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ORIGINAL ARTICLE

Outcome and risk factor analysis of patients who underwent open infrarenal aortic aneurysm repair

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Summary *Introduction:* The aim of this study was to evaluate the short- and long-term outcomes in patients who underwent open infrarenal aortic aneurysm repair.
Methods: Consecutive patients who underwent open repair of infrarenal aortic aneurysms at our institution from July 1st 1990 to June 30th 2012 were reviewed from a prospective collected departmental database. Short-term outcomes included 30-day mortality and peri-operative complications. Independent risk factors to predict 30-day mortality were identified. Long-term survival and secondary interventions were also reported.
Results: Three hundred and eighty-three patients (317 males, median age 72 years with a range of 15—90 years) underwent open infrarenal aortic aneurysm repair during the period, of whom 266 (69.5%) were elective, 18 (4.7%) were urgent for symptomatic but nonruptured cases, and 99 (25.8%) were emergency procedures for ruptured aneurysms. Mean aneurysm size was 6.5 cm (ranging from 2.5 cm to15 cm). All patients were followed up for at least 24 months with a mean follow up period 163 months. Overall 30-day mortality was 11.0% (36.4% for ruptured cases, 11.1% for symptomatic cases, and 1.5% for elective cases; $p < 0.001$). Preexisting renal disease and ruptured aneurysms were independent risk factors for 30-day mortality ($p = 0.001$ and $p = 0.006$ respectively). Systemic complications included 50 cardiac events, 52 respiratory events, six renal events, three cerebral vascular accidents, and one deep vein thrombosis/pulmonary embolism. Local complications included two anastomotic/graft hemorrhage, 10 distal thrombosis/embolisms, five bowel ischemias, one spinal cord ischemia, and 17 wound complications. The ruptured group presented survival rates of 53.5%, 50.5%, 47.5%, 42.3%, 38.0%, 21.9%, and 12.5% at 1 year, 2 years, 3 years, 4 years, 5 years, 10 years, and 15 years, respectively; while nonruptured survival rates were 91.5%,

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88.0%, 83.7%, 78.3%, 73.0%, 43.0%, and 25.3%, respectively (log rank $p < 0.001$). For those who died 30 days after the operation, only six patients (1.8%) died from aneurysm related mortality. A total of three (0.9%) patients underwent late re-interventions, one for late aorto-enteric fistulae and two for anastomotic pseudoaneurysms.
Conclusion: In the current era of endovascular repair, open infrarenal aneurysm repair is effective and durable, and has very low secondary interventions rates.

1. Introduction

Ever since Nicolai Volodos in 1986[1] and Juan Carlos Parodi in 1990[2] demonstrated the feasibility of aortic aneurysm exclusion with endografts, endovascular stent graft repair (EVAR) became the standard of care for infrarenal abdominal aortic aneurysms (AAA) at the end of past century. There was a resurge of interest in open repair when long-term results from the EVAR1 trial,[3] DREAM trial,[4] OVER trial,[5] and ACE[6] trial were published recently. They all showed that the early mortality advantage of EVAR was lost at around 2 years of follow up, and re-intervention, long term complications, and cost were significantly higher in the EVAR group compared to the open repair group. This observation was reconfirmed using meta-analysis.[7]

We present the long-term outcomes of patients who underwent open infrarenal AAA repair in our department. This is the first paper reporting the long-term durability of open repairs in the Han Chinese population. Patients and clinicians can now be informed about the relative merits of open treatment versus endovascular treatment.

2. Methods

We reviewed all patients who received open repair of infrarenal aortic aneurysm at our institution, a tertiary referral center in Hong Kong for the period of July 1st 1990 to June 30th 2012. Data were subtracted from a prospective collected departmental database, supplemented by clinical notes and computer records. Only infrarenal aneurysms were included; while pararenal, suprarenal, and thoracoabdominal aneurysms were excluded.

Patients presented with ruptures, either suspected clinically or diagnosed using imaging. These patients were treated as surgical emergencies. Midline laparotomy and infrarenal clamps were the preferred approaches. Often a supraceliac clamp may be needed temporarily. Asymptomatic patients were offered repair when the aneurysm size reached 5.0 cm. Symptomatic patients included those with pain, infection, embolic phenomenon, and an aneurysm expansion rate >0.5 cm/6 mo. They were treated in an early elective basis. Incision was rooftop or midline with an infrarenal clamp. Tube or bifurcated grafts of woven Dacron or knitted Dacron were used.

Patients were nursed in intensive care units after their operations. After discharge, patients were regularly followed up in the outpatient clinic. Surveillance duplex or computer tomography (CT) scans were not routine.

During the same period of time, our center also performed endovascular stenting but these patients were not reported in the current study.

Patients' baseline characteristics and follow-up periods were reported. Short-term outcomes included perioperative morbidities and mortalities. Variables including age, sex, comorbidities, preoperative hemoglobin level, preoperative base excess, whether the aneurysm had ruptured or not, and American Society of Anesthesiologists (ASA) grades were used to predict the 30-day mortality using a binary logistic regression model. Long-term survival and secondary interventions were reported. Chi-square test was used to differentiate significant differences between categorical variables, while Student *t* test was used for continuous variables. Statistical analysis was calculated by SPSS version 22 (SPSS Inc., Chicago, IL, USA). A p value <0.05 was defined as significant.

Definitions of comorbidities were as follows. Cardiac history included stable angina, unstable angina, myocardial infarction, congestive heart failure, and arrhythmia. Pulmonary history included all patients with dyspnea or chest roenterogramic changes. Renal impairment was defined as serum creatinine level >120 μmol/L. Positive smoking history included all patients who had quit <10 years.

Thirty-day mortality was defined as death ≤30 days after index open repair. Late aneurysm-related mortality was defined as death >30 days after index operation and as a direct result of aneurysm rupture. Late re-intervention was defined as further intervention >30 days after the index operation. Graft related events were defined as those occurring as a direct consequence of prosthetic aortic replacement and consisted of graft thrombosis, pseudoaneurysm formation, graft infection, and graft-enteric fistula. Other aneurysms remote from the index operation, e.g., thoracic or iliac aneurysm, requiring further intervention were not counted and were reported separately.

3. Results

Three hundred and eighty-three patients underwent open infrarenal aortic aneurysm repair during the study period (Fig. 1). Three hundred and seventeen (82.8%) were males while 66 (17.2%) were female. The median age was 72 years ranging from 15 years to 90 years, of whom 266 (69.5%) were elective, 18 (4.7%) were urgent for symptomatic but nonruptured cases, and 99 (25.8%) were emergency procedures for ruptured aneurysms. Mean aneurysm size was 6.5 cm ranging from 2.5 cm to 15.0 cm. Other baseline

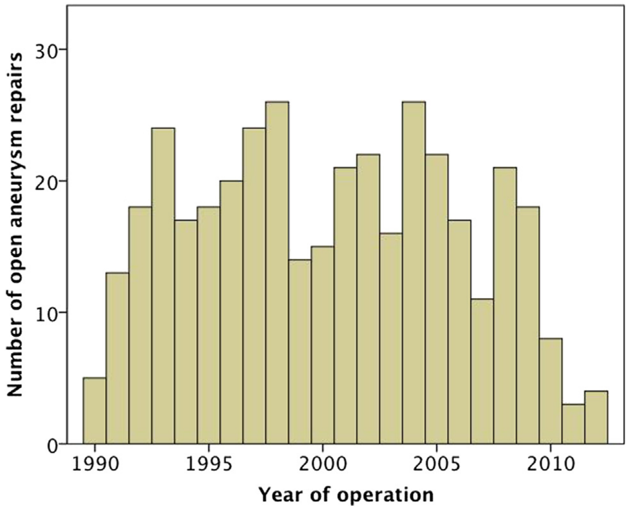


Fig. 1 Number of open infrarenal abdominal aortic aneurysm repairs over the years.

characteristics are shown in Table 1. All patients were followed up for at least 24 months, with a mean follow up period 163 months.

3.1. Short-term results

Overall, 30-day mortality was 11.0% (36.4% for ruptured cases, 11.1% for symptomatic cases, and 1.5% for elective cases; $p < 0.001$). Univariate logistic regression analysis showed age, smoking history, hypertension, pre-existing renal disease, preoperative hemoglobin level, preoperative base excess, ruptured aneurysm, ASA grades 3–5, and aneurysm size were predictors of 30-day mortality (Table 2) With subsequent multivariate logistic regression, only pre-existing renal disease and ruptured aneurysms were found to be independent significant risk factors for 30-day mortality ($p = 0.001$ and $p = 0.006$, respectively; Table 3).

Compared with nonruptured aneurysms, ruptured aneurysms led to significant longer aortic clamp time, prolonged operative duration, larger amount of blood loss, and increased postoperative ventilator assisted time (Table 4). Systemic complications included 50 cardiac events, 52 respiratory events, six renal events, three cerebral vascular accidents, and one deep vein thrombosis/pulmonary embolism. Local complications included two anastomotic/graft hemorrhage, 10 distal thrombosis/embolism, five bowel ischemias, one spinal cord ischemia, and 17 wound complications. Compared with nonruptured aneurysms, ruptured aneurysms led to significantly more adverse events in cardiac, respiratory, renal, and bowel ischemia complication subgroups (Table 4).

Table 1 Baseline characteristics of patients who underwent open surgical repair ($n = 383$).

Variable	No.	%
Age	Median age 72 y (range, 15–90 y)	
≥70 y	230	60.1
<70 y	153	39.9
Gender		
Male	317	82.8
Female	66	17.2
Presentation		
Ruptured	99	25.8
Symptomatic	18	4.7
Elective	266	69.5
Coexisting condition		
Smoking	226	59.0
Hypertension	213	55.6
Diabetes mellitus	39	10.2
Cardiac disease	129	33.7
Cerebral vascular accident	44	11.5
Pulmonary disease	49	12.8
Renal impairment	89	23.2
Family history of aneurysm	3	0.8
Aneurysm size	Median size 6.5 cm (range, 2.5–15.0 cm)	
<5 cm	21	5.5
5–7 cm	251	65.5
>7 cm	111	29.0

3.2. Long-term results

The ruptured group presented survival rates of 53.5%, 50.5%, 47.5%, 42.3%, 38.0%, 21.9%, and 12.5% at 1 year, 2 years, 3 years, 4 years, 5 years, 10 years, and 15 years, respectively; while the nonruptured group had survival rates of 91.5%, 88.0%, 83.7%, 78.3%, 73.0%, 43.0%, and 25.3% (log rank $p < 0.001$; Fig. 2). For those who died 30 days after their operation, only six patients died from

Table 2 Univariate analysis of preoperative variables to predict 30-day mortality.[a]

Variable	Odd ratio	95% Confidence interval		p
Male	1.046	0.443	2.469	0.918
Age	1.055	1.012	1.100	0.013
Smoking	0.269	0.135	0.537	<0.001
Hypertension	0.401	0.206	0.782	0.007
DM	0.411	0.095	1.770	0.233
Cardiac disease	1.390	0.721	2.680	0.325
CVA	0.792	0.269	2.337	0.673
Pulmonary disease	2.052	0.915	4.602	0.081
Renal disease	2.541	1.302	4.959	0.006
Preoperative hemoglobin level	0.669	0.578	0.773	<0.001
Preoperative base excess	0.883	0.832	0.936	<0.001
AAA size	1.314	1.097	1.573	0.003
Ruptured	26.476	10.695	65.546	<0.001
ASA 3–5	5.807	1.747	19.303	0.004

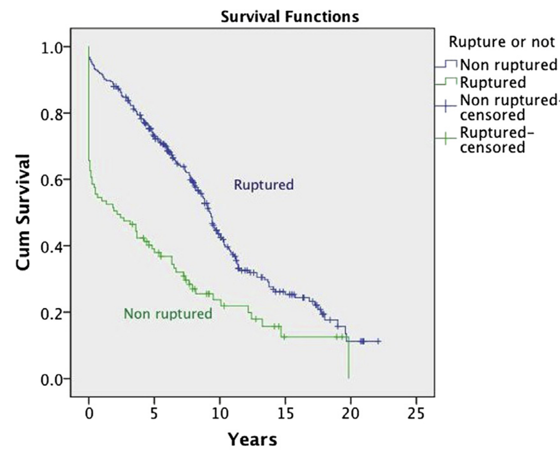
AAA = abdominal aortic aneurysm; ASA = American Society of Anaesthesiologist; CVA = cerebrovascular accident; DM = diabetes mellitus.

[a] By binary logistic regression. Age, preoperative hemoglobin level, preoperative base excess, and AAA size are continuous variables, while others are categorical variables.

Table 3 Multivariate analysis of preoperative variables to predict 30-day mortality.[a]

Variable	Odd ratio	95% Confidence interval		p
Age	1.037	0.960	1.119	0.358
Smoking	1.005	0.322	3.138	0.994
Hypertension	0.385	0.106	1.389	0.145
Renal disease	8.434	2.349	30.284	0.001
Preoperative hemoglobin level	0.867	0.668	1.124	0.280
Preoperative base excess	0.952	0.889	1.019	0.156
AAA size	1.193	0.909	1.566	0.203
Ruptured	7.803	1.778	34.233	0.006
ASA 3—5	2.266	0.223	23.032	0.489

AAA = abdominal aortic aneurysm; ASA = American Society of Anesthesiologists score.
[a] By binary logistic regression. Age, preoperative hemoglobin level, preoperative base excess, and AAA size are continuous variables, while others are categorical variables.



No. at Risk					
Ruptured	99	34	12	4	0
Non-ruptured	284	189	79	31	5

Log rank p<0.001

Fig. 2 Survival curve of ruptured versus nonruptured (log rank $p < 0.001$).

aneurysm related causes, giving a late aneurysm-related mortality of 1.8% (Table 5). There were a total of three (0.9%) patients who underwent late re-interventions due to graft related events. The first patient underwent open repair in 1994 at the age of 66 years. The 4.4 cm infrarenal aortic aneurysm and 5.7 cm left iliac aneurysm were replaced with aorto-bi-iliac knitted Dacron graft. He presented with recurrent gastrointestinal bleeding of unknown origin 6 years later. Upper endoscopy and colonoscopy failed to localize the bleeding source. Laparotomy and enteroscopy showed suspicious bleeding from the proximal jejunum and possible graft-to-jejunum fistula. Bleeding was settled with aorto-uni-iliac endovascular stenting and cross femoral bypass. The patient is still alive to date (Fig. 3). The second patient underwent open repair with aorto-bi-femoral woven Dacron graft in 1993 at the age of 72 years. Seven years later, he was incidentally found to have a pulsatile mass at the epigastrium with a CT scan showing an infrarenal 8 cm proximal anastomosis pseudoaneurysm. Treatment was standard endovascular repair (Fig. 4). The last patient had open repair surgery with aorto-bi-iliac woven Dacron graft in 1993 at the age of 76 years. He complained of epigastric pain 20 years later with a CT scan showing a 9 cm proximal perivisceral pseudoaneurysm, which was settled with endovascular stenting

Table 4 Short-term outcomes.

	Overall (n = 383)	Ruptured (n = 99)	Nonruptured (n = 284)	p
Mean aortic clamp time (min)	62.4	72.8	59.5	<0.001[a]
Mean operative time (min)	202.5	180.3	209.7	0.001[a]
Blood loss (mL)	1748	3858	1055	<0.001[a]
Mean days of assisted ventilation (d)	2.2	7.6	0.5	<0.001[a]
30 d mortality	42 (11.0)	36 (36.4)	6 (2.1)	<0.001[b]
Systemic complications				
Cardiac	50 (13.0)	21 (21.2)	29 (10.2)	0.009[b]
Respiratory	52 (13.6)	32 (32.3)	20 (7.0)	<0.001[b]
Renal	6 (1.6)	5 (5.1)	1 (0.4)	0.005[b]
CVA	3 (0.8)	1 (1.0)	2 (0.7)	1.000[b]
DVT/PE	1 (0.3)	1 (1.0)	0 (0)	0.258[b]
Local complications				
Graft complication	2 (0.5)	0 (0)	2 (0.7)	1.000[b]
Distal thrombosis/embolism	10 (2.6)	5 (5.1)	5 (1.8)	0.134[b]
Bowel ischemia	5 (1.3)	4 (4.0)	1 (0.4)	0.017[b]
Spinal ischemia	1 (0.3)	1 (1.0)	0 (0)	0.258[b]
Wound complication	17 (4.4)	7 (7.1)	10 (3.5)	0.158[b]

Data are presented as n or n (%).
CVA = cerebrovascular accident; DVT = deep vein thrombosis; PE = pulmonary embolism.
[a] Student t test.
[b] Chi-square test.

Table 5 Causes of death after 30 days.

Causes	No. (n = 341)	
Cardiovascular related	41	
Noncardiovascular related	108	
Ruptured aneurysm/complications	6	1 type A dissection with hemopericardium 1 ruptured arch aneurysm 3 ruptured thoracic aneurysm 1 suspected perigraft infection
Unknown	71	
Still alive	115	

with fenestration to all four visceral vessels (Fig. 5; Table 6). In addition, 17 (5.0%) patients developed thoracic or iliac aneurysms in later life. They were treated with open or endovascular repair (Table 7).

4. Discussion

Our indications for surgical management of infrarenal abdominal aortic aneurysm were similar to well established standards.[8–13] One-fourth of open repairs were for ruptured cases with 36.4% 30-day mortality. The mortality rate for open elective infrarenal aortic aneurysm repair was 1.5%. Symptomatic aneurysms only account for a small proportion.

World reported perioperative mortality and morbidity varied greatly. A meta-analysis of the reported literature showed 30-day or in-hospital mortality from ruptured aneurysm ranging from 27% to 69%.[14] As for elective cases, 30-day or in-hospital mortality ranged from 1.4% to 6.5%. Overall 30-day mortality of the open arm of EVAR1,[3] DREAM,[4] OVER,[5] and ACE[6] trials was 3.69% (range, 0.6–4.6%). While certain high volume centers reported excellent mortality rates of 0% to 1.2%,[15–17] multi-institutional nationwide data continued to show higher incidences of mortality ranging from 4.2% to 8.4%.[16,17] There were strong relationships between operative outcomes and the case volume of the surgeon or hospital. Birkmeyer et al[18,19] reported an elective AAA repair mortality rate of 7.8% in low volume centers (<17 cases/y), as opposed to 4.9% in high volume centers (>79 cases/y).

Despite advancements in operative, anesthetic, and intensive care, perioperative mortality of ruptured aneurysms was still extremely high. Several meta-analyses are available in literature. Hoornweg et al[20] reported an overall mortality of 48.5%. Bown et al[21] reported the rate as 48%. Kantonen et al[22] reported the rate as 68%. This high mortality rate is most likely related to factors such as delays in recognition and intervention, hemodynamic instability, profound blood loss, and suboptimal perioperative care in emergency setting.[21,22] The relatively low rates in our institution were probably related to short travel times to

Fig. 3 Late intervention, Patient 1.

Fig. 4 Late intervention Patient 2.

the hospital, availability of dedicated vascular surgeons, and outstanding anesthetic and intensive care.

Several factors have been identified as predictive factors for operative mortality. These included advanced age, women, elevated body mass index (BMI), ruptured aneurysm, large aneurysm size, smoking, renal impairment, chronic obstructive pulmonary disease, coronary artery disease, prolonged aortic clamp time, greater blood loss, and positive fluid balance.[23–34] Furthermore, a few risk scoring systems have been developed to identify high risk patients undergoing open AAA repair. The Glasgow Aneurysm score (GAS),[35] Vascular Physiology only-Physiological and Operative Severity Score for enUmeration of Mortality

Table 6 Late re-interventions.

Causes	No. ($n = 341$)	Treatments
Aorto-enteric fistula	1	EVAR
Proximal anastomotic pseudoaneurysm	2	EVAR

Table 7 Treatment of aneurysm elsewhere.

Types of aneurysm	No. ($n = 341$)	Treatments
Thoracoabdominal aneurysm	10	TEVAR
	1	Open
Iliac aneurysm	5	EVAR
	1	Open

(T)EVAR = (Thoracic) endovascular aortic repair.

[V(p)-POSSUM],[36] Vascular Biochemical and Hematological Outcome Model (VBHOM),[37] Lee's Revised Cardiac Risk Index (RCRI),[38] and Preoperative Risk Score of the Estimation of Physiological Ability and Surgical Stress Score (PRS of E-PASS)[39] were the best known predictors. Bryce et al[40] and Tang et al[41] showed that V(p)-POSSUM and E-PASS better predict outcome than the other two. However, due to the size of our patient cohort, our study only showed that pre-existing renal disease and ruptured aneurysms were associated with increased mortality in elective surgery and in emergency open repair. The most commonly reported risk factors of early mortality, such as advanced age and female gender, were insignificant in this study.

The merits of open repair compared with endovascular repair were lower late aneurysm-related mortality and lower late re-intervention rates. Both EVAR1[3] and DREAM[4] trials reported their long-term survival after a mean

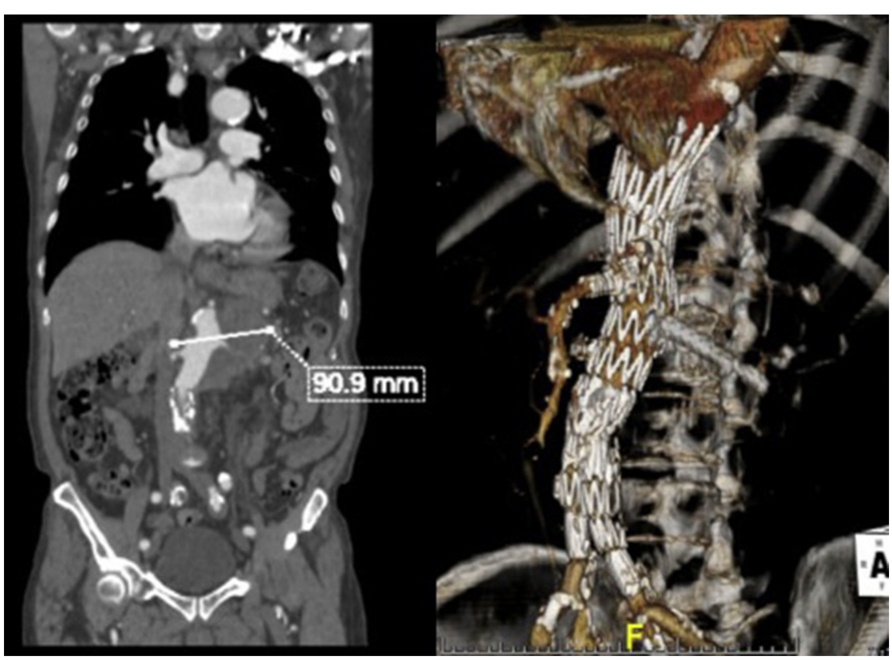


Fig. 5 Late intervention, Patient 3.

follow up of 6 years and 6.4 years respectively. Late aneurysm related mortality after open repair was 2.2% and 0.6% in EVAR1 and DREAM respectively. Late re-intervention rate was 1.7% per year in the EVAR1 trial, and 18.1% in the DREAM trial. Both studies demonstrated significant lower re-intervention rates after open repair compared with those who underwent endovascular repair (5.1%/y and 29.6%/y in the EVAR1 trial and DREAM trial respectively). The Mayo clinic reported re-intervention rates for late aortic graft-related events of 5.1—5.3% at a median follow up of 5.8—7 years, with an associated operative mortality rate of 17—19%.[42,43] Biancari et al[44] from Finland reported a re-intervention rate of 10.6% at the median follow up of 8 years, with an associated operative mortality rate of 9%. Adam et al[45] from Australia reported a re-intervention rate of 3.4% at the median follow up of 41 months in non-ruptured aneurysms and a rate of 5% at the median follow up of 30 months in ruptured cases. Our data of 1.8% late aneurysm-related mortality and 0.9% late re-intervention rate demonstrated that open AAA repair has excellent long-term durability in our population, and furthermore, the results compare favorably with previous reports from North America, Europe, and Australia (Table 8).

Graft occlusion and anastomotic pseudoaneurysm were the more frequent graft-related indications for re-intervention, while graft infection and graft-enteric fistula occurred infrequently.[42—47] All re-interventions in our study were for symptomatic complications, while it may be difficult to identify asymptomatic complications as imaging follow ups after open repair were not routine in our center. CT scans were included in the follow up protocol for patient randomized to open repair in EVAR1 trial,[48] and it is anticipated that further reports from the trial will determine the true incidence of late graft-related events.

There are several limitations in this study, as this study had a relatively small case number and incomplete long-term data collection. Completeness of patient follow up was an inherited limitation in our retrospective study. Being a tertiary referral center, every patient with symptomatic late graft related events would be referred back to us for management. The late re-intervention rate should therefore be accurate. However, the causes of death of a vast number of patients were unknown despite every effort to determine the cause of death, adding uncertainty to the late aneurysm-related mortality. Another important limitation of this study was the lack of comparison with the endovascular group. Our center began endovascular treatment for AAA in 1999. We were eagerly waiting the long-term outcomes of endovascular AAA repair. In the current era of endovascular repair, open infrarenal aneurysm repair is safe and effective, and still has its place in cases with difficult necks and access. As our study spanned from 1990 to 2012, there is always an issue with different emerging techniques over time, but nonetheless it represents one of the largest databases of Chinese patients receiving open AAA management.

Table 8 Late aneurysm related mortality and late reintervention rate in other studies.

	Late aneurysm related mortality (%)	Late reintervention rate (%)	Mean follow up period
EVAR 1	2.2	1.7%/y	6 y
DREAM	0.6	18.1	6.4 y
Mayo clinic		5.1—5.3	5.8—7 y
Biancari et al[44] (Finland)		10.6	8 y
Adam et al[45] (Australia)		3.4 (nonruptured) 5 (ruptured)	41 mo 30 mo
Our data	1.8	0.9	13.6 y

Acknowledgments

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