls. The study suggests that interventions designed to screen for AAA can decrease the rate of RAAA. The series by Johansen also concluded that "screening of patients at high risk for abdominal aortic aneurysm, followed by elective aneurysmorrhaphy, is clearly indicated."[13]

CONCLUSIONS

This is one of the first U.S., population-based studies of RAAA. The study demonstrates that there has been an increase in the number of RAAAs in the state. The increase in the per capita rate of RAAAs was less than the increase in AAAs, despite an increase in operations for patients who are recognized to have abdominal aneurysms and to treat these patients. Sadly, the mortality rate remains extremely high, and although there is a slight trend toward improvement and survival, possibly the most concerning finding in the study is that the mortality rate remains high and unchanged over the 6 years of the study.

Finally, this study shows an association between both hospital and physician experience and expertise and patient survival. Because of database limitations, these associations should be viewed circumspectly. Further studies are needed to determine if such associations are real or simply secondary to other associated factors that were unidentified in this study.

Acknowledgments

The authors thank Ms. Beverly Greer for her extensive editorial advice and assistance.

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