Aneurysm of Abdominal Aorta *

Analysis of Results of Graft Replacement Therapy One to Eleven Years After Operation

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ANEURYSM of the abdominal aorta is one of the most serious of all diseases, in most cases producing death from rupture and hemorrhage within a few years after diagnosis. Although an effective method of treatment had been sought for well over a century, the presently accepted form of therapy was introduced only a little over a decade ago when Dubost and his associates,[4] in 1952, first reported the successful application of the procedure of excision and homograft replacement of an aneurysm of the abdominal aorta. The effectiveness of this form of treatment, combined with progressive refinements in technic and types of vascular replacement, has since been verified by numerous reports.[1-4, 6-11]

During the little over 11 years from November 6, 1952, following our first successful excision and graft replacement of an abdominal aortic aneurysm, until January 1, 1964, we have employed this form of therapy in 1,719 patients (Fig. 1). This report, however, is based upon a study of 1,449 patients in this series whose operation was performed prior to January 1, 1963, in order to provide follow-up results ranging from one to 11 years. Current follow-up results of treatment were actually obtained on 1,432 patients (98.8%). Eleven additional patients were known to be alive one to four years after operation, and only six patients (0.4%) were thus completely lost to follow up. Accordingly, this report is concerned with certain significant observations derived from an analysis of this experience with particular emphasis upon factors influencing long-term survival.

The great majority of patients with aneurysms of the abdominal aorta admitted to the hospital during this period were treated surgically, since contraindications to operation were limited to the presence of severe and disabling associated systemic disease. Ages of the patients ranged from 33 to 90 years, with the highest incidence occurring in the seventh decade of life (Fig. 2). An important consideration is the fact that 282 patients (20%) were 70 years of age or older. The ratio of men to women was 9:1 (Fig. 3). The women were older, the median age being 65 years for women and 63 for men. Arteriosclerotic heart disease, demonstrated in most cases by electrocardiographic evidence of old myocardial infarction, and in some by manifestations of angina pectoris and congestive heart failure, was present in 418 patients. Patients with blood pressure greater than 150 mm. Hg systolic and 90 mm. Hg diastolic were considered hypertensive, and on this basis, 566 patients (39%) had hypertension. Of these,

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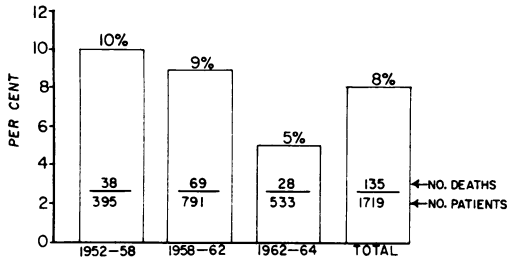

FIG. 1. Decreasing operative mortality rates during the various periods of treatment in patients with aneurysm of abdominal aorta.

342 (23%) had both hypertension and heart disease (Fig. 4). The aneurysm had ruptured in 117 patients, 28 per cent of whom were in shock at the time of admission (Fig. 5).

Since the predominant underlying pathogenic factor in aneurysms of the abdominal aorta is arteriosclerosis, lesions of this nature either in the form of segmental occlusive or aneurysmal disease in other parts of the aorta or major arterial trunks occur not infrequently in the same patient. With greater experience and awareness of these characteristic patterns of arteriosclerotic or atherosclerotic disease, an increasing number of patients with aneurysms of the abdominal aorta have been encountered with various combinations of these different forms of vascular disease, such as cerebrovascular insufficiency, renovascular hypertension, arterial insufficiency of the lower extremities, and aneurysms of the thoracic aorta and major arterial branches. Surgical

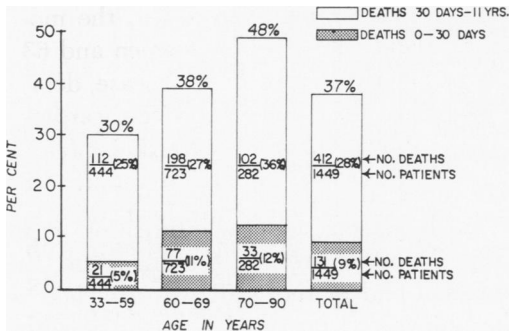

FIG. 2. Mortality rates according to age of patients with aneurysm of abdominal aorta.

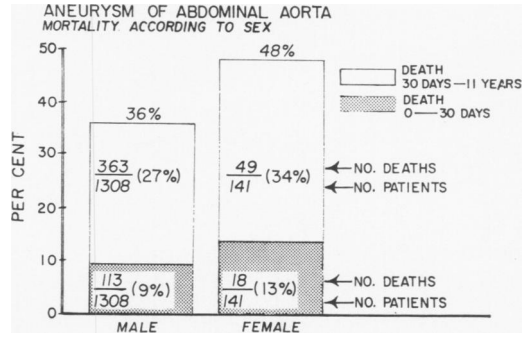

FIG. 3. Mortality rates according to sex in patients with aneurysm of abdominal aorta.

treatment is indicated for these associated lesions in the great majority of patients either during the operative procedure for the abdominal aneurysm or at another time (Fig. 7–9, Table 1).

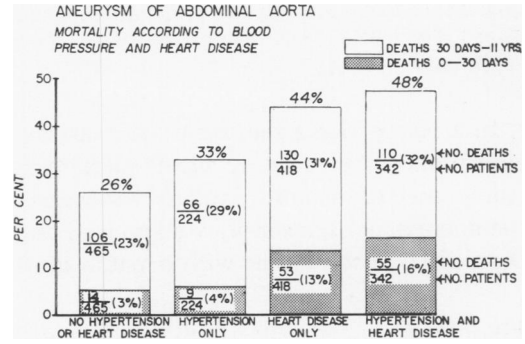

FIG. 4. Mortality rates according to presence of hypertension and heart disease in patients with aneurysm of abdominal aorta.

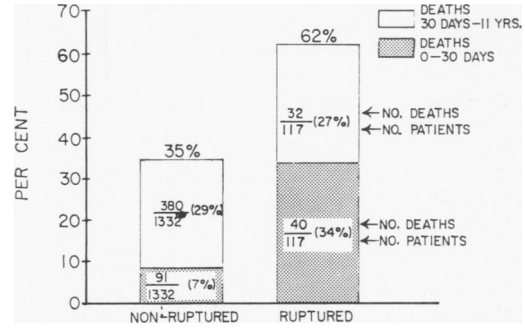

FIG. 5. Mortality rates in cases of ruptured and nonruptured aneurysm of abdominal aorta.

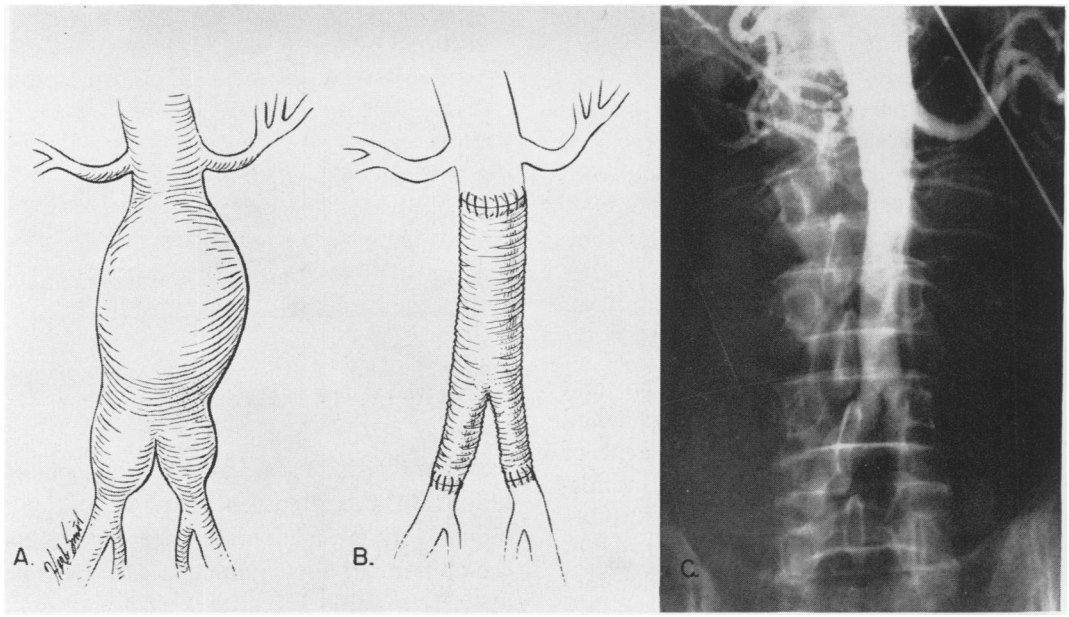

FIG. 6. A. Characteristic type of arteriosclerotic aneurysm arising just below renal arteries and involving both common iliac arteries. B. Treatment by resection and replacement with bifurcation dacron graft. C. Aortogram made five years after operation showing restoration of normal circulation.

Treatment

In a few patients the aneurysm was sacciform and involved only a part of the circumference of the aortic wall. In these cases the aneurysmal sac simply was excised and the defect closed either with a patch graft or by attaching to the edges of the defect the proximal end of an aortic bifurcation graft used to bypass associated occlusion of the iliac arteries. The aneurysm in the remaining cases was fusiform in nature, involving the entire aortic circumference, and required complete replacement of the involved segment. In some of these cases the aortic bifurcation was not involved and the aneurysm was treated by segmental aortic replacement, but usually the aneurysm involved the aortic bifurcation and proximal segments of the common iliac arteries. In the presence of patent iliac vessels, the involved segment was replaced with a bifurcation graft attached by end-to-end anastomosis (Fig. 6). In the presence of obstruction in the iliac arteries, the aneurysm was replaced and the obstructed iliac arteries bypassed with a bifurcation graft (Fig. 7). After excising the aneurysm, the proximal end of the graft was attached to the uninvolved proximal segment of aorta. The distal ends of the uninvolved aorta or common iliac arteries were closed by suture

TABLE 1. *Tabulation of Associated Atherosclerotic Lesions Occurring in Patients with Aneurysm of Abdominal Aorta*

Disease	No. Patients	Surgically Treated	
		No. Patients	Death
Occlusive			
Cerebrovascular	104(7%)	48	2(4%)
Renal	35(2%)	34	2(6%)
Iliac	237(16%)	237	11(5%)
Femoral	158(11%)	88	1(1%)
Other	3(0.2%)	3	0(0%)
Aneurysm			
Thoracic	62(4%)	26	4(15%)
Femoral	43(3%)	40	2(5%)
Popliteal	27(2%)	22	1(5%)
Other	3(0.2%)	3	0(0%)

if incompletely obstructed, and the distal ends of the iliac limbs of the graft were attached by end-to-side anastomosis to the external iliac arteries in the pelvis or to the common femoral arteries in the groin, depending upon the extent of obstruction. In some patients with associated obstruction of the superficial femoral artery, the graft was extended down as a bypass to the popliteal artery (Fig. 7).

Small aneurysms were usually excised in toto, but the excision is greatly facilitated by a somewhat different procedure in aneurysms of large size, in those that have ruptured, and in those with a thick, somewhat granulomatous wall with marked adherence to surrounding structures. Under these circumstances proximal and distal control of circulation through the aneurysm is first obtained by applying occluding clamps to

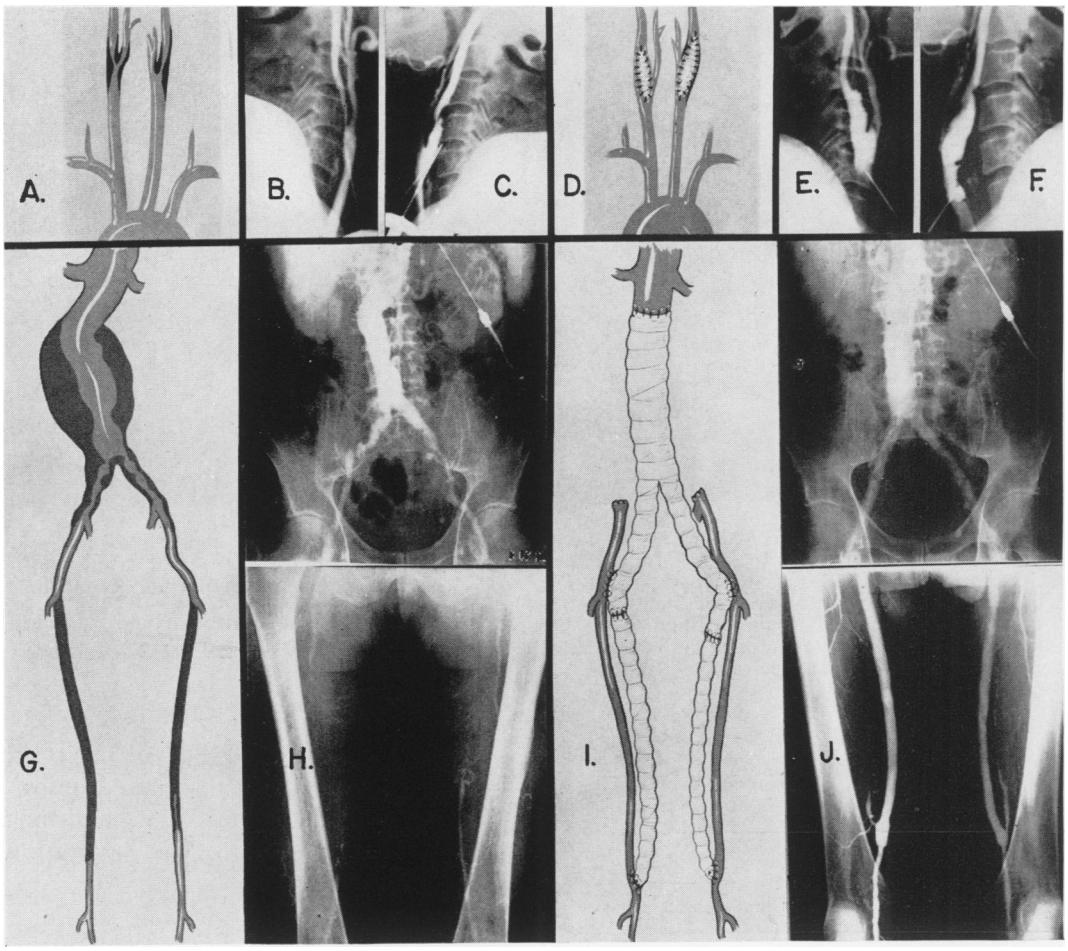

FIG. 7. A. Preoperative. B. Right and C. Left carotid arteriograms showing well localized partial segmental occlusive lesions of both internal carotid arteries near their origin. D. Operative procedure consisting of patch graft angioplasty. E. Right and F. Left carotid arteriograms made five years after operation demonstrating restoration of normal circulation. G. Drawing. H. Preoperative aortogram and femoral arteriograms showing fusiform aneurysm of abdominal aorta involving both iliac arteries along with complete occlusive lesions of both superficial femoral arteries. I. Operative procedure consisting of resection of aneurysm of abdominal aorta and replacement by bifurcation dacron graft and dacron bypass grafts to both common femoral arteries and popliteal arteries below occlusive lesion. J. Aortogram and femoral arteriograms made five years after operation demonstrating restoration of normal blood flow to extremities.

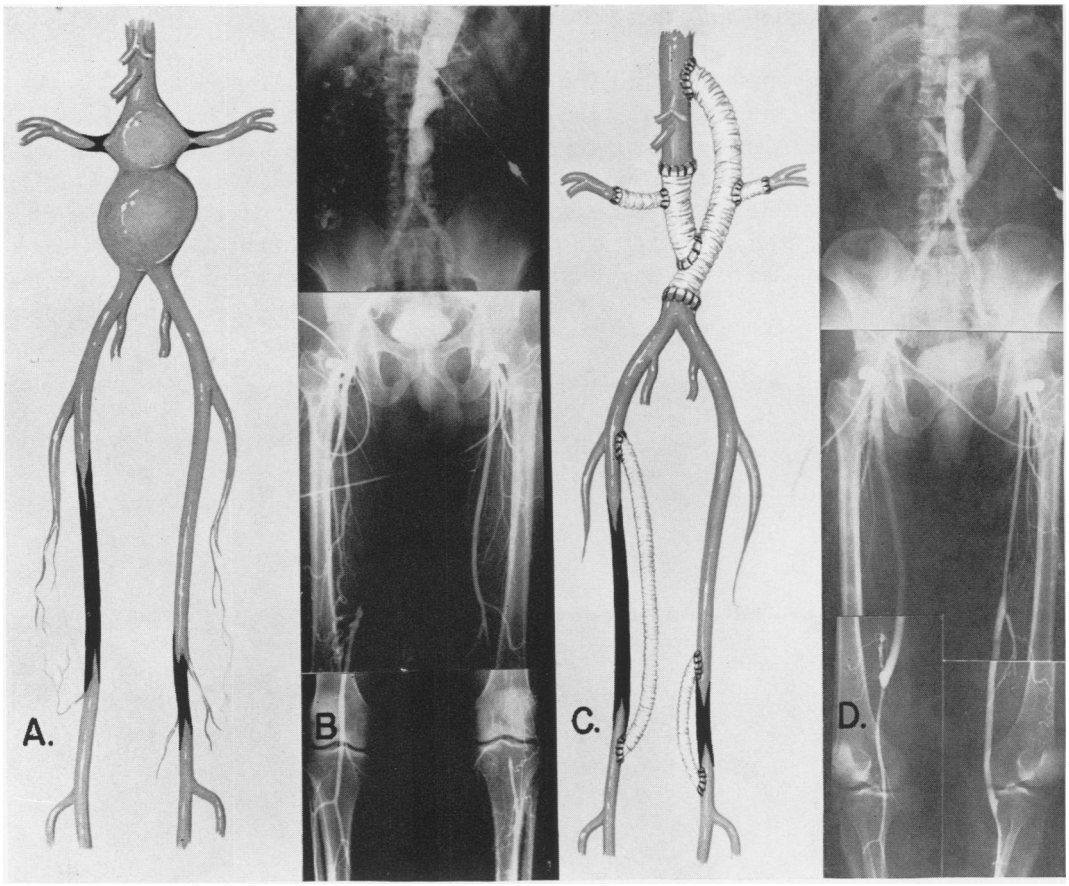

FIG. 8. A. Drawing and B. Aortogram and femoral arteriograms showing large fusiform aneurysm of abdominal aorta involving both renal arteries, along with occlusive lesions of both renal arteries (associated with hypertension) and of both superficial femoral arteries. C. Operative procedure consisting of resection of aneurysm of abdominal aorta and replacement with dacron grafts including both renal arteries and bypass grafts from femoral to popliteal arteries. D. Aortogram and femoral arteriograms made several months after operation showing restoration of normal circulation. Patient has remained asymptomatic and normotensive since operation.

TABLE 2. *Tabulation of Graft Replacements and Incidence of Graft Complications Occurring in Patients with Aneurysm of Abdominal Aorta*

Graft	No. of Patients	Graft Complications
Homograft	194	27(14%)
Nylon	67	14(21%)
Orlon	12	4(33%)
Ivalon	5	3(60%)
Nylon-Dacron	25	3(12%)
Teflon	8	1(13%)
Dacron	1138	21(2%)
Total	1449	73(5%)

the aorta immediately above the aneurysm and to the iliac arteries below, following which the aneurysm is entered by a longitudinal incision. The mural thrombus and the intimal layer within the aneurysm were removed, leaving the outer layer of the aneurysmal wall attached to adjacent structures. The graft was inserted as described above and the outer layer of the aneurysm was sutured around the graft before closure of the posterior peritoneum. This technic limited the need for dissection, minimized injury to adjacent structures, and provided

a suitable covering to separate the graft from the gastro-intestinal tract.

Many types of aortic replacements were used during this 11-year period (Table 2). Aortic homografts were used almost exclusively until 1955, at which time a variety

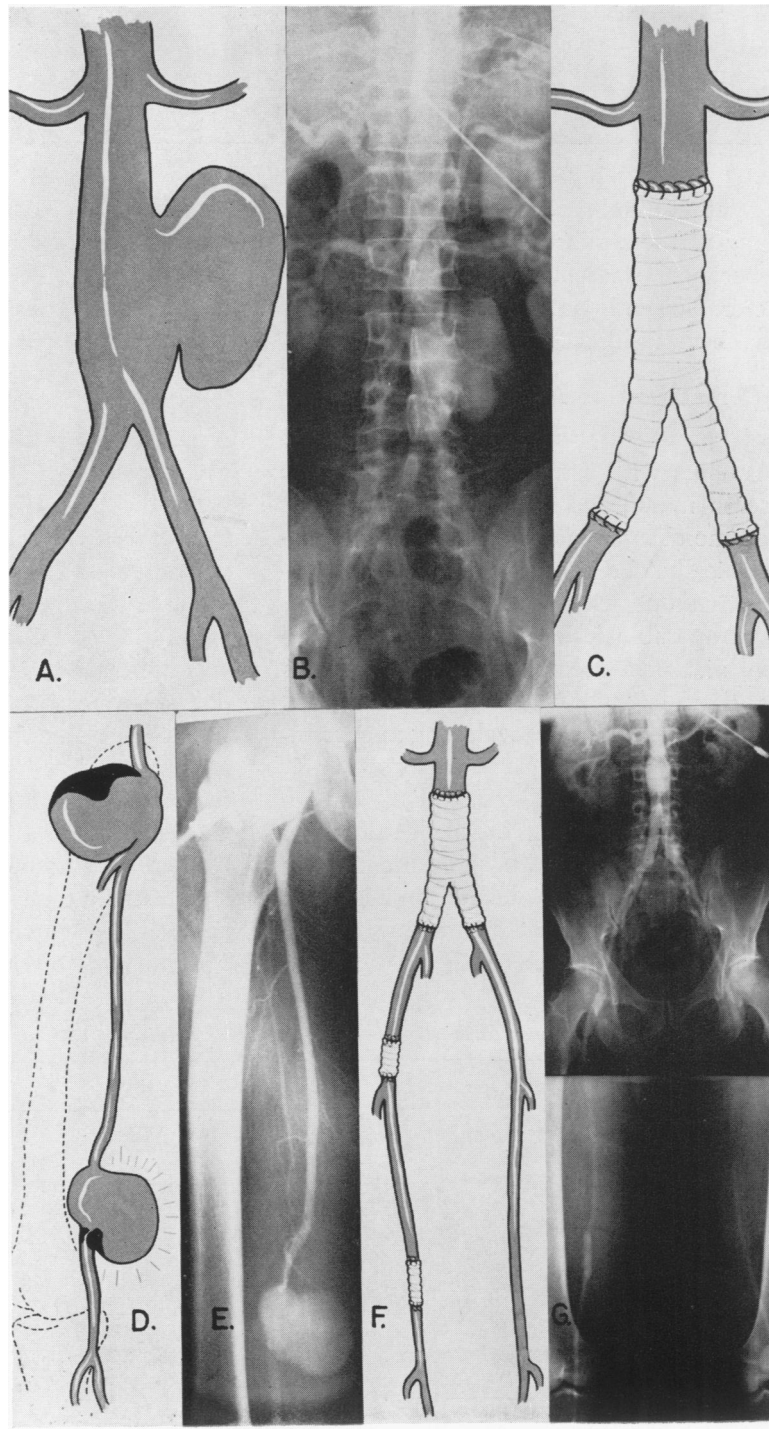

FIG. 9. A. Drawing and B. preoperative aortogram showing aneurysm of abdominal aorta which at operation was found to be ruptured into retroperitoneal tissues. C. Operative procedure consisting of resection of aneurysm and replacement with bifurcation dacron graft. D. Drawing and E. Preoperative right femoral arteriogram made two years after operation for aneurysm of abdominal aorta showing aneurysms of right common femoral and popliteal arteries (the latter of which at operation was found to be ruptured). F. Operative procedure consisting of resection of aneurysms of right common femoral and popliteal arteries and replacement with Dacron graft. G. Postoperative aortogram showing restoration of normal circulation.

TABLE 3. *Tabulation of Causes of Death in Patients Submitted to Operation for Aneurysm of Abdominal Aorta*

Disease	0–30 Days	30 Days–11 Yrs.	Total
Atherosclerosis	101(77%)	263(64%)	364(67%)
Complications of Operation	28(21%)	48(12%)	76(14%)
Cancer	0	44(11%)	44(8%)
Other	2(2%)	17(4%)	19(4%)
Unknown	0	40(9%)	40(7%)
Total	131(100%)	412(100%)	543(100%)

of synthetic substances became available. Many of these substances were tried until it became apparent that dacron was the preferable synthetic material. Dacron grafts have been used exclusively since 1957.

Treatment of Associated Atherosclerotic Disease

Patients with associated cerebrovascular disease manifested clinically before or at the time of admission were studied arteriographically. Treatment by arterial reconstructive operation was directed first toward operable lesions causing this condition, and at a second operation, seven to ten days later, the abdominal aneurysm was excised. Patients developing manifestations of cerebrovascular disease after operation for aneurysm were studied, and reconstructive operation of the extracranial arteries done immediately in patients with persistent neurologic deficits, and later in patients with transient symptoms. Of the 104 patients with this condition, 48 were found to have segmental lesions, and were submitted to arterial reconstructive operation (Fig. 7). Associated occlusive disease of the iliac arteries in 237 patients was treated as described above (Fig. 7). Associated lesions of the celiac axis and the superior mesenteric or of the renal arteries were treated at the same operation as the abdominal aneurysm (Fig. 8). In most cases the bypass principle was employed. One end of an 8 mm. knitted Dacron tube was attached to the side of the aortic segment of the graft employed to replace the aneurysm, and the other end of the tube was attached to the distal patent segment of the proper artery. Endarterectomy and patch graft angioplasty were used to treat certain patients with associated renal artery occlusion. Of the 158 patients with occlusive lesions of the femoral arteries, 88 had an operation to correct these lesions either at the time of the primary operation as described above or at a later date.

Aneurysms of the femoral and popliteal

TABLE 4. *Tabulation of Male Patients Surviving Operation According to Age Group and Time After Operation*

	Time After Operation											
Age	Less than 30 days	30 days–1 yr.	1–2 yr.	2–3 yr.	3–4 yr.	4–5 yr.	5–6 yr.	6–7 yr.	7–8 yr.	8–9 yr.	9–10 yr.	10 yr.
25–34	1	1	1	0	0	0	0	0	0	0	0	0
35–44	10	7	3	3	2	1	0	0	0	0	0	0
45–54	156	152	127	69	46	26	16	3	1	0	0	0
55–64	556	512	436	298	208	137	87	38	17	5	1	0
65–74	509	455	448	317	236	167	114	75	28	13	4	1
75–84	72	65	81	73	64	42	32	22	14	7	1	1
85+	4	3	5	4	6	4	2	2	0	0	0	0
Totals	1,308	1,195	1,101	764	562	377	251	140	60	25	6	2

TABLE 5. *Tabulation of Female Patients Surviving Operation According to Age Group and Time After Operation*

Age	Time After Operation										
	Less than 30 days	30 days–1 yr.	1–2 yr.	2–3 yr.	3–4 yr.	4–5 yr.	5–6 yr.	6–7 yr.	7–8 yr.	8–9 yr.	9–10 yr.
25–34	0	0	0	0	0	0	0	0	0	0	0
35–44	1	1	0	0	0	0	0	0	0	0	0
45–54	13	13	12	8	4	2	0	0	0	0	0
55–64	45	43	35	24	18	10	6	3	0	0	0
65–74	62	53	53	40	29	22	12	6	1	1	0
75–84	18	13	15	12	12	7	6	2	3	2	1
85+	2	0	0	0	1	1	1	1	0	0	0
Totals	141	123	115	84	64	42	25	12	4	3	1

arteries were excised and replaced at the time of abdominal operation to prevent postoperative thrombosis and other complications in good risk patients (Fig. 9). In patients in which some risk was involved, the peripheral aneurysm was excised at a later date. The treatment of associated aneurysm of the thoracic aorta was dependent upon a number of considerations, including the nature of symptoms, time of onset of the thoracic aneurysm, and advance knowledge of its presence. In most patients the abdominal aortic aneurysm was removed first to prevent thrombosis, embolization, and other complications which may result from or interfere with left atrium to common femoral artery extracorporeal pump-bypass, a technic frequently used to provide distal blood flow during removal of the thoracic aneurysm. In the presence of symptoms, the thoracic lesion was removed first. In some cases both lesions were removed at one operation or at a second operation on the same day because of rupture of the remaining aneurysm. In some cases rupture and death occurred before the second operation could be performed, indicating the desirability of an aggressive approach to the problem of multiple aortic aneurysms.

Results

Death occurred within 30 days after operation in 9 per cent of the patients and after 30 days in 28 per cent (Table 3). The major causes of the 543 deaths were such complications of atherosclerosis as myocardial infarction, heart failure, rupture of thoracic aneurysm, and cerebrovascular disease. Complications related to operation, such as hemorrhage, graft complication, infection, renal failure, homologous serum jaundice, and pulmonary embolism, occurred in 76 patients, and cancer in 44 (Table 3). Of the 1,449 patients submitted to operation, 1,318 (91%) lived over thirty days; 1,216 (84%) lived at least one to two years; and 63 per cent of all patients are alive at the present time. A considerable number of patients lived or are still living up to ten years after operation (Tables 4, 5). From the number living and dying during the interval of study an actuarial table or life table was constructed according to sex (Tables 6, 7) and total resected population (Table 8) and compared with a similar table of the United States population, adjusted for sex and age at ten-year intervals, constructed from information provided by the census report of the U. S. Public Health Service for 1960 (Table 9).[12] A comparison of survivors and the cumulative deaths per thousand per interval of time for the two groups shows that the greatest period of risk in the group with aneurysmal resection was the first 30 days, and that the deaths during this time account for more than one third of the difference in the ten-year sur-

TABLE 6. *Modified Life Table Based Upon 1,000 Male Patients Submitted to Operation for Aneurysm of Abdominal Aorta*

Time Interval After Operation	No. Entering Interval	No. Dying During Interval	Observed Death Rate per 1,000	Expected Death Rate per 1,000*
0–30 days	1,000	89	88.7	2.97
31 da.–1 yr.	911	71	78.2	32.4
1–2 yr.	840	65	76.5	38.2
2–3 yr.	775	51	65.5	40.7
3–4 yr.	724	56	78.4	43.4
4–5 yr.	668	65	98.4	44.0
5–6 yr.	603	48	80.0	45.2
6–7 yr.	555	84	151.1	51.5
7–8 yr.	471	72	152.5	53.1
8–9 yr.	399	48	120.0	58.5
9–10 yr.	351	59	166.7	53.2
More than 10 yr.	292	—	—	75.8

* Sex and age adjusted (10-year intervals) rates based on USPHS, National Vital Statistics Division, 1960.[12]

TABLE 7. *Modified Life Table Based Upon 1,000 Female Patients Submitted to Operation for Aneurysm of Abdominal Aorta*

Time Interval After Operation	No. Entering Interval	No. Dying During Interval	Observed Death Rate per 1,000	Expected Death Rate per 1,000*
0–30 days	1,000	128	127.7	2.39
31 da.–1 yr.	872	64	73.2	22.4
1–2 yr.	808	42	52.2	26.6
2–3 yr.	766	91	119.0	27.8
3–4 yr.	675	127	187.5	33.4
4–5 yr.	548	104	190.5	34.8
5–6 yr.	444	36	80.0	42.2
6–7 yr.	408	34	83.3	45.7
7–8 yr.	374	94	250.0	64.7
More than 8 yr.	280	—	—	60.6

* Sex and age adjusted (10-year intervals) rates based on USPHS, National Vital Statistics Division, 1960.[12]

TABLE 8. *Modified Life Table of All Patients Based Upon 1,000 Individuals Submitted to Operation for Aneurysm of Abdominal Aorta*

Time Interval After Operation	No. Entering Interval	No. Dying During Interval	Observed Death Rate per 1,000	Expected Death Rate per 1,000*
0–30 days	1,000	93	92.5	2.92
31 da.–1 yr.	907	71	77.7	31.4
1–2 yr.	836	62	74.3	37.1
2–3 yr.	774	55	70.8	39.4
3–4 yr.	719	65	89.6	42.4
4–5 yr.	654	71	107.7	43.1
5–6 yr.	583	47	80.0	44.9
6–7 yr.	536	78	145.7	51.1
7–8 yr.	458	73	158.7	53.9
8–9 yr.	385	41	107.1	58.7
9–10 yr.	344	49	142.9	56.6
More than 10 yr.	295	—	—	75.8

* Sex and age adjusted (10-year intervals) rates based on USPHS, National Vital Statistics Division, 1960.[12]

vival of the two groups (Fig. 10). These data translated into per cent survival and compared with the survival rate of patients not undergoing surgery (the combined series of Estes and Wright and associates) [5, 13] demonstrate that once the patient survives the immediate operation his chances of surviving ten years closely approach those of the normal population, the curves being almost parallel although at a lower level because of the operative mortality (Fig. 11). These data also show that long-term survival following operation is greatly increased as compared with the nonresected patients.

A number of factors influenced the early mortality and long-term survival including the condition of the aneurysm, associated disease, sex and age of the patient, and

TABLE 9. *Life Table Based Upon 1,000 Individuals from the United States Population Adjusted for Sex and Age to be Comparable to that of Patients Submitted to Operation for Aneurysm of Abdominal Aorta*[12]

Time Interval After Operation	No. Entering Interval	No. Dying During Interval	Death Rate per 1,000*
0–30 days	1,000	3	2.92
31 da.–1 yr.	997	31	31.4
1–2 yr.	966	36	37.1
2–3 yr.	930	37	39.4
3–4 yr.	893	38	42.4
4–5 yr.	855	37	43.1
5–6 yr.	818	37	44.9
6–7 yr.	781	40	51.1
7–8 yr.	741	40	53.9
8–9 yr.	701	41	58.7
9–10 yr.	660	37	56.6
10+ yr.	623	—	75.8

* Sex and age adjusted (10-year intervals) rates based on USPHS National Vital Statistics Division, 1960.[12]

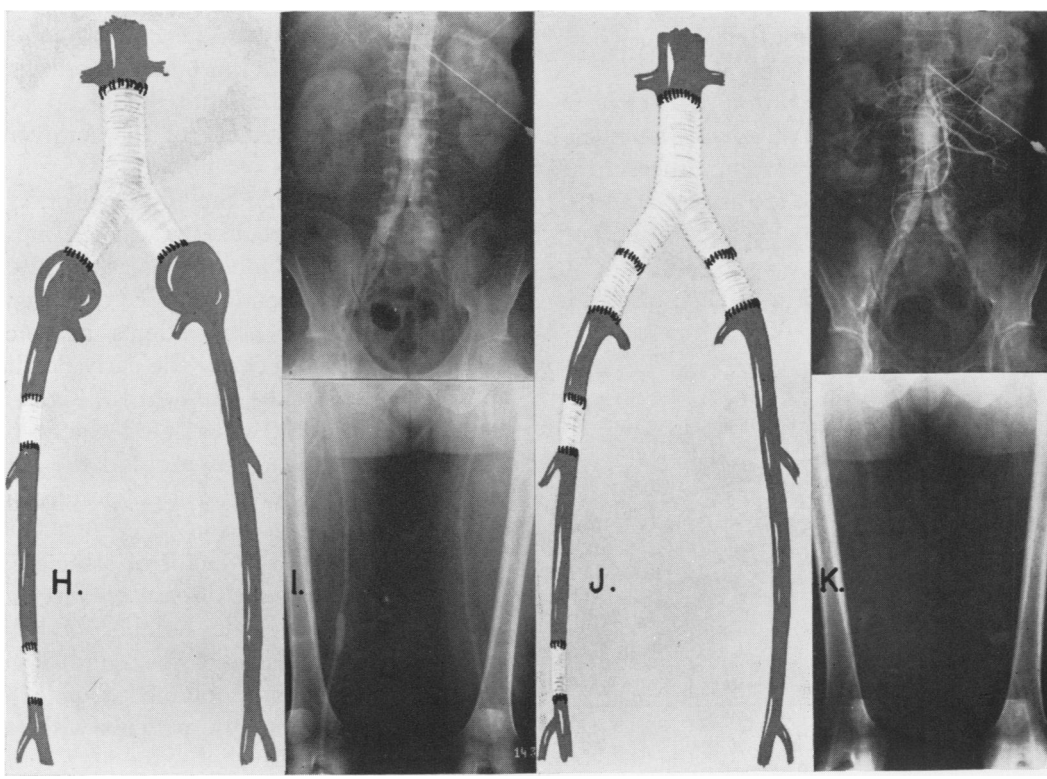

FIG. 9. H. Drawing and I. Preoperative aortogram made four years after first operation for aneurysm of abdominal aorta showing aneurysms of both common iliac arteries. J. Operative procedure consisting of resection of both aneurysms of common iliac arteries and replacement with Dacron grafts. K. Aortogram made five years after first operation for aneurysm of abdominal aorta showing complete restoration of normal circulation.

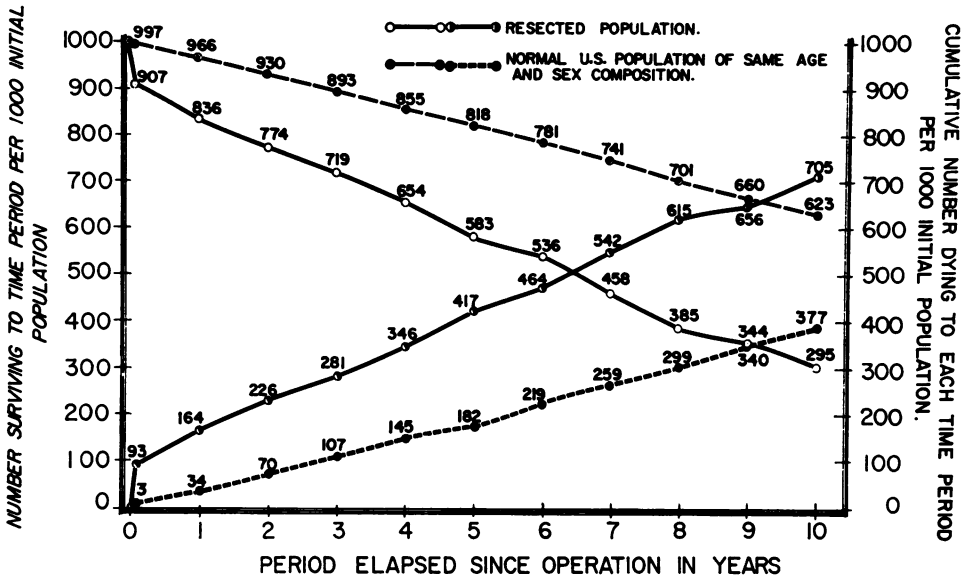

FIG. 10. Survival and cumulative deaths per thousand over ten-year period comparing resected cases with normal population adjusted for sex and age.

technical features of the operation. These factors are considered separately.

Condition of the aneurysm. Recent hemorrhage, indicating rupture of the aneurysm, was found at operation either in the tissues surrounding the aneurysm or in the peritoneal cavity, as well as in surrounding tissues, in 117 patients (8%—Fig. 5). Deaths in patients with advanced or terminal forms of the disease accounted for 30 per cent of the early mortality. There was little difference during the follow up period in the late mortality of the survivors in the two groups.

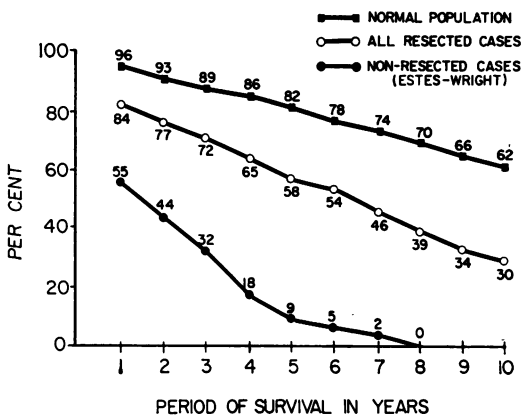

FIG. 11. Life expectancy of patients with abdominal aortic aneurysm in this study compared with normal population adjusted for sex and age and with a nonresected series by Estes and Wright and others.

Associated disease. The presence of hypertension and heart disease was the most significant factor influencing survival after operation. These conditions were present in 68 per cent of the patients and accounted for 89 per cent of the early deaths and 74 per cent of the late deaths (Fig. 4). The early mortality was related chiefly to the presence of heart disease and the late mortality was affected by both hypertension and heart disease.

The influence of the factor of associated hypertension and heart disease on survival was determined by the number of survivors per thousand and the cumulative deaths per thousand, obtained from life tables constructed for the patients without hypertension and heart disease and compared with these associated conditions (Tables 10, 11). These data show a significant difference in survival in the patients with and without hypertension and

TABLE 10. *Modified Life Table Based Upon 1,000 Patients without Heart Disease or Hypertension Submitted to Operation for Aneurysm of Abdominal Aorta*

Time Interval After Operation	No. Entering Interval	No. Dying During Interval	Observed Death Rate per 1,000	Expected Death Rate per 1,000*
0–30 days	1,000	30	30.1	2.8
31 da.–1 yr.	970	67	68.7	30.0
1–2 yr.	903	43	47.7	35.5
2–3 yr.	860	28	32.2	36.9
3–4 yr.	832	46	54.8	39.9
4–5 yr.	786	48	60.6	43.1
5–6 yr.	738	53	71.4	43.1
6–7 yr.	685	87	127.0	49.5
7–8 yr.	598	69	115.4	47.9
8–9 yr.	529	118	222.2	40.0
9–10 yr.	411	103	250.0	49.0
More than 10 yr.	308	—	—	103.0

* Sex and age adjusted (10-year intervals) rates based on USPHS, National Vital Statistics Division, 1960.[12]

heart disease. In fact, the life expectancy of patients without associated hypertension and heart disease is almost the same as that of the normal population for the first five years, but development of other arteriosclerotic complications increased the late mortality in the former group, and life expectancy approached that in patients with associated heart disease and hypertension (Fig. 12). The significance of these factors is demonstrated by a comparison of the survival rate in untreated cases with those treated surgically and in whom these factors were present or absent (Fig. 13). The most important consideration is the fact that patients with hypertension and heart disease submitted to operation for abdominal aneurysm have a much better chance of long-term survival than the patients not surgically treated (Fig. 13).

The presence of other atherosclerotic lesions was an important factor in survival. Such lesions in the form of coronary artery disease and intracranial arterial occlusive disease accounted for the majority of deaths both at the time of operation and later (Table 3). An important consideration in this regard is the fact that the majority of patients with associated lesions operated on at the time of operation for aneurysm survived, indicating both the feasibility of associated operation and the protection

TABLE 11. *Modified Life Table Based Upon 1,000 Patients with Hypertension or Heart Disease or Both*

Time Interval After Operation	No. Entering Interval	No. Dying During Interval	Observed Death Rate per 1,000	Expected Death Rate per 1,000*
0–30 days	1,000	117	117.1	3.0
31 da.–1 yr.	883	73	83.0	32.5
1–2 yr.	810	72	89.1	38.3
2–3 yr.	738	69	93.3	40.9
3–4 yr.	669	74	110.8	43.9
4–5 yr.	595	82	137.8	43.2
5–6 yr.	513	44	85.4	44.4
6–7 yr.	469	75	159.1	49.7
7–8 yr.	394	73	184.2	53.7
8–9 yr.	321	17	52.6	62.0
More than 9 yr.	304	—	—	58.0

* Sex and age adjusted (10-year intervals) rates based on USPHS, National Vital Statistics Division, 1960.[12]

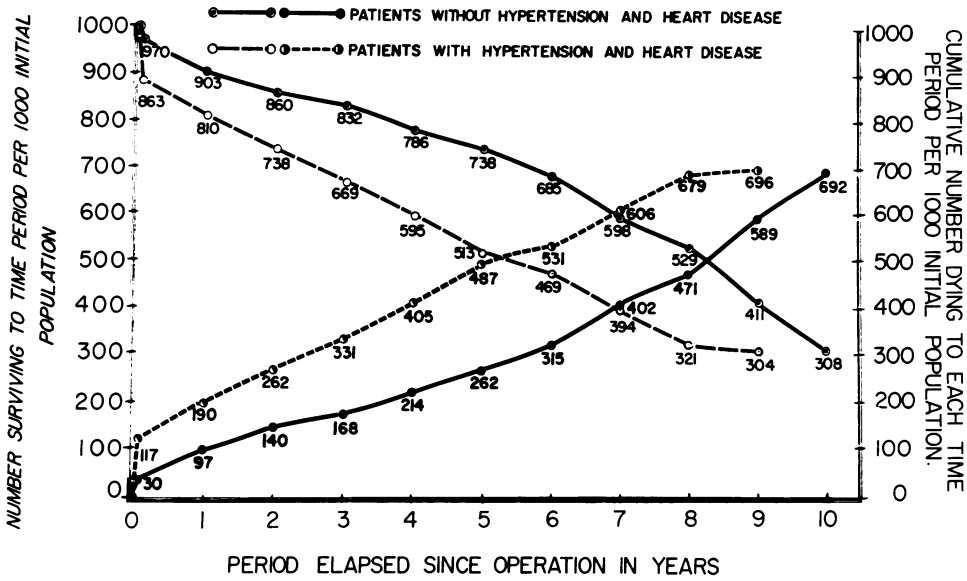

FIG. 12. Survival and cumulative deaths per thousand over ten-year period comparing patients having hypertension or heart disease with patients not having these conditions.

which this approach may have to offer (Table 1).

Sex. The number of women in the series was small, 141 (9%), and comparison with the male patients is therefore not very significant. Both early and late mortality rates in women, however, were higher than in men (Fig. 3). This phenomenon may be explained by the fact that the women were older and had a higher incidence of associated hypertension and heart disease.

Age. Survival was related to age in that the early mortality was twice as great in patients over 59 years of age as in younger patients and late mortality was significantly greater in patients 70 to 90 years of age (Fig. 2). These differences in mortality, however, are related to the higher incidence of hypertension and heart disease in older patients. For example, there was little difference in mortality and long-term survival in patients over 70 years of age who did not have associated hypertension and heart disease and in comparable patients in the younger age groups. Thus, age in itself was not a significant factor in survival.

Technical features of operation. The mortality from operation has progressively decreased from 10 per cent in the period up to 1958 to 5 per cent in the period from 1962 to 1964 (Fig. 1). This improvement in survival rate reflects improvements in technic and management of associated diseases. Homografts and replacements made of various synthetic materials which were associated with a relatively high incidence of complications (Fig. 14) were employed almost exclusively in the first series of cases (Table 2). Dacron graft replacements, either knitted or woven, have been employed exclusively in the most recent series, and graft complications have occurred in only 2 per cent of all patients in whom this material has been used. Other improvements in technic, including more frequent use of the bypass principle in patients with associated occlusive disease, development and application of better suture material, and decrease in time of operation, have all contributed toward better results. The inauguration of an intensive care unit with special equipment, including monitoring devices, and personnel with a better understanding of the nature and treatment of

associated disease has improved the care of the patient and has increased survival.

Discussion

This experience, like that of others, indicates that arterial reconstructive operation can be safely employed in most patients with abdominal aortic aneurysm regardless of the condition of the aneurysm, age and sex of the patient, and presence of associated disease. Moreover, even in patients with associated disease, this form of therapy provides a much longer life expectancy than that of patients not treated surgically. Analysis of factors contributing to mortality suggests certain areas in which the results may be improved. If operation could be limited to patients in whom the aneurysm has not ruptured, the operative mortality would be reduced by approximately one third. Despite the relatively high mortality rate in patients with ruptured aneurysm, these patients must continue to be treated surgically because this complication occurs frequently in patients known to have aneurysm, and 66 per cent of such patients survive operation whereas survival without operation is rare indeed. When the poor prognosis of an untreated aneurysm on the one hand and the relative safety of operation on the other is generally understood and accepted, operation will be performed earlier. The incidence of rupture will then decrease with further improvement in long-term survival.

One of the most important factors influencing long-term survival is the presence of heart disease. This would suggest that improvement in late survival may be obtained by selection of patients with the less severe forms of heart disease, particularly for elective operations. Undoubtedly, results in this series would have been better following such a selection. The total incidence of deaths, however, would have been greater than presented here. Early in this

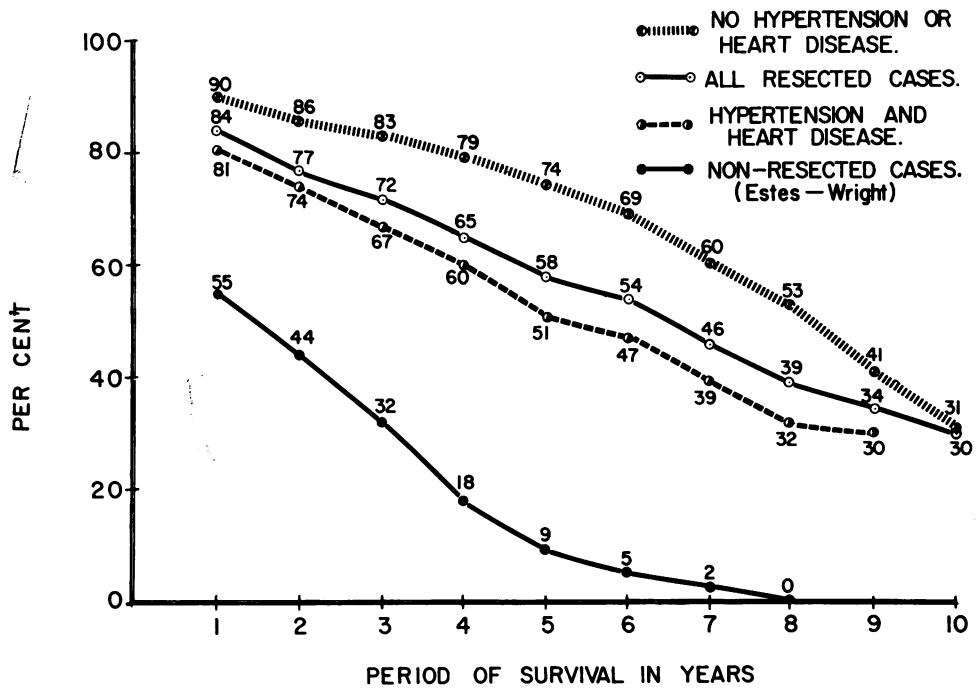

FIG. 13. Life expectancy of all patients with abdominal aortic aneurysm in this series, those without hypertension or heart disease, those with hypertension and heart disease, and the non-resected cases of Estes and Wright.

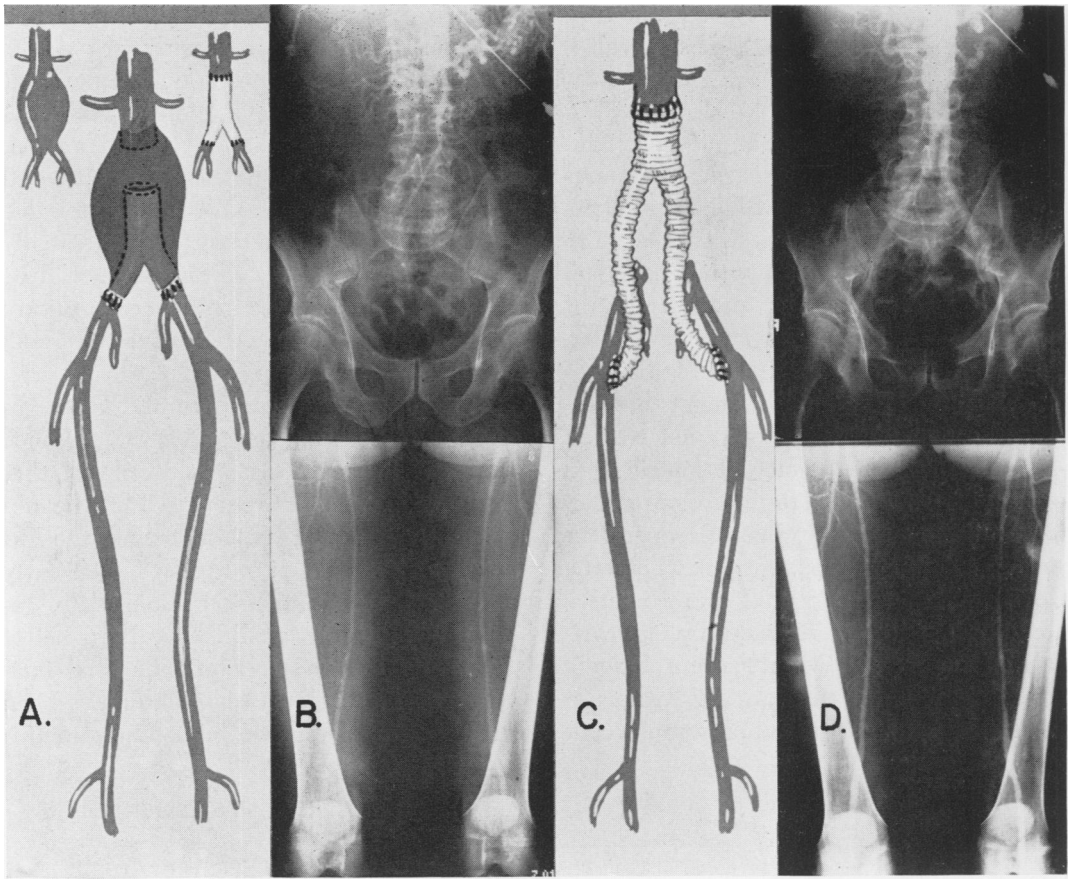

FIG. 14. A. Drawings (inset) showing aneurysm of abdominal aorta treated by resection and replacement with bifurcation nylon graft (Edwards-Tapp). Patient returned six years later with recurrent, painful, pulsatile abdominal mass. Larger drawing illustrates findings at operation with disruption and disintegration of nylon graft resulting in false aneurysm. B. Preoperative aortogram showing false aneurysm of abdominal aorta. C. Operative procedure consisting of resection of false aneurysm and disintegrated nylon graft and replacement with bifurcation Dacron graft with bypass to common femoral arteries. D. Aortogram made two years after second operation showing restoration of normal circulation.

experience an attempt was made to exclude from operation patients with the more severe forms of associated arteriosclerotic disease, such as those producing coronary, renal and cerebrovascular insufficiency. The aneurysm ruptured in almost every case and many deaths occurred in spite of attempts at operation. Because of the risk of certain death from rupture and the evidence of better life expectancy of treated patients, we believe that operation should be performed in most, if not all patients with aneurysms of the abdominal aorta even in the presence of some of these associated arteriosclerotic diseases. In patients, however, undergoing acute myocardial infarction, operation should be delayed from six weeks to three months unless the aneurysm develops signs of rupture, when operation should be performed immediately.

Improvement is also likely to occur in the management of associated disease. With a better understanding of the nature of the atherosclerotic process, better means will be devised to handle the problem. Surgical technics are already available to treat patients with cerebrovascular disease result-

ing from extracranial arterial occlusion and with hypertension from renal artery disease. In addition, considerable advances have recently been made in the diagnosis and surgical treatment of coronary artery disease.

Summary

Surgical treatment consisting of resection and graft replacement has been employed for aneurysms of the abdominal aorta from November 6, 1952, to January 1, 1964, in 1,719 patients, 1,449 of which were treated prior to January 1, 1963, permitting follow-up studies from one to eleven years after operation, and forming the basis of this report. Current follow-up studies were completed in 98.8 per cent of these cases.

The great majority of patients with aneurysms of the abdominal aorta admitted to the hospital during this period were treated surgically since contraindications to operation were limited to the presence of severe and disabling associated systemic disease. Ages ranged from 33 to 90 years with the highest incidence occurring in the seventh decade of life. Twenty per cent were 70 years of age or older. The aneurysm had ruptured in 117 patients; hypertension or heart disease was present in 68 per cent of the cases; and other atherosclerotic lesions including other aneurysms and occlusive lesions of the aorta and major arteries occurred frequently.

Although replacement therapy was employed in all of these cases, the method of its application was dependent upon the extent of the aneurysm and the presence of associated disease of the renal, iliac, and femoral arteries. A small number of patients had sacciform aneurysms involving only a part of the circumference of the vessel wall. The lesions were excised and the defect closed by insertion of a graft. The aneurysm in the majority of cases was fusiform and involved the entire circumference of the vessel wall. Aneurysms limited to the aorta were treated by segmental replacement of the lesion using a straight tube graft. Aneurysms involving the distal aorta and iliac arteries were replaced using a bifurcation graft attached by end-to-end anastomosis, unless occlusive disease was present in the iliac arteries, in which case the aneurysm was replaced and the obstructed iliac arteries bypassed with a bifurcation graft. Associated occlusion of the visceral or the femoral arteries was treated by bypass extension from the graft used to replace the aneurysm.

Various types of vascular replacements from aortic homografts to different types of synthetic fabrics were used during the early period of this experience until it became apparent that the knitted Dacron graft replacement was the most satisfactory and this has been used exclusively since 1957.

Death occurred within 30 days in 9 per cent of the patients and later in the follow-up period in 28 per cent. The principal causes of death were myocardial infarction and cerebrovascular disease. Of the 1,449 patients submitted to operation, 1,318 (91%) lived over thirty days, 1,216 (84%) lived at least one to two years, and 63 per cent of all cases are still alive.

Life tables were constructed from the resected series in this study and compared with a normal population adjusted for sex and age. The greatest period of risk in the resected cases was during the first 30 days after operation. The deaths occurring during this time accounted for one third of the difference in the survival rates of the two groups. Survival was related primarily to condition of the aneurysm and presence of associated disease. Associated hypertension and heart disease were associated with 89 per cent of early deaths and 74 per cent of later deaths.

A comparison of the long-term survival rates of patients treated surgically with those not treated surgically shows a significantly better life expectancy for the former group. Moreover, these studies show

that once the patient survives the immediate effects of the operation, his life expectancy closely approaches that of the normal population during the first five years, following which there is a gradual decrease in life expectancy.

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Discussion

Dr. D. Emerick Szilagyi (Detroit): The justification for the resective treatment of abdominal aortic aneurysm, excepting those lesions with expansion or rupture, is the prolongation of the life expectancy of the patient. The extent to which this goal has been achieved can be judged in two principal ways: first, by comparing the postoperative survival rates with the survival rates of a comparable standard population, as was done by the essayists in their beautiful and monumental study; and, secondly, by comparing the survival rates of two groups that are essentially similar but had surgical and nonsurgical treatment respectively. It may further clarify the problem of the value of abdominal aortic aneurysmectomy if we take a brief look at the results of a study in which the second method was used.

(Slide) In this slide the percentages of postoperative survival of 305 patients with abdominal aortic aneurysm that had resective therapy between 1952 and the early part of 1963 are compared with the survival rates of 200 cases of abdominal aortic aneurysm without surgical treatment observed both before and after the inception of resective surgical management in 1952.

Aside from the fact that the two series were not simultaneous, the statistical parameters were in both groups essentially the same. In particular, the nonsurgical group comprised very few cases that were refused surgical treatment for reasons of operative risk, as our own operative indications were nearly as broad as those of the essayists.

It is evident that the survival rate of the surgically treated patients was consistently and considerably higher than that of the nonsurgical cases throughout a recorded period of eight years, at