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Epidemiology of abdominal aortic aneurysms in a Chinese population during introduction of endovascular repair, 1994 to 2013

A retrospective observational study

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Abstract

The aim of this study was to examine changes in abdominal aortic aneurysm repair and mortality during a period when endovascular aneurysm repair (EVAR) was introduced.

Open repair surgery was the mainstay of treatment for abdominal aortic aneurysm (AAA), but EVAR is increasingly utilized. Studies in the Western population have reported improved short-term or postoperative mortality and shorter length of hospital stay with EVAR. However, scant data are available in the Chinese population.

We conducted a retrospective observational study using the database of the Hospital Authority, which provides public health care to most of the Hong Kong population. AAA patients admitted to public hospitals for intact repair or rupture from 1994 to 2013 were included in this study. We calculated the incidence of ruptured AAA, annual repair rates according to type of AAA and surgery, as well as death rates (operative and overall short-term). We calculated whether there were significant changes over time and compared short-term mortality between open surgery and EVAR.

One thousand eight hundred eighty-five patients were admitted for intact repair and 1306 patients were admitted for AAA rupture, of whom 795 underwent rupture repair. Intact repair rates significantly increased in all age groups (7.3–37.8%, $P < .001$) over the study period.

The incidence of ruptured AAA increased, in all age groups, except in < 64 years old. By 2013, 85% of intact repairs and 55.4% of rupture repair were done by EVAR. Over time, there was a significant decrease in operative mortality for intact repair (16.5 in 1994 to 7.1 in 2013, $P = .01$) and rupture repair (59.7 in 1994 to 30.8 in 2013, $P = .003$). Over the same time period, short-term AAA-related deaths decreased by more than half (73% in 1994 to 24% in 2013, $P < .001$), with a significant decline in all age groups, except < 64 years old. Short-term mortality was significantly lower for EVAR than for open repair (17.2% vs 40.3%, $P < .01$).

Short-term AAA-related deaths have declined likely due to decreased operative mortality and rupture deaths during the period of EVAR introduction and expansion.

Abbreviations: AAA = abdominal aortic aneurysms, CDARS = Clinical Data Analysis and Reporting System, EVAR = endovascular aneurysm repair, ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification.

Keywords: abdominal aortic aneurysm, endovascular aneurysm repair

1. Introduction

Abdominal aortic aneurysm (AAA) is one of the most common silent killers in the elderly men.[1] Ruptured aneurysms have a high mortality rate at 60% to 65%.[2] To prevent or treat rupture of AAA, repair is indicated for symptomatic patients or patients with an aneurysm larger than 5 to 5.5 cm as a prophylaxis against rupture.[3] Although open repair surgery was the mainstay of treatment for AAA for almost 5 decades, endovascular aneurysm repair (EVAR) is increasingly utilized[2,4] in view of reported improved short-term or postoperative mortality and shorter length of hospital stay in western population.[1,3,5] EVAR made repair of AAA possible in previously high-risk patients (e.g., those with multiple comorbidity and old age).[2,3] Subsequently, rates of intact AAA repair in those over age 80 in the USA have dramatically increased[6] Nedeau et al[7] suggested that EVAR should be the standard treatment for patients with AAA. However, EVAR is more expensive[3] and requires regular screening.[8]

Most randomized controlled trials comparing EVAR and open repair were conducted in Europe, UK, and USA.[5,9] A meta-analysis of these studies reported decreased short-term mortality

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after EVAR.[5] In contrast, scant data are available in Chinese population. Previous studies in Taiwan,[9] China,[10] and Hong Kong[11] were small and did not find a significant benefit in short-term mortality for EVAR. It has been suggested that Chinese patients may have more challenging aortic anatomies (e.g., shorter common iliac arteries) and more access-related and device-related complications.[2,9] To better understand the effect of introducing EVAR into an Asian population, we analyzed data on AAA repair and rupture of patients from the public hospital during the period that EVAR was introduced. We hypothesize that similar to the results of Western studies, EVAR resulted in increased AAA repair rates and decreased short-term mortality.

2. Methods

2.1. Study population

In Hong Kong, the majority of health care services are provided by the public sector under Hospital Authority, which provides more than 90% of in-patient care to the population of Hong Kong.[2] Patients with intact AAA undergoing repair and patients hospitalized for ruptured AAA were identified from January 1994 to December 2013 were retrieved by the Clinical Data Analysis and Reporting System (CDARS) of the Hospital Authority. We conducted a retrospective observational study using these data. The time period was chosen to observe changes before and after introducing EVAR in Hong Kong. Patients were classified according to hospitalization diagnosis: intact (ICD-9-CM code 441.4) or ruptured (ICD-9-CM code 441.3) AAA. For intact AAAs, only those with repair (open or EVAR) were included, as diagnostic codes without operational procedures might not be clinically relevant AAAs. For ruptured AAAs, only those with a primary diagnosis code for AAA rupture were included, as this is likely the reason for their index admission. Rupture patients were then divided into those performing repair (open or EVAR) and no repair. Patients who had diagnosis codes for AAA rupture in other diagnosis fields were excluded, as these might indicate a history of AAA rupture irrelevant to the primary admission or might be miss-coded. The procedure codes used for open repair were aneurysmorrhaphy 39.52 (0), Rupture repair for ruptured infrarenal aortic aneurysm 39.52,[12] Rupture repair for ruptured suprarenal aortic aneurysm 39.52,[13] Intact repair of infrarenal aortic aneurysm 39.52,[14] Intact repair of suprarenal aortic aneurysm 39.52,[15] Resection of abdominal aorta with replacement 38.44 and aorta-iliac-femoral bypass (excluding peripheral vascular disease) 39.25. The procedure codes used for EVAR were Endovascular stenting of abdominal aortic aneurysm 39.90,[16] Dilation/Stenting of major great vessels (noncoronary) 39.90 and other repair of aneurysm 39.52. The following codes were excluded: atherosclerosis of native arteries of the extremities (440.2), atherosclerosis of bypass graft of the extremities (440.3), peripheral vascular disease, unspecified (443.9), and embolism and thrombosis of arteries of the extremities (444.2).

Between the years 1994 and 2013, 1885 patients were admitted for intact repair and 1306 patients were admitted for AAA rupture, of whom 795 underwent rupture repair. Total annual intact repairs increased from 6 in 1994 to 199 in 2013. Total annual AAA ruptures increased from 12 in 1994 to 93 in 2013 and total annual rupture repairs increased from 3 in 1994 to 56 in 2013.

2.2. Outcomes

Short-term related death was defined as combined deaths related to intact repair and rupture (with or without repair). Intact repair death was defined as death within 30 days of a repair procedure or within the repair hospitalization period. Rupture death was defined as deaths within primary hospitalization or within 30 days of a repair procedure.

2.3. Statistical analysis

Annual incidence and mortality rates of intact AAA repair, ruptured AAA repair, and rupture without repair were calculated and standardized by using 2013 public hospital AAA patient population as our standard population. Annual rates (1994–2013) were first calculated with gender and stratified by age groups (<65, 65–74, 75–79, ≥80 years). Subsequently, rates were standardized by gender and age. To assess the change of study outcomes by time, simple linear regression models used year as the independent variable and tested whether the slope of time trend was different from zero. The significance of the time effect is equivalent to that obtained in Pearson coefficient analysis. Log transformation was used for the rates showing nonlinear trend. Chi-square test was used to compare the death rate between EVAR and open repair, which was also adjusted for year of operation, using data from 1999 onwards (when EVAR was introduced). Results are reported as statistically significant at the $P < .05$ level. All statistical analyses were conducted using IBM SPSS Statistics software (SPSS Statistics 23.0, SPSS Science) and Statistical Analysis Software version 9.4 (SAS Institute Inc., Cary, NC). The study was approved by the Joint CUHK-NTEC Clinical Research Ethics Committee.

3. Results

EVAR was introduced for intact AAA in 1999 and for ruptured AAA in 2005. Demographic characteristics of patients undergoing intact and rupture repair are shown in 3-year increments in Table 1. The mean age of patients undergoing intact repair increased from 67.4 in 1994 to 76.2 in 2013. The mean age of patients undergoing rupture repair also increased from 74.5 in 1994 to 76.8 in 2013.

3.1. Trends in AAA repair

From years 1994 to 2013, intact repair rates (age and gender-adjusted) significantly increased from 7.3% in 1994 to 37.8% in 2013 ($P < .001$). Intact repair rates increased in all age groups, with the greatest increase in ages 65 to 74 years (18.6–56). Figure 1 shows the trend in intact repair rate across time, by age group. Annual rupture rates decreased (23.1% in 1994 vs 15.4% in 2013), while rupture repair rates (age and gender-adjusted) increased (15.4% in 1994 vs 45% in 2013). The vast majority of patients receiving AAA repair (whether intact or rupture) were men, with no significant trend over time (Table 1).

EVAR was increasingly utilized for both intact (from 1999 onwards) and rupture repair (from 2005 onwards). Proportion of intact repair using EVAR reached 85% by 2013. There was a significant increase in using EVAR for intact repair in patients older than 85 years. Overall, the mean age of patients receiving EVAR increased significantly over the study period (Table 1). From 2005 to 2009, rates of rupture repair by EVAR were very low, until a sharp increase the following year (Fig. 2). Proportion of rupture repair using EVAR reached 55.4% in 2013.

3.2. Operative mortality

There was a significant decrease in operative mortality for intact repair over time ($P = .01$) (Fig. 3), particularly in 75 to 79 years

Table 1

Demographics and trends across time.

															Trends across all years (1994–2013)			
	1994–1996		1997–1999		2000–2002		2003–2005		2006–2008		2009–2011		2012–2013		Open		EVAR (without considering 1994–1996)	
Intact repairs	Open	EVAR	Open	EVAR	Open	EVAR	Open	EVAR	Open	EVAR	Open	EVAR	Open	EVAR	T-statistic	*P*	*T*-statistic	*P*
Annual number of repairs	54	0	117	4	156	45	180	99	196	164	145	325	62	338	0.380	.720	8.341	.001
Age (mean)	70.3	0	72.2	74	72.3	73.7	72.8	75.7	74.2	76.7	73.2	76.5	72.5	76.6	2.091	.091	3.781	.019
<65	22%	0	15%	25%	14%	7%	17%	5%	11%	6%	18%	8%	21%	10%	0.000	1.000	−1.180	.303
65–69	26%	0	17%	25%	22%	22%	17%	14%	15%	6%	14%	11%	15%	10%	−3.057	.028	−3.118	.036
70–74	26%	0	25%	0%	27%	24%	22%	27%	26%	23%	22%	20%	19%	21%	−2.475	.056	1.125	.324
75–79	17%	0	27%	25%	21%	29%	26%	27%	27%	38%	27%	27%	24%	23%	1.440	.210	−0.102	.923
80–84	4%	0	14%	25%	12%	16%	15%	16%	13%	19%	12%	23%	15%	23%	1.714	.147	0.393	.714
85+	6%	0	3%	0%	5%	2%	3%	10%	8%	9%	7%	11%	7%	14%	1.447	.208	5.458	.005
Gender (% Male)	82%	0	81%	75%	75%	87%	83%	87%	84%	89%	80%	89%	74%	86%	−0.800	.460	1.655	.173

															Trends across all years (1994–2013)			
	1994–1996		1997–1999		2000–2002		2003–2005		2006–2008		2009–2011		2012–2013		Open		EVAR (without considering 1994–2002)	
Rupture repairs	Open	EVAR	Open	EVAR	Open	EVAR	Open	EVAR	Open	EVAR	Open	EVAR	Open	EVAR	*T*-statistic	*P*	*T*-statistic	*P*
Annual number of repairs	30	0	72	0	115	0	109	2	159	7	125	57	57	62	0.982	.371	3.614	.069
Age (mean)	70.2	0	75.8	0	76.5	0	76.7	78	78	71.6	76.4	77	75.2	77.3	1.451	.206	0.207	.855
<65	23%	0	4%	0	4%	0	7%	0	4%	43%	10%	9%	12%	11%	−0.541	.612	−0.010	.993
65–69	20%	0	13%	0	9%	0	8%	0	8%	0%	10%	14%	18%	7%	−0.465	.661	1.291	.326
70–74	30%	0	28%	0	29%	0	23%	50%	23%	0%	19%	14%	14%	16%	−7.115	.001	−0.896	.465
75–79	10%	0	28%	0	31%	0	27%	0	21%	14%	22%	23%	25%	19%	1.048	.343	2.275	.151
80–84	10%	0	22%	0	15%	0	21%	50%	26%	29%	30%	19%	21%	27%	2.183	.081	−1.713	.229
85+	7%	0	6%	0	12%	0	14%	0%	18%	14%	9%	21%	11%	19%	1.110	.317	2.526	.127
Gender (% Male)	83%	0	81%	0	76%	0	80%	100%	81%	100%	84%	88%	84%	76%	0.930	.395	−4.041	.056

EVAR = endovascular aneurysm repair.

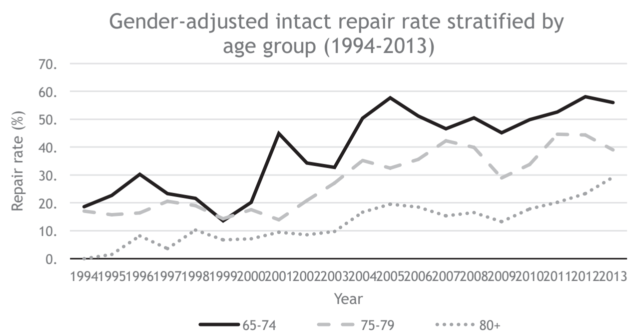

Figure 1. Trends in intact repair rate across time, by age group (gender adjusted).

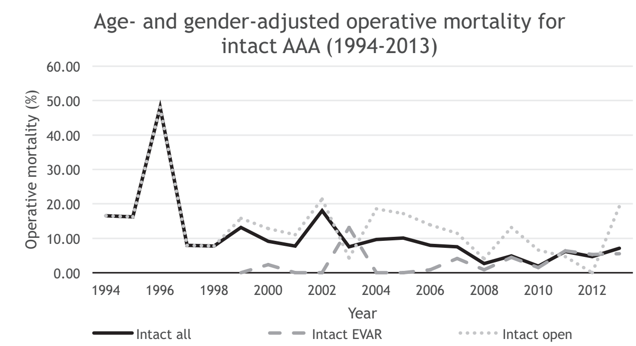

Figure 3. Operative mortality for intact AAA (age and gender adjusted).

old (from 78% in 1994 to 0% in 2013). Overall operative mortality for intact (change in diagram too) repair was lower with EVAR than open repair (3.4% vs 8.5%; $P<.001$). Similarly, operative mortality for rupture AAA significantly declined ($P=.003$) (Fig. 4), particularly in 65 to 74 years old (from 100% in 1994 to 20% in 2013) and 80+ years old (78% to 40%). Overall operative mortality for rupture repair was also lower with EVAR than open repair (32.8% vs 54.4%; $P<.05$).

3.3. Short-term AAA-related deaths

Between 1994 and 2013, the overall short-term AAA-related deaths (age and gender adjusted) significantly decreased from 73% to 24% ($P<.001$) (Fig. 5). This was mainly due to the steep decline in rupture deaths, from 56.5 to 19.4 ($P<.001$). In addition, despite increasing intact repair rates, short-term deaths related to intact repair significantly declined from 16.5 to 5.5 ($P=.01$). Intact repair deaths significantly declined in 75 to 79 years old. There was a significant decline in short-term AAA-related deaths in all age groups, except in < 65 years old. Rupture death significantly decreased across all age groups except in <65 years old, with the most significant decline in ages 65 to 74 and 80 + years. Short-term mortality was significantly lower for EVAR than open repair (17.2% vs 40.3%, $P<.01$).

4. Discussion

We studied the changes in AAA mortality from 1994 to 2013, during which EVAR was introduced to Hong Kong in 1999. By using data from the hospital authority, we captured most patients who presented for AAA repair or died due to AAA-related causes in Hong Kong, a place populated by 7.2 million people. Our analysis showed that while intact AAA repair rates increased, operative mortality declined due to introduction of EVAR and its lower mortality rates. In addition, although rupture incidence increased, AAA rupture deaths declined by more than half. Rupture incidence may have increased due to improving emergency services and therefore more rupture patients staying alive until hospital admission. Decline in rupture deaths is likely due to increased rupture repair rates with declining operative mortality. Although EVAR was first used for rupture repair in 2005, it was not widely adopted until 2010. Logistics and funding difficulties were cited as barriers.[4] By 2010, increasing expertise in the technique, increasing adoption elsewhere, and evidence of lower mortality compared with open repair may have helped overcome these barriers. In the U.S., use of EVAR for rupture repair increased from 0.8% in 2000 to 34.8% in 2010, with a significant decline in operative mortality.[3] In 2009, data from 49 centers showed that operative mortality of EVAR for rupture repair was significantly better than open repair.[19] These trends likely contributed to declining short-term AAA-related deaths while EVAR was introduced.

Previous studies analyzed data in our population.[11] These included data from patients over a period of a few years, demonstrating a low intact repair rate[15] and acceptable morbidity and mortality for EVAR.[11] Our analysis includes data over a longer period, enabling us to capture the time period when EVAR was introduced for both intact repair (in 1999) and rupture repair (in 2005). In addition, we accounted for population changes over time. Our study demonstrated substan-

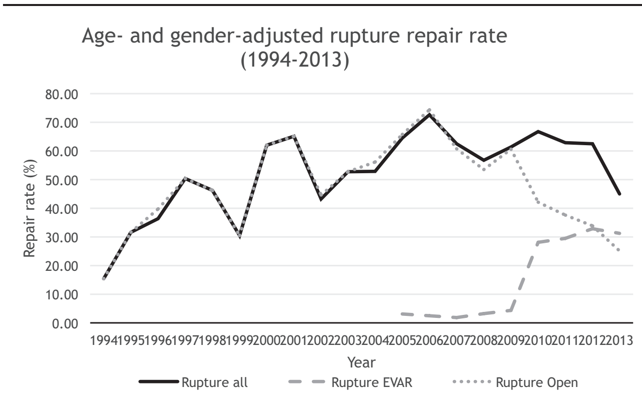

Figure 2. Trends in rupture repair rate across time, by all repair, EVAR, and open surgery (age and gender adjusted).

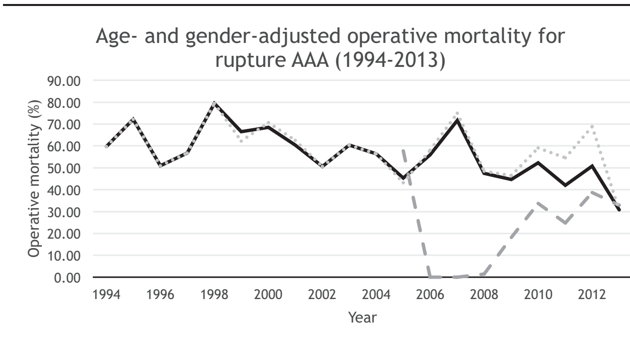

Figure 4. Operative mortality for ruptured AAA (age and gender adjusted).

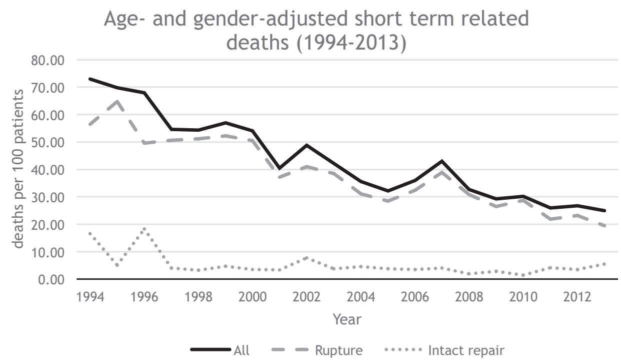

Figure 5. Short-term AAA-related deaths (age and gender adjusted).

tial differences according to age and trends in repair rates and mortality rates, specifically comparing EVAR to open repair.

Short-term AAA-related deaths have declined due to decreased operative mortality for both intact and rupture repair. Declining AAA rupture deaths might also be explained by AAA incidence; however, there are no studies showing trends in AAA incidence in this population. A Western study postulated that their data showing decreasing intact repair rates in the younger population in contrast to increasing rates in the older population supported the theory of decreasing AAA incidence in the younger population.[6] In contrast, our data showed increasing intact repair rates across all age groups, suggesting a different epidemiology from our Western counterparts. Previous studies in Asian countries have postulated that Chinese patients may have different anatomy that affects outcome or suitability for EVAR,[2,9,10] as results showed no difference in mortality when comparing EVAR to open repair.[9–11] However, our study showed that patients undergoing EVAR had lower mortality than open repair. This is in line with findings from European countries where mortality of EVAR was lower than open repair.[5] Nevertheless, postoperative mortality was generally higher than European studies: Postoperative mortality for other countries was around 1% for intact repair by EVAR and 4% for intact repair by open surgery; and 27% for rupture AAA repair by EVAR and 41% for rupture AAA repair by open surgery.[3,17] Apart from possible differences in anatomy of Chinese patients, another reason could be delayed presentation. Currently, there is no AAA screening program in Hong Kong. Chinese patients tend to refuse early intervention to prevent rupture due to perceived complications, while primary health care doctors may advise against surgery because it is perceived as extremely risky.[2] Selection of patients for surgery could also play a role: Chinese AAA patients undergoing operation may have more comorbidities.

Studies in western countries have shown that in the early years after introduction of EVAR, intact repair rates declined.[16,18–20] When intact repair rates increased, it was in 80+ years old, while rates in <75 years old declined.[6] In contrast, our results showed that intact repair rates steadily increased in all age groups. In our population, EVAR expanded access to repair in all age groups. Thus, there may be long-term benefits for the younger patients, whose lives may have been prolonged. In rupture patients, our findings of lower operative mortality for EVAR compared with open repair were similar to other studies.[20] Overall rupture repair mortality significantly decreased over time to an all-time low in 2013, providing evidence that EVAR contributed to a reduction in overall operative mortality.[21,22]

Our study has several limitations: Our data are subject to coding errors, and there might be bias if coding accuracy changed over time. Our data were also unable to capture rupture deaths that died before reaching hospital. Our analysis is also limited by lack of information on comorbidities, which could affect operative mortality rates. Reduction in AAA-related mortality may be due to advances in medicine during the study period, which were not included in the study. In addition, we have no data on AAA diameter, thus we are unable to comment on any changing practices regarding diameter that might affect repair rates.

In conclusion, during our study period, which coincided with the introduction of EVAR, a decline in short-term AAA-related mortality, operative mortality, and rupture deaths was observed. EVAR utilization has expanded in both intact and rupture repairs, suggesting that EVAR will be increasingly utilized. Intact repair rate has been increasing, with an increasing mean age of these patients. This suggests that AAA incidence may be increasing in an aging population. In the absence of a screening program, a continuing trend of increasing rupture incidence may be seen as intact repair rates fail to keep up with rising AAA incidence, although this may need to be confirmed with other studies.

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